NEW ZEALAND JOURNAL OF MARINE AND FRESHWATER RESEARCH
https://doi.org/10.1080/00288330.2024.2387583

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RESEARCH ARTICLE

Adaption of a traditional Māori fishing method for biomonitoring: using whakaweku for sampling benthic macroinvertebrates in streams

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ABSTRACT

Whakaweku are bundles of bracken fern (*Pteridium esculentum*) traditionally placed in lakes and rivers by Māori to harvest kōura (freshwater crayfish, *Paranephrops* spp.) in Aotearoa, New Zealand. Previous studies show they are effective for monitoring populations of kōura and toitoi (small eleotrid fish, *Gobiomorphus* spp.). We wanted to determine whether whakaweku are also effective for monitoring benthic macroinvertebrate communities in streams. We placed whakaweku in a hard-bottomed and a soft-bottomed reach of a rural stream in the Waikato, and took standard 'kick-net' samples from the same locations. We retrieved whakaweku after two and four weeks submerged. Whakaweku gave comparable results to kick-net sampling for common macroinvertebrate metrics (MCI, SQMCI, total richness and EPT* richness). Macroinvertebrate community composition was significantly different between the two methods, but most taxa were common to both. Macroinvertebrate metrics did not change significantly between two-week and four-week colonisation periods. A wider study would show whether whakaweku can distinguish between sites over a gradient of human impact. We recommend whakaweku in Māori cultural and community stream monitoring as it is inexpensive, simple to use, captures many macroinvertebrate taxa used in biomonitoring, works in different stream types and can be used to monitor kōura, toitoi and macroinvertebrates simultaneously.

ARTICLE HISTORY
Received 21 February 2024
Accepted 30 July 2024

HANDLING EDITOR
Deniz Özkundakci

KEYWORDS
Biomonitoring; cultural monitoring; methods; mātauranga Māori; tau kōura; traditional knowledge; indigenous knowledge

Introduction

Benthic macroinvertebrates are widely used, globally and in New Zealand, for ecological monitoring of streams and rivers. Representing a broad range of taxa with different degrees of tolerance to degraded water and habitat conditions, macroinvertebrates act as biological indicators from which water and habitat quality can be inferred. In New Zealand, the National Policy Statement for Freshwater Management (NPS-FM; Ministry for the Environment 2024) requires regional authorities to monitor macroinvertebrates as a measure of ecosystem health, and to report results for State of the Environment reporting in a biotic index called the Macroinvertebrate Community Index (MCI)

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(Ministry for the Environment 2023). Many community groups and landowners use a simplified version of this index based on a reduced number of macroinvertebrate taxa for community-based stream monitoring (Moffett and Neale 2015; Storey and Wright-Stow 2017; NIWA 2019).

Māori cultural monitoring is given importance in the NPS-FM, which recognises the authority and obligations of Māori, alongside regional councils, to manage freshwater ecosystems. Increasingly, cultural monitoring is being used alongside scientific monitoring in State of the Environment monitoring (e.g. Taranaki Regional Council 2022). Harmsworth et al. (2011) found that many cultural indicators were comparable to scientific monitoring indicators and could be used in a similar manner. While the aim of cultural monitoring is not to replicate scientific monitoring, if some cultural methods give similar results to scientific methods, then it becomes easier to relate results from the two perspectives.

Macroinvertebrates have not been included as an indicator in most cultural monitoring frameworks to date (Rainforth and Harmsworth 2019), however they are compatible with cultural monitoring. Macroinvertebrates are a component of the indigenous fauna, an important indicator of the mauri (life force, essence) of a stream, and they support mahinga kai (traditional food) species which are an important component of the Cultural Health Index (Tipa and Teirney 2006). Insect life was identified as a key indicator of the Tangaroa (marine and connected inland waters) domain by iwi/hapu of the Motueka catchment (Harmsworth et al. 2011).

The method recommended in New Zealand's National Environmental Monitoring Standards (NEMS 2022) for State of the Environment macroinvertebrate monitoring of hard-bottomed and soft-bottomed streams is semi-quantitative sampling by a 'kick-net' or D-net. The same method is recommended for community groups and landowners in the Stream Health Monitoring and Assessment Kit (SHMAK; NIWA 2019). However, in non-wadeable (deep or fast-flowing) rivers this method may be difficult to use (Collier et al. 2009), and for such rivers no standard method exists (NEMS 2022). In soft-bottomed streams the main microhabitats used by macroinvertebrates, such as macrophytes, are less stable than the microhabitats in hard-bottomed streams, leading to higher temporal variability in macroinvertebrate monitoring data (Collier 2004). Artificial substrate samplers have been shown to provide a practical sampling method in hard-to-access sites and consistent and comparable results in environments where natural substrates are highly variable (Blocksom and Flotemersch 2005; Collier et al. 2011; Letovsky et al. 2012). Whereas kick-net methods involve dislodging macroinvertebrates from natural streambed sediments or vegetation and collecting them in a net, artificial substrate sampling involves introducing an artificial sampler to the stream for a period of time and allowing it to be colonised by the local macroinvertebrate fauna, after which it is removed and the fauna extracted. Samplers made of hardboard multi-plates, cement, glass or porcelain spheres, rock baskets, 'conservation webbing', coir mats and leaf packs have all been tried (Barnden and Harding 2005; Collier et al. 2009 and references therein). Macroinvertebrate data from artificial samplers sometimes differs significantly from *in situ* sampling, but comparable results have been achieved when the artificial substrate mimics the local natural substrate (Alonso and Camargo 2005).

Whakaweku are artificial substrates made from bracken fern (*Pteridium esculentum*) that are traditionally used by Māori to harvest kōura (freshwater crayfish, *Paranephrops*

spp.) and small fish from streams and lakes (Hiroa 1921; Best 1929). Bundles of bracken fern (also known in Māori language as rarauhe, rahurahu, rarauwhe, manehu, taakaka, maarohi) are anchored underwater, and after being colonised by kōura and fish, are lifted out and the animals collected. Kusabs et al. (2018) have shown that as well as harvesting, they are suitable for monitoring both kōura and toitoi ('bullies', small native fish in the genus *Gobiomorphus*). As whakaweku have been used for monitoring kōura and toitoi, it has been noted that benthic macroinvertebrates also colonise them.

Our overall objective was to determine whether whakaweku can be used to monitor macroinvertebrate communities as they have been for kōura and toitoi. To answer this question, our first aim was to determine whether whakaweku collect the same range of stream benthic macroinvertebrates, and in similar proportions, as standard semi-quantitative methods in hard- and soft-bottomed streams, and whether the two sampling methods give similar results using standard reporting indices. Our second aim was to determine the length of time required for macroinvertebrates to colonise whakaweku and provide stable community metrics.

Methods

Site

This study was located on the Mangaotama Stream in the Waikato region of the North Island, New Zealand (Figure 1). The stream, which has a mean annual discharge of 0.41 $m^3 s^{-1}$, flows into the Waipa River approximately 113 km upstream from the sea (Kusabs et al. 2018). At the upper (hard-bottomed) site, the catchment was mostly in native forest; the stream wetted channel was 2–3 m wide, 0.05–0.15 m deep in riffle and run sections, up to 50 cm deep in pools and with a gradient of about 1:400. At the lower (soft-bottomed) site, the catchment was mainly in pasture, and the wetted channel was 1.5–2 m wide and 0.5–0.8 m deep with a similar gradient.

Constructing and deploying whakaweku

The study was conducted between 12 February (late summer) and 17 March (early autumn) 2019. Each whakaweku was made of 10 freshly cut 1 m-long bracken fern (*Pteridium esculentum*) fronds, bound together by their stems using plastic cable ties (after Kusabs et al. 2018). Eight whakaweku (four pairs) were placed in each site (16 in total). Each whakaweku was positioned parallel to the stream flow and attached to the streambank or to a stake in the streambed with a rope (Figure 2A). In deep pools, whakaweku were weighted with a rock to prevent them from floating. At the hard-bottomed (HB) upper site, where the streambed was composed of gravels and cobbles, pairs of whakaweku were deployed in one riffle, two runs and one pool along a 30 m reach. The remaining whakaweku were deployed in pairs in two runs and two pools along a 30 m reach in the soft-bottomed (SB) lower site, where the streambed was composed of silt and clay (riffles were absent from this site). In each pair, one whakaweku was left in place for two weeks and the other for four weeks. Following this, a further eight whakaweku were deployed (four at each site) to test a quick method of retrieval (see below).

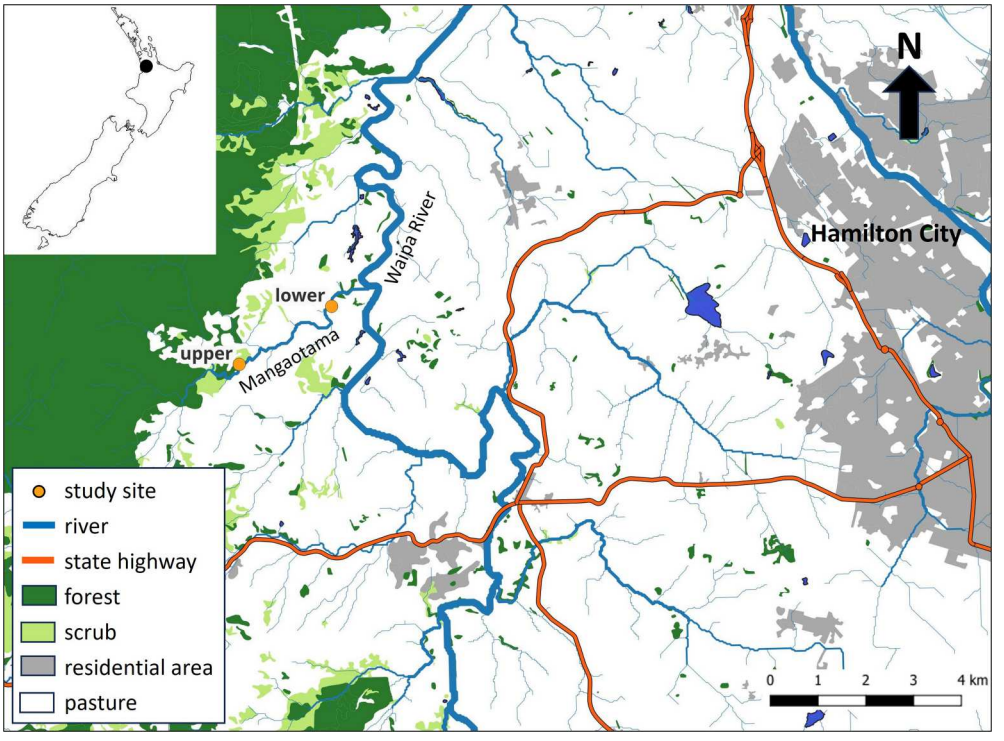

Figure 1. Location of upper (hard-bottomed) and lower (soft-bottomed) study sites on the Mangaotama Stream, Waikato region, New Zealand.

Retrieving whakaweku

Whakaweku were retrieved using a korapa (landing net), 1.4 m wide and 1.5 m high. The korapa was made from a plastic shade cloth stretched between 2 wooden poles, with a chain along the bottom of the shade cloth and a strong cord along the top (Kusabs et al. 2018). It was placed underneath the whakaweku as it was being lifted out of the stream to capture invertebrates disturbed by the removal process (Figure 2B). Whakaweku were then transferred from the korapa into a 70 L plastic 'fish bin'. All organic matter and macroinvertebrates collected by the korapa were also rinsed into the fish bin. Individual fern fronds were removed from the whakaweku and thoroughly rinsed into the fish bin to remove all macroinvertebrates. The contents of the fish bin were then poured through a 0.5 mm mesh net to remove the water, then the invertebrates and residual organic matter were transferred into a container containing 70% alcohol.

A quick retrieval method was also tested to determine whether the time and effort taken to process the whakaweku in the field and the laboratory affected the results. In the field, the quick retrieval process involved separating the invertebrates from the whakaweku in the same way but less thoroughly than the standard retrieval process, completing the task in about ten minutes, compared to 30–40 min for the standard retrieval. The laboratory method is described below.

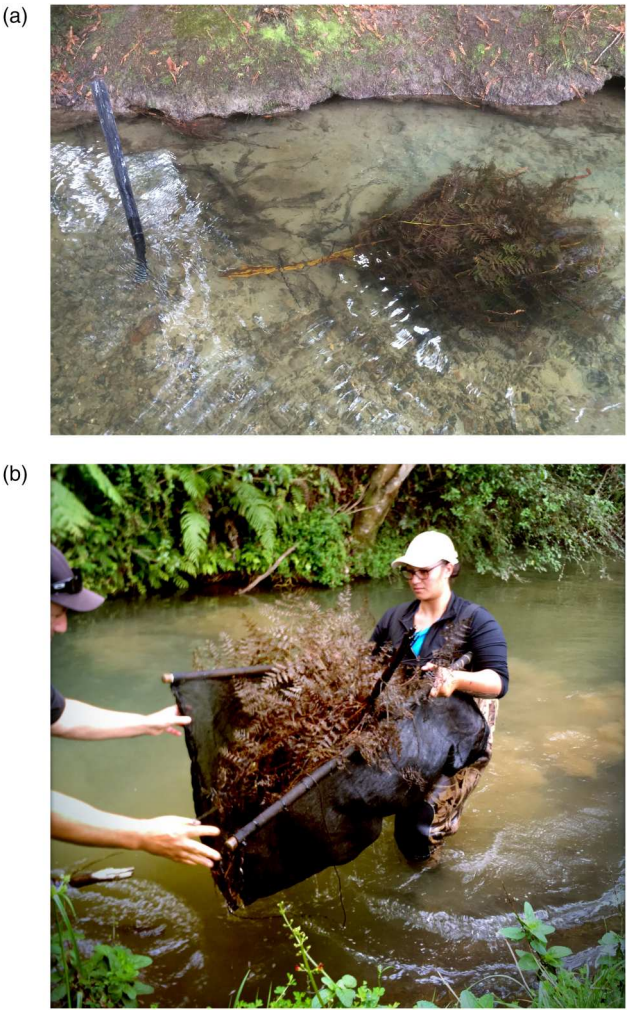

Figure 2. A, Whakaweku deployed in the stream. **B,** Retrieving the whakaweku, with the korapa (net) held underneath to prevent loss of macroinvertebrates.

Kick-net sampling

'Kick-net' samples were taken on the same date as the whakaweku were deployed, at the same locations as each pair of whakaweku. The kick-net was a triangular net (0.3 m wide across the base, 0.5 mm mesh size), so-called because in hard-bottomed streams it is held vertically on the stream bed to collect benthic macroinvertebrates that are dislodged by kicking the streambed substrates in a defined area immediately upstream. For each kick-net sample in the HB site seven areas, each *c.* 0.1 m^2, were sampled in the vicinity of each whakaweku in a riffle, run or pool habitat, and combined to form a single composite sample representing a total area of *c.* 0.7 m^2, following semi-quantitative Protocol C1 in NEMS (2022). In the SB site, macroinvertebrates were collected by sweeping the kick-net through beds of macrophytes and by hand-scrubbing pieces of submerged large wood while holding the net downstream, until a total area of *c.* 0.7 m^2 had been sampled (Protocol C2; NEMS 2022).

Laboratory methods

The first set of kick-net samples was counted using a full count method with semi-quantitative abundance categories: 'present' (1–4 individuals) 'common' (5–19 individuals) and 'abundant' (20+ individuals) (Stark et al. 2001). The second set of kick-net samples were counted using a fixed count method, whereby the first 200 macroinvertebrates were counted and identified, and the remaining sample scanned for missed taxa (Stark et al. 2001).

Whakaweku samples were split into quarters using a barrel sample splitter due to the large number of invertebrates. All macroinvertebrates in a one-quarter subsample were counted and their abundances were multiplied by four. After subsampling, numbers were similar to those in the kick-net samples.

Macroinvertebrates were identified to genus level using the key of Winterbourn et al. (2006) under a microscope with 50X magnification. Samples collected with the quick field method were identified to the taxonomic levels in the Stream Health Monitoring and Assessment Kit (SHMAK; NIWA 2019), using the SHMAK Benthic Macroinvertebrates Identification Field Guide. Sorting and identifying using the quick method took less than one hour per sample, compared with up to four and a half hours per sample using the standard method. For comparing quick vs. standard samples, taxa in standard samples were re-classified using SHMAK level taxa, then SHMAK level indices were calculated for both quick and standard samples.

Data analysis

Macroinvertebrate data for each sample were summarised in several metrics: two diversity metrics (total taxa richness and EPT* richness, i.e. the number of taxa belonging to the orders Ephemeroptera, Plecoptera and Trichoptera, excluding the Trichoptera family Hydroptilidae), one compositional metric (%EPT* abundance), two tolerance metrics (the Macroinvertebrate Community Index (MCI), and its semi-quantitative variant SQMCI) and a multimetric called Average Score Per Metric (ASPM). ASPM (Collier 2008) combines EPT* richness, %EPT* abundance and MCI, each scaled to a score between 0 and 1.

Richness metrics were compared without rarefaction, despite a large difference in total abundance between whakaweku and kick-net samples. This was because, first, only one-quarter of each whakaweku sample was actually counted, and second, abundances were dominated by a single taxon. HB samples were dominated by the common snail, *Potamopyrgus*, which comprised 64%–87% of total abundances, and SB samples were dominated by the freshwater shrimp *Paratya*, which comprised 40%–71% of total abundances. Considering only the number of animals actually counted and excluding *Potamopyrgus* and *Paratya* (both of which were present in both whakaweku and kick-net samples), total abundances in whakaweku samples were comparable to kick-net samples.

MCI and SQMCI were calculated using the tolerance scores for hard-bottomed and soft-bottomed streams (Stark and Maxted 2007) as appropriate, and the formulae in Stark and Maxted (2007). In addition, SMI (SHMAK Macroinvertebrate Index) and SQSMI (semi-quantitative SMI) were calculated using the formulae in the SHMAK User Manual (NIWA 2019). Differences in metric scores between whakaweku and

kick-net samples were tested using paired-sample *t*-tests in Excel 2016 version 1808, first with all samples together, then separately for each streambed type (HB and SB).

Differences in community composition between samples were displayed by non-metric Multidimensional Scaling (MDS) on a Bray–Curtis similarity matrix of the macroinvertebrate data, and differences between whakaweku and net samples were tested for significance using ANOSIM, with 999 permutations, in Primer version 7 (Primer-e). The taxa driving differences between groups were identified using SIMPER (Similarity Percentages) in Primer. These routines were applied first to presence–absence data and then to percent abundance data that had been log $(x + 1)$-transformed to reduce the dominance of highly abundant taxa.

Results

Macroinvertebrate metrics

Abundance and richness metrics

The total abundance of macroinvertebrates was much higher in the whakaweku samples (mean 8876 per sample, range 2543–21,104) than the kick-net samples (mean 898, range 218–1584).

Overall, 42 taxa were collected across all samples, 38 taxa in whakaweku samples and 37 taxa in kick-net samples. Slightly more taxa were found at the HB site (34 taxa in whakaweku and 34 taxa in kick-net samples) than at the SB site (26 taxa in whakaweku and 24 taxa in kick-net samples). Per sample, total richness was typically higher among whakaweku samples than among kick-net samples (Table 1). The difference was significant among all samples and in the HB site but not in the SB site.

Whakaweku samples had slightly higher EPT* richness than kick-net samples, overall and in the SB site, but these differences were not significant (Table 1). EPT* % abundance was significantly lower in whakaweku samples than kick-net samples overall and in the HB site, but not in the SB site (Table 1).

MCI, SQMCI and ASPM

We did not find a consistent or statistically significant difference between whakaweku and kick-net samples overall in either MCI or SQMCI (Figure 3; $t = 0.94$, df = 15, $p = 0.36$ for MCI; $t = 1.90$, df = 15, $p = 0.08$ for SQMCI). Among the HB sites, MCI values of whakaweku samples were on average 7 points lower than kick-net samples, which

Table 1. Macroinvertebrate richness metrics and *t* statistics for differences between means.

Metric	Site	Whakaweku	Kick-net	*t*	df	*p*
Total richness	Overall	17.2 ± 1.3	14.9 ± 1.4	**3.07**	**15**	**0.008**
	HB	21.5 ± 1.5	19.8 ± 1.2	2.41	7	0.05
	SB	12.9 ± 0.9	10.1 ± 1.7	2.11	7	0.07
EPT* richness	Overall	8.1 ± 1.2	7.4 ± 1.1	2.02	15	0.06
	HB	12.1 ± 1.1	11.6 ± 0.7	0.94	7	0.38
	SB	4.1 ± 1	3.1 ± 0.7	1.87	7	0.1
EPT* % abundance	Overall	9.5 ± 1.8	25.9 ± 5.4	**3.57**	**15**	**0.003**
	HB	13.3 ± 3.2	44.8 ± 6.1	**6.94**	**7**	**0.0002**
	SB	5.7 ± 2.8	7 ± 2.4	0.605	7	0.56

Notes: Values are shown as means ± standard error. Significant differences are shown in bold. EPT* = Ephemeroptera, Plecoptera and Trichoptera (excluding Hydroptilidae).

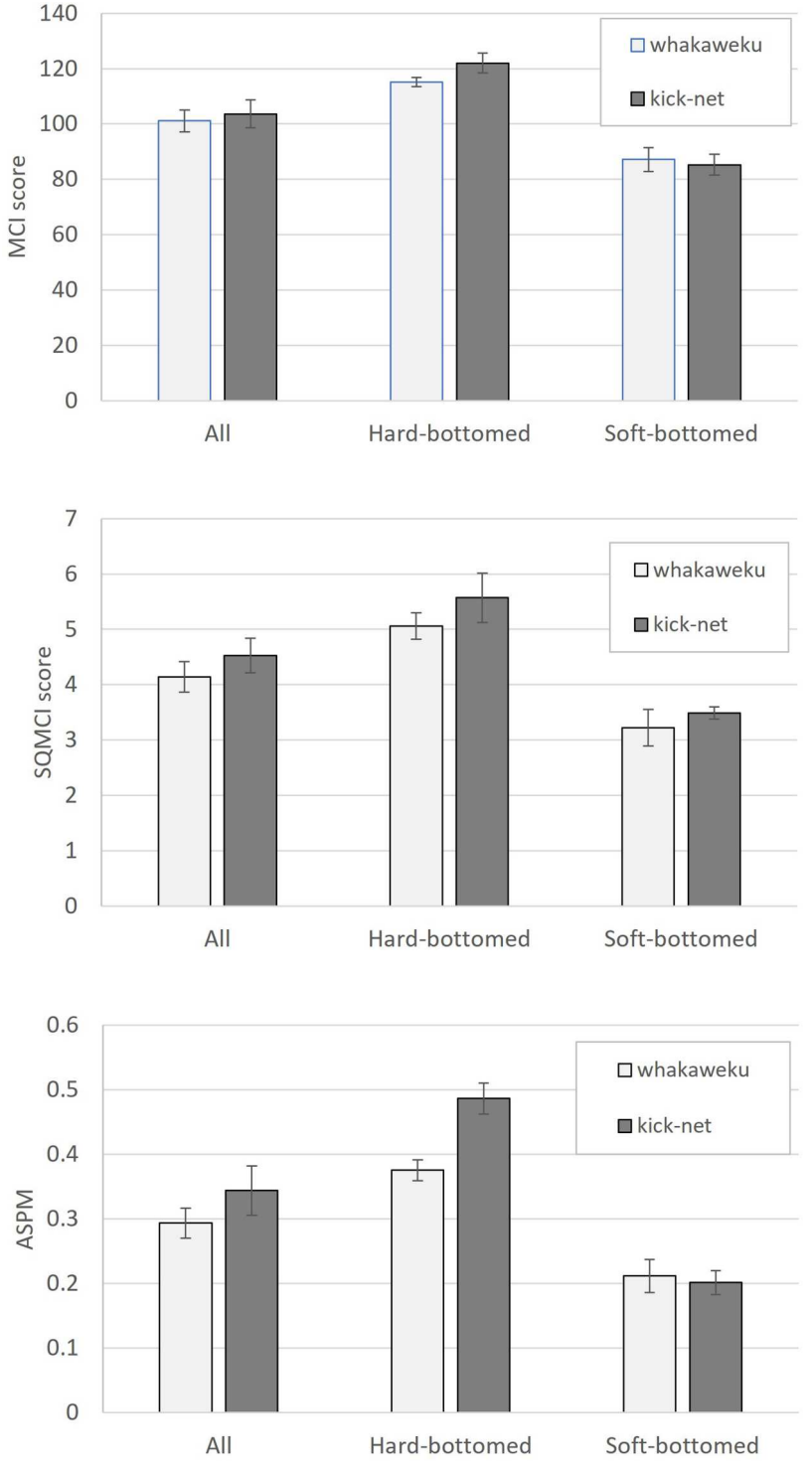

Figure 3. MCI (Macroinvertebrate Community Index), SQMCI (semi-quantitative MCI) and ASPM (Average Score Per Metric) scores in whakaweku and kick-net samples, two retrieval dates combined. Error bars are ±1 standard error.

was a statistically significant difference ($t = 3.16$, df = 7, $p = 0.02$), but SQMCI values of whakaweku samples were not significantly lower than kick-net ($t = 1.39$, df = 7, $p = 0.2$). Whakaweku samples had significantly lower ASPM scores than kick-net samples overall (Figure 3; $t = 2.53$, df = 15, $p = 0.02$) and at the HB site ($t = 5.96$, df = 7, $p < 0.001$) but not at the SB site ($t = 0.59$, df = 7, $p = 0.57$). The difference between whakaweku and kick-net samples at the HB site was due to the difference in %EPT abundance.

Comparing two-week and four-week deployment times

We found no consistent or significant change in any of the diversity, composition or tolerance metrics between two-week and four-week deployment times (Table 2).

Quick vs. standard method of sample processing and analysis

We found no consistent or significant difference in any of the SHMAK-level macroinvertebrate metrics between the quick method and standard method (Table 3).

Community composition

Presence–absence data

The taxa identified in each sample type and streambed type are listed in Table 4. The community composition in whakaweku samples was somewhat distinct from the composition in kick-net samples (Figures 5 and 6). The average similarity between these sample types was 58.8%, according to SIMPER, and the difference between them was statistically significant ($R = 0.363$, $p = 0.001$) according to a two-way crossed ANOSIM. Community composition was more consistent (tighter clustering in Figure 4) among whakaweku

Table 2. Macroinvertebrate metrics for whakaweku samples, comparing two-week and four-week deployment times.

	mean (2-weeks)	mean (4-weeks)	*t*	df	*p*
Total abundance	8932	8820	0.1	7	0.9
Total richness	17.5	16.9	1.3	7	0.2
EPT* richness	8.4	7.9	0.7	7	0.5
EPT* % abundance	6.5	12.4	2.2	7	0.06
MCI	101.0	101.2	0.06	7	0.96
SQMCI	4.0	4.2	0.8	7	0.4
ASPM	0.29	0.30	0.7	7	0.5

Note: EPT* = Ephemeroptera, Plecoptera and Trichoptera (excluding Hydroptilidae), MCI = Macroinvertebrate Community Index, SQMCI = Semi-Quantitative MCI. ASPM= Average Score per Metric

Table 3. Macroinvertebrate metrics for whakaweku samples, comparing a quick retrieval and processing method to the standard method.

	Mean (quick method)	Mean (standard method)	*t*	df	*p*
SMI	108.0	108.5	0.26	7	0.8
SQSMI	5.02	5.10	0.96	7	0.4
Total richness	15.3	15.0	0.51	7	0.6
EPT* richness	6.4	6.0	0.60	7	0.6

Note: SMI = SHMAK Macroinvertebrate Index, SQSMI = Semi-Quantitative SMI.

Table 4. Macroinvertebrate taxa found in the study.

Higher taxon	MCI taxon	KN_HB	KN_SB	WHK_HB	WHK_SB
Ephemeroptera	*Acanthophlebia*	6	0	2	0
	Coloburiscus	4	1	4	0
	Ameletopsis	1	0	3	0
	Austroclima	3	0	2	0
	Deleatidium	7	2	2	1
	Nesameletus	6	0	4	0
	Oniscigaster	1	0	2	0
	Zephlebia	6	5	8	6
Plecoptera	*Austroperla*	7	0	6	1
	Megaleptoperla	0	0	2	0
	Zelandobius	0	0	4	0
Trichoptera	*Helicopsyche*	1	1	0	0
	Hudsonema	5	0	5	1
	Hydrobiosis	6	2	7	4
	Hydropsyche (Aoteapsyche group)	7	0	7	2
	Neurochorema	2	0	2	0
	Olinga	7	1	8	4
	Oxyethira	4	3	7	8
	Plectrocnemia	2	5	6	4
	Psilochorema	5	0	6	1
	Pycnocentria	5	0	3	0
	Pycnocentrodes	6	2	6	1
	Triplectides	6	6	8	7
	Triplectidina	0	0	0	1
Hemiptera	*Sigara*	0	0	0	3
	Microvelia	6	3	5	2
Coleoptera	Elmidae	8	5	7	5
Odonata	*Antipodochlora*	0	1	5	1
	Xanthocnemis	1	8	2	8
Megaloptera	*Archichauliodes*	7	0	8	3
Diptera	*Austrosimulium*	5	3	8	8
	Chironomidae	5	6	8	6
	Eriopterini	5	1	0	2
	Hexatomini	3	0	0	0
	Other fly larvae	2	4	3	0
Acari	Mite	1	2	0	1
Crustacea	*Paratya*	2	8	7	8
Mollusca	*Latia*	0	1	1	0
	Physa	0	1	0	0
	Potamopyrgus	8	6	8	8
Oligochaeta		5	4	0	0
Platyhelminthes		0	0	5	6

Notes: Values indicate the number of samples containingthe corresponding taxon. Abbreviations: KN kick-net, WHK whakaweku, HB hard-bottomed, SB soft-bottomed.

samples (average similarity 70.1%) than among kick-net samples (average similarity 60.6%). Also, there was less difference between HB and SB sites among whakaweku samples than among kick-net samples (Figure 4). The similarity (overlap in Figure 4) between whakaweku and kick-net samples was greater at the SB site ($R = 0.306$, $p = 0.001$) than at the HB site ($R = 0.421$, $p = 0.003$).

Out of a total of 42 taxa, 33 taxa were common to both whakaweku and kick-net samples (Figure 5). Five taxa (the stoneflies *Megaleptoperla* and *Zelandobius*, the caddisfly *Triplectidina*, the hemipteran *Sigara*, and platyhelminth flatworms) were found only in whakaweku, and four taxa (the caddisfly *Helicopsyche*, the dipteran Hexatomini, the snail *Physa* and oligochaete worms) were found only in kick-net samples. Of the nine taxa found in only one sample type, two were found in just one sample. These

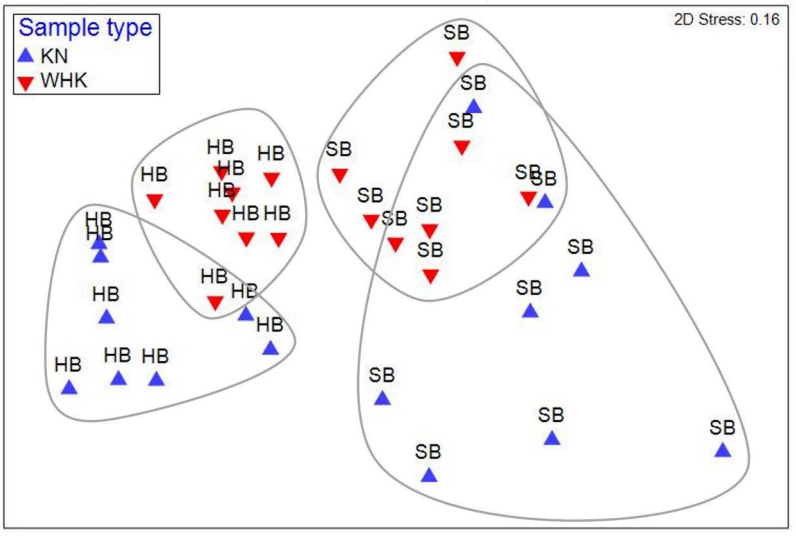

Figure 4. nMDS (Non-metric Multi Dimensional Scaling) plot of macroinvertebrate presence/absence in whakaweku and kick-net samples from pools, riffles and runs on both retrieval dates at hard bottomed (HB) and soft bottomed (SB) sites.

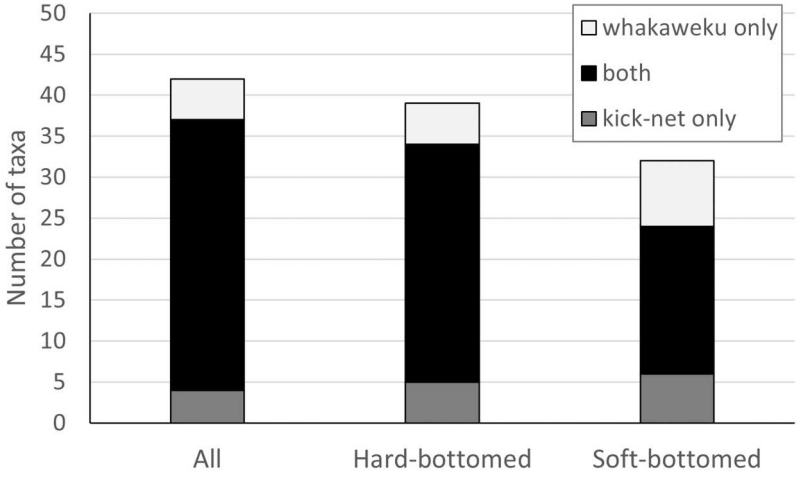

Figure 5. Number of taxa in common between whakaweku and kick-net samples, compared with the number unique to each sample type.

were the main taxa responsible for the difference between whakaweku and kick-net sample: at the HB site, the dipterans Eriopterini and Hexatomini and oligochaete worms were absent and the mayfly *Deleatidium* was uncommon among whakaweku samples but they were all fairly common among kick-net samples. In contrast, the stonefly *Zelandobius* and flatworms were absent among kick-net samples but they were all fairly common among whakaweku samples. The shrimp *Paratya* was also more common among whakaweku samples. The remaining 29 taxa were about as common

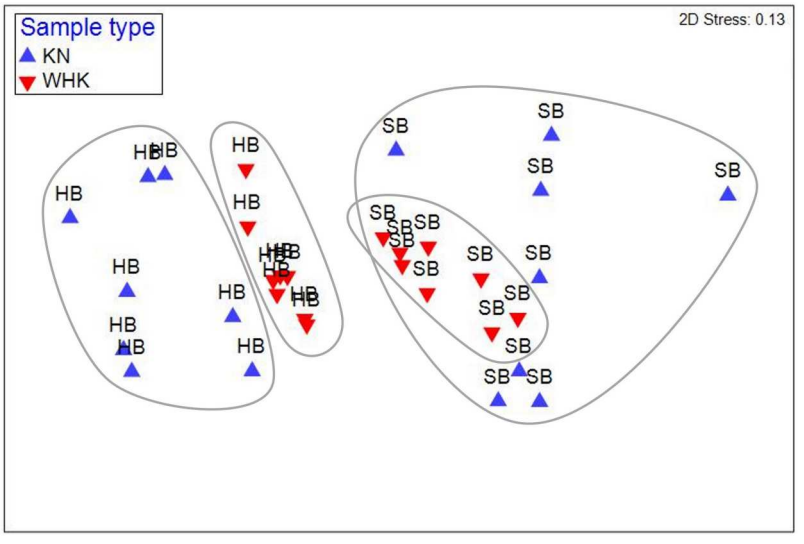

Figure 6. nMDS (Non-metric Multi Dimensional Scaling) plot of macroinvertebrate percent abundance in whakaweku and kick-net samples from pools, riffles and runs on both retrieval dates at hard bottomed (HB) and soft bottomed (SB) sites.

in both sample types. In the SB site, oligochaete worms were absent from whakaweku but fairly common in kick-net samples, whereas flatworms, *Archichauliodes* (dobsonfly), *Sigara* and the caddisfly *Hydropsyche* (*Aoteapsyche* group) were absent from kick-net samples but found in more than one whakaweku sample. *Oxyethira* (caddisfly) and *Austrosimulium* (Diptera) were also more common among whakaweku than kick-net samples. The remaining 18 taxa were about as common in both sample types.

Percent abundance data

The difference in community composition between whakaweku and kick-net samples was greater based on taxa relative abundances than based on presence–absence (Figure 6). Average similarity between the two sample types was 54.1%, according to SIMPER, and the difference between them was statistically significant (ANOSIM, $R = 0.494$, $p = 0.001$). As with the presence–absence data, community composition was more consistent (tighter clustering in Figure 6) among whakaweku samples (average similarity 71.4%) than among kick-net samples (average similarity 56.8%), and there was less difference between HB and SB sites among whakaweku samples than among kick-net samples (Figure 6). The similarity between whakaweku and kick-net samples was slightly greater among SB samples (ANOSIM, $R = 0.48$, $p = 0.001$) than among HB samples (ANOSIM, $R = 0.51$, $p = 0.001$).

Among the HB samples, the main taxa responsible for the difference were *Paratya*, the dipterans Chironomidae and *Austrosimulium* (all more abundant in whakaweku samples), *Deleatidium* and elmid beetles (more abundant in kick-net samples). Among the SB samples, the main taxa responsible for the difference were *Oxyethira*, *Austrosimulium* (both more abundant in whakaweku samples) and the damselfly *Xanthocnemis* (more abundant in kick-net samples). The greater taxonomic richness of the whakaweku samples also separated them from the kick-net samples at the SB site.

Discussion

In this study, we compared the benthic macroinvertebrate fauna collected in standard kick-net samples with that collected in whakaweku, an artificial substrate made of bracken fern. We compared the use of these two methods at two different sites, one hard-bottomed and the other soft-bottomed. We also assessed the deployment time required for sufficient colonisation of the whakaweku.

Macroinvertebrate metrics in whakaweku vs. kick-net samples

Our study indicated that whakaweku and kick-net sampling gave comparable results for several commonly used macroinvertebrate metrics. We found that total abundance was much higher, taxonomic richness was as high or higher and EPT* richness was as high or higher in whakaweku compared to kick-net samples. In contrast to our results, most other studies comparing multiplate samplers to kick-net samples have typically found the multiplate samplers contain a subset of the fauna found in the natural sediments (Boothroyd and Stark 2000; Blocksom and Flotemersch 2005; Letovsky et al. 2012). Whakaweku in our study had relatively high taxonomic richness compared to multiplate samplers in other studies, likely because whakaweku offers a more complex habitat than multiplate samplers, greater surface area to colonise, and habitats suitable for a wider range of taxa. Collier et al. (2009) tested an artificial sampler made of folded coir (coconut fibre mat), which was physically more complex than multiplate samplers and probably more similar to whakaweku. Although Collier et al. (2009) didn't compare coir samplers to natural substrates, they found that coir samplers had higher macroinvertebrate density and slightly different taxonomic composition than multiplate samplers, but overall taxonomic richness was similar. Our results indicate that whakaweku are as effective as kick-net sampling, and possibly more effective than other artificial substrates, in capturing the range of macroinvertebrate taxa present at a site.

Whakaweku gave comparable results to kick-net sampling for two commonly used biotic indices, the Macroinvertebrate Community Index (MCI) and its semi-quantitative variant (SQMCI). This result occurred despite some differences in community composition between the two sample types, because the taxa occurring exclusively (or mainly) in one sample type included both high-scoring and low-scoring taxa. Although in our study whakaweku showed no bias towards high- or low-scoring taxa, we cannot be certain that this will be true in all situations. Therefore, while our results suggest that MCI and SQMCI values from kick-net and whakaweku across different sites could be compared or combined, we are cautious about concluding this will be true in all contexts. Average Score Per Metric (ASPM), a multimetric, that is required for State of the Environment reporting in New Zealand, differed significantly between whakaweku and kick-net samples due to the compositional metric EPT* % abundance, which is one of the three metrics underlying ASPM.

Community composition in whakaweku vs. kick-net sampling

One might expect that the whakaweku habitat, comprising densely packed fine leaves, would harbour a different macroinvertebrate assemblage to the habitat of a natural

stream bed. Our study showed that there were some differences in community composition between whakaweku and kick-net samples, but most (33 out of 42) taxa were present in both sample types in roughly the same number of samples. Of the nine taxa present in only one of the sample types, four were found in just one or two samples. At such low numbers, their distribution among samples would be strongly influenced by chance, and could not be attributed to the difference between whakaweku and natural streambed substrates based on these data. The taxa that were common in kick-net samples but absent from whakaweku (oligochaetes and Tipulidae crane fly larvae) typically burrow in soft sediment, which was not present in whakaweku, though it could accumulate over time as Collier et al. (2009) found in coir samplers. *Deleatidium* were much less common in whakaweku than in kick-net samples, though Winterbourn (1974) found this taxon occurring as commonly in leaf litter as on rocks in a forest stream. *Deleatidium* graze algal biofilms on rocks, and perhaps whakaweku lack suitable surfaces for such grazing. *Zelandobius*, which in this study were found only in whakaweku samples, also feed mainly on algal biofilms, but they are also 'shredders', chewing particulate organic matter which would be abundant in whakaweku. They are typically found in leaf packs (de Araujo Barbosa et al. 2022). As well as a potential food source, whakaweku may offer greater habitat complexity and refuge than natural streambed substrates, as Collier et al. (2009) suggested for coir mat samplers. This may explain why *Paratya*, and perhaps Platyhelminthes and *Austrosimulium* were more common and abundant in whakaweku than in kick-net samples.

The macroinvertebrate assemblage in whakaweku was more similar to that in kick-net samples at the soft-bottomed site (as shown by lower ANOSIM R values) than at the hard-bottomed site. This is likely because the fine leaves in the whakaweku are physically more similar to the macrophytes and wood sampled at the soft-bottomed site than to the stones, gravel and fine sediment sampled at the hard-bottomed site. Whakaweku samples were also less variable than kick-net samples, especially at the soft-bottomed site, and there was less difference between hard-bottomed and soft-bottomed sites than in kick-net samples. Samples collected using standard methods in soft-bottomed streams often show high variability, presenting a challenge for obtaining representative results and comparing sites and times (Collier 2004), and the sampled macroinvertebrate communities are usually not directly comparable between soft-bottomed and hard-bottomed streams (Maxted et al. 2003). Both of these effects are reduced using whakaweku.

Required deployment time for whakaweku

We found no significant change in common macroinvertebrate metrics between two-week and four-week deployment periods, suggesting that two weeks is sufficient time to obtain representative results using whakaweku. This is a shorter deployment period than found by several other authors for macroinvertebrate sampling using other kinds of artificial substrate. For example, Boothroyd and Dickie (1989) found taxa richness in multiplate samplers stabilised after 28 days though community composition continued to change for up to 70 days. Others have found that, abundance, richness and diversity increased for between four weeks and 60 days (e.g. Weber 1973; Meier et al. 1979; Waters et al. 2005). However, it is the same colonisation time as found by Kusabs et al. (2018) for sampling of kōura (freshwater crayfish) and toitoi (a native fish) using whakaweku. A

short deployment time has the advantages of obtaining results faster and reducing the risk of samplers being washed away by floods.

Quick vs. standard method

We found no significant or consistent differences in any of the SHMAK-level macroinvertebrate metrics between the quick method and standard method. Therefore, when using SHMAK-level macroinvertebrate metrics, the quick method is adequate and considerably reduces retrieval and processing time. SHMAK-level macroinvertebrate taxa are considerably simplified compared to MCI-level taxa, so SMI and SQSMI scores may have less resolution than MCI and SQMCI for distinguishing sites with different degrees of impairment. However, based on a study by Storey and Wright-Stow (2017), SMI and SQMCI data collected by volunteers can be expected to show a strong correlation and little bias (consistent over- or under-estimating) compared to MCI and SQMCI data collected by professionals.

Even using the quick method, whakaweku require more effort and time than kick-net sampling, particularly as they require two visits for deployment and retrieval, as well as time to make the whakaweku bundles. However, if whakaweku are being used for sampling kōura and/or toitoi, macroinvertebrates can be sampled at the same time with little extra effort.

Benefits, limitations and further research

Whakaweku have several benefits, including some advantages over kick-net sampling. They are, cheap, easy to arrange and deploy and are biodegradable. Whakaweku can be used in a wide range of habitats, including both hard- and soft-bottomed streams as well as habitats such as non-wadeable rivers and streams with mobile beds where kick-net sampling may be difficult. The greater consistency of results among samples and stream types makes them useful for comparing across sites or within a site over time.

Bracken fern (*Pteridium esculentum*) is found throughout New Zealand, Australia, Malaysia and Polynesia, so whakaweku could be used throughout these regions. However, in New Zealand it is less common in winter/early spring, limiting whakaweku to the warmer seasons in this temperate climate. Another disadvantage of whakaweku, like all artificial substrates, is that they are vulnerable to floods and disturbance by the public.

This study was limited to comparing whakaweku and kick-net sampling in two closely spaced sites in one North Island stream. To assess whether whakaweku are suitable for biological monitoring and whether the two methods are comparable for this purpose, further research is needed comparing the two methods across sites in different stream types or spanning a gradient of human impact. Even if the two methods do not correlate closely, whakaweku can be useful for stream cultural monitoring provided they will allow healthy streams to be distinguished from degraded streams. Our results suggest that they will, and therefore can add useful information for whanau (families and community group) and iwi (tribes) who want to monitor their stream for macroinvertebrates as well as kōura and toitoi.

Conclusions

At two lowland Waikato sites, whakaweku were shown to provide comparable results to kick-net samples for MCI, SQMCI, EPT* richness and total richness, but not %EPT* abundance or ASPM. Although community composition differed significantly between whakaweku and kick-net samples, most taxa retrieved were common to both sample types. A two-week deployment time appears sufficient for the available macroinvertebrate taxa to colonise whakaweku, consistent with the colonisation time for kōura and toitoi (Kusabs et al. 2018). A quick method gave comparable results to the standard method for simplified (volunteer-friendly) versions of the main macroinvertebrate metrics. These results show that iwi and community groups can add macroinvertebrates to cultural monitoring of kōura and toitoi using whakaweku, as recommended by Kusabs et al. (2018).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the National Institute for Water and Atmospheric Research (NIWA) Te Kuwaha summer internship programme.

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