Ecological health of stream invertebrate communities in Northland

Can state of the environment data identify drought impacts?

Russell G. Death[1], Carol Nicholson[2], Manas Chakraborty[2] and Stephen Pohe[3]

[1] School of Agriculture and Environment - Ecology, Massey University, Palmerston North, PN4442, New Zealand.

[2] Northland Regional Council, Private Bag 9021, Whangārei Mail Centre, Whangārei 0148

[3] Pohe Environmental, 144 Three Mile Bush Road, Kamo, Whangārei 0112.

Figure 1 Waipoua River

Executive Summary

1. In this study we investigated the current state and trends in ecological health of invertebrate communities in 67 streams and rivers monitored by Northland Regional Council as part of their State of the Environment program.
2. Northland has experienced droughts in recent history in 2010, 2013 and 2017 with potential adverse impacts on the aquatic communities of its rivers and streams. We have investigated whether the collected State of the Environment data could give any indication these droughts are having an impact on invertebrate communities.
3. Four of the 67 sites, between 2015 and 2019, had median MCIs greater than 120 (clean water), 12 had medians between 120 and 100 (mild pollution), 29 had MCI's between 100 and 80 (moderate pollution) and 22 had MCIs lower than (or equal to) 80 (polluted). Based on the NPSFM (2020) 37 sites would be classed as D, 22 as C, 7 as B and only 1 an A.
4. Six of the 67 sites, between 2015 and 2019, had median SQMCIs greater than 6 (clean water), 7 had medians between 6 and 5 (mild pollution), 16 had SQMCI's between 5 and 4 (moderate pollution) and 38 had SQMCIs lower than (or equal to) 4 (polluted). Based on the NPSFM (2020) 47 sites would be classed as D, 11 as C, 6 as B and 3 an A.
5. Three of the 67 sites, between 2015 and 2019, had median ASPM sites classed as an A in the NPSFM (2020), 15 would be a B, 13 would be a C and 36 a D.
6. One site of the 32 sites with a long enough record to assess temporal change, Waitangi at Waimate North Road, exhibited an increase in SQMCI over the last 10 years. Thirteen sites had significant declines in MCI, SQMCI or EPT animals. Of the two reference sites with records of significant length Waipoua at SH12 exhibited no change with time, but Waipapa at Forest Ranger had a decline in EPT animals.
7. Invertebrate communities were distinctive between pasture and indigenous forest land use and between soft and hard substrates. Deposited fine sediment seemed to be the habitat variable most strongly correlated with patterns in invertebrate communities. Freshwater management unit, FENZ class, REC network position, REC geology and order did not represent distinctive groupings or gradients in invertebrate community composition.

8. Two drought indices were used to investigate potential adverse effects on the stream invertebrate communities. The New Zealand Drought Index (NZDI) was developed by NIWA from four commonly used climatological drought indicators and is calculated on a regional basis. For Northland NZDI values have been calculated for the Far North, Kaipara and Whangarei districts. The other index the Standardised Discharge Index (SDI) is calculated from actual discharge data measured at individual rivers.
9. The LifeNZ index, higher scores of which indicate ecological communities with greater flow, declined at Manganui at Mititai Road and Kenana at Kenana Road in years when the New Zealand Drought Index (NZDI) was higher (i.e. drought years). Interestingly, the LifeNZ index increased at Parapara at Taumata Road. No other sites had correlations between LifeNZ and the NZDI.
10. The LifeNZ.W index, which is a flow weighted version of the LifeNZ index, also declined at Kenana at Kenana Road and at Mangahahuru at Apotu Road as the NZDI increased, and increased at Watercress at SH1.
11. More sites had MCI and SQMCI values that declined with increasing drought, although the indices are designed to indicate organic enrichment. The MCI index declined as the NZDI increased (i.e. increased drought) at Mangere at Kokopu Road, Kaeo at Dip Road, Parapara at Parapara Toatoa Road, Tapapa at SH1, Wairau at SH12, and increased at Hatea at Whangarei Falls, Otaika at Cemetery Road. The SQMCI index declined with the NZDI at Mangahahuru at Apotu Road, Hatea at Whangarei Falls, Kenana at Kenana Road, Pekepeka at Ohaeawai, Tapapa at SH1, and increased at Punaruku at Russell Road.
12. Although state of the environment monitoring, which occurs in early summer, is not ideally timed to evaluate drought impacts, that will likely increase over summer, several sites indicated invertebrate communities were adversely impacted by drought (based on the NZDI). Interestingly the MCI/SQMCI indices indicated more effects than the specialised flow indices, although we cannot rule out changes in organic enrichment associated with flow declines.
13. There were far fewer correlations between biological indices, including the two LifeNZ indices, and the other drought measure the SDI. Mangahahuru at Main Road, Utakura at Okaka Road, and Mangakahia at Twin Bridges were the only sites with negative correlations with any of the biotic indices, and the SDI.

14. There did not appear to be any temporal changes in invertebrate community composition associated with drought years.
15. Standard annual SoE monitoring data provides limited evidence of any adverse effects of droughts in 2010, 2013 and 2017 on the invertebrate communities collected at 67 state of the environment streams and rivers. Pastoral land use and deposited fine sediment appear to have the greatest impacts on invertebrate communities in these streams and rivers.

Introduction

This report has been prepared as a continuation of the Northland Regional Council's Macroinvertebrate Environmental Monitoring Programme. It provides an assessment of aquatic macroinvertebrate communities present at 67 State of the Environment (SoE) River Water Quality Monitoring Network (RWQMN) sites throughout the Northland region sampled annually until 2019. It builds on the results of previous monitoring undertaken annually from 1997 at the some of the same sampling sites and additional sites added over the subsequent years. This data will further build on the Council's freshwater ecosystems database.

Why we monitor macroinvertebrates

The use of macroinvertebrate communities to assess stream health is widespread both internationally and in New Zealand (Rosenberg and Resh 1993, Stark *et al* 2001) because community composition is affected by environmental conditions over an extended period of time, unlike water quality samples, which tend to be spot measurements, i.e. measurements taken at an exact point in time. Different macroinvertebrates show different responses to changes in their environment such as water quality or low flows and different species show different tolerances to pollution (Boothroyd and Stark 2000). Invertebrates such as snails and worms and chironomid midges tend to be quite tolerant of pollution compared to others such as stone flies, caddisflies and mayflies which tend to be sensitive to pollution. Macroinvertebrates are a good indicator of the life supporting capacity of a stream or river, as they are usually near the middle of the food web and are an important component of stream ecosystems.

Other ecological factors such as the variety and abundance of habitat types, riparian vegetation, surrounding land uses and periphyton growth (slime and algae) will directly impact on macroinvertebrate communities. Mayfly, stonefly and caddis fly species tend to favour stony streams with just a thin layer of diatom type periphyton present however thick layers of periphyton can develop in response to nutrient enrichment, low flows and high water temperature. In these conditions grazing type feeders such as snails and beetle larvae will tend to be more abundant. To help interpret the macroinvertebrate data, habitat assessments are carried out in conjunction with the macroinvertebrate sampling and the results of the periphyton monitoring programme (conducted monthly throughout the summer at the same sites) are presented.

Drought effects

Drought is likely to become an increasing pressure on water resources and waterway ecosystems as patterns of precipitation, temperature and water use change in response to global climate alteration (Dunn et al. , IPCC 2013, Ledger et al. 2013, Salinger and Alexander 2020). Ironically, for some regions, reduced rainfall and increased temperature may be further exacerbated by increases in the frequency, intensity, spatial extent, predictability and duration of floods (Aldous et al. 2011, Dankers et al. 2013). Furthermore, many freshwater ecosystems may already be altered or stressed by increases in anthropogenic pressure from land use intensification and water abstraction (Allan 2004, Death et al. Resubmitted 21/4/2020).

Human responses to drought are also likely to be highly variable. Many may see a decrease in water availability a greater incentive to increase water abstraction and/or storage to allow for the actual or potential uncertainty in future water availability. This in turn may place greater pressure on already stressed ecosystems experiencing uncharacteristically low and/or high flows. Investigations of drought on aquatic invertebrate communities have been largely restricted to those in the Northern Hemisphere (Ledger et al. 2013, Chadd et al. 2017, Aspin et al. 2018) or Australia (Leigh et al. 2015a, Leigh et al. 2015b, Leigh et al. 2016, Leigh and Datry 2016).

Decisions around water abstraction and/or storage rely on the ability of natural water sources to supply water at times of limit or times of excess when storage can potentially occur. However, those ecosystems provide multiple resources other than the out of river use of water, including māhinga kai, recreation, spiritual and cultural, and natural ecosystem function. The latter of course may determine the future ability of those ecosystems to provide adequate safe water.

State of the environment monitoring usually occurs in early summer (January and February) and is therefore not specifically timed to evaluate any potential drought impacts, that are more likely to be most pronounced at the end of summer. We used two drought indices to investigate whether the SoE data could indicate drought impacts. The New Zealand Drought Index (NZDI) developed by NIWA is a regional scale index. It combines commonly used climatological drought indicators the Standardised Precipitation Index, the Soil Moisture Deficit, the Soil Moisture Deficit Anomaly, and the Potential Evapotranspiration Deficit and is calculated on a regional basis. For Northland NZDI values have been calculated for the Far North, Kaipara and Whangarei districts. The other index the Standardised Discharge Index (SDI) is more local and calculated from actual discharge data measured at individual rivers., several sites indicated. In this study we investigated whether there are particular streams and rivers that have been more or less impacted by current drought impacts in the Northland region?

Report aim

This study investigates temporal and spatial trends in the invertebrate communities at 67 State of the Environment sites. Although, as mentioned above, State of the Environment collections are not ideally timed to investigate drought impacts we also explored whether temporal trends in the data correlates with potential changes in the severity of drought impact. Northland has experienced droughts in recent history in 2010, 2013 and 2017 with potential adverse impacts on the aquatic communities of its rivers and streams. Changes in climate patterns will result in drought becoming more frequent and potentially severe in the future. Northland Regional Council have been monitoring the ecological health of stream and river macroinvertebrate communities since 1997. Some of these waterways are likely to be less affected than others by drought and may be able to serve as a control of “natural” summer changes against which to judge drought impacts.

We have also re-sampled 12 potentially drought impacted State of the Environment sites and an additional 10 “new” sites in March 2020 at the height of the current 2020 drought. We will resample these sites when “normal” flows return, and with SOE sampling in 2021, to assess their resilience to the low flow stress. Results of that assessment will be presented in a future report.

Methods

Sampling Protocols

Macroinvertebrate Sampling

The freshwater macroinvertebrate samples were collected using the Stark sampling protocols (Stark et al. 2001). Both hard-bottom and soft bottom rivers occur in the Northland Regional Council area and these are sampled with the appropriate respective semi-quantitative hard-bottomed and soft-bottom protocols.

- **Hard-bottom rivers** are characterised by having substrate dominated by bedrock/cobble and gravel. These rivers were sampled using protocol C1 (Hard-bottomed Semi-quantitative). The samples were collected using a net with 500 µm mesh, over an area of 1 m^2. This was composed of five replicate unit efforts of 0.2 m^2. Each was taken in a different place so that a range of substrate sizes and water velocity regimes were sampled. Each sample was taken by kicking and disturbing the substrate in the sample area while the net was held directly downstream, flush with the streambed. This ensured that all invertebrates were dislodged and swept into the net. After all the replicates were taken, the sample was transferred into a jar and preserved with 80 percent ethanol, ready for processing.

- **Soft-bottom rivers** have a substrate dominated by fine sediment such as sand, silt or mud. These sites were sampled using the sampling Protocol C2 (soft-bottomed semi-quantitative). This protocol is designed to maximise invertebrate collection in streams that have silty/muddy bottoms, with in-stream macrophytes and woody debris. Each of these samples was taken from an area of $3m^2$, made up of five $0.6m^2$ replicates. Sampling effort was concentrated within the main habitat types (bank margins, submerged woody debris, and aquatic macrophytes) in proportion to their occurrence. Bank margins were sampled by jabbing the net into the bank for a distance of 1 metre, then following with 2-3 cleaning sweeps to catch any displaced organisms. A similar technique was used for sampling macrophytes. This involved moving the net through a 1m stretch of submerged plants, followed with two cleaning sweeps. Care was taken in both these cases, to avoid collecting excess silt or algae. Submerged woody debris was sampled by holding the wood over the mouth of the net, while washing the invertebrates off with stream water. Once complete, the sample was transferred into a jar and preserved in 80 percent ethanol as above.

Sample processing used coded abundance from 1997 to 2013, but full counts have been used subsequently (Stark et al. 2001).

Habitat Sampling

At each site National Rapid Habitat Assessment protocols (Clapcott 2015) were used from 2015. This involved assigning scores to a number of stream characteristics; fine sediment deposition (for hard bottom streams), invertebrate habitat, fish cover, hydraulic heterogeneity, bank stability, bank vegetation, riparian buffer, riparian shade and channel alteration. Scores for each characteristic ranged from 0 to 10, with 0 to 2 indicating poor habitat quality for that characteristic, 3 – 5 indicating marginal, 6 – 7 suboptimal and 8– 10 indicating optimal habitat quality. Habitat condition was then scored as a percentage of reference condition taken from one of the three sample sites of the same River Environment Classification (REC) for geology, valley landform and climate. Where a suitable reference site was not available an approximation of reference condition was used by taking the median score of the three reference sites.

Periphyton Sampling

Historically, periphyton monitoring was conducted with the macroinvertebrate monitoring programme. Since 2015 the periphyton monitoring has been monthly. The protocols used for sample collection are those outlined in Kilroy et al (2008).

Physiochemical Measurements

Several physiochemical measurements (temperature, pH and conductivity) were taken at the time of macroinvertebrate sampling using a Eutech PCST estr. A range of parameters, including temperature, dissolved oxygen, pH, water clarity, nutrients and bacterial levels are also measured monthly as part of the regular SOE WQ monitoring programme

Data Analysis

Several biotic indices were calculated which are used to give an indication of stream health and change over time in these streams (Stark, 1985, Stark and Maxted, 2007):

- Number of taxa – The number of taxa present at each site is a measure of diversity or species richness, although it is unclear how it might respond to anthropogenic stresses. Thus, while it is a good descriptor of an ecological community it is not overly useful for assessing environmental impacts.

- MCI - (MCI-hb and MCI-sb) – are based on the presence of macroinvertebrate taxa, which are assigned scores, which reflect their tolerance to environmental changes/extremes. These scores range between 1 and 10 (1 being highly tolerant and 10 being sensitive). The final score for each stream incorporates the sum of the MCI scores for each taxon with one or more individuals. A score of 120 or greater indicates a stream in pristine condition, a score between 80 and 120 indicate a moderately impacted stream, and a score lower than 80 indicate a severely polluted stream.

- SQMCI - (SQMCI-hb and SQMCI-sb) – are based on the abundance of macroinvertebrate taxa, which are assigned scores, which reflect their tolerance to environmental changes/extremes. The SQMCI index is used rather than the QMCI as prior to 2014 coded abundances were used for sample processing. SQMCI values post 2014 are thus actually QMCI values. The taxa scores range between 1 and 10 (1 being highly tolerant and 10 being sensitive). The final score for each stream incorporates the sum of the MCI scores for each taxon weighted by the number of individuals. A score of 6 or greater indicates a stream in pristine condition, a score between 4 and 6 indicate a moderately impacted stream, and a score lower than 4 indicate a severely polluted stream

- Percent EPT animals - is the percentage of taxa identified that belong in the Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddis fly) groups. These groups of insects are generally considered to be sensitive to pollution. The greater the proportion of these groups in the stream community, the healthier the stream is considered to be. The caddis flies Oxyethira, and Paraoxyethira were excluded from this analysis, as they are relatively tolerant to pollution.

- Average Score per metric (ASPM) – this is the average of three standardised metrics percent EPT abundance, EPT richness and MCI. Each metric is first standardised by using the following equation:
  $[X - X_{min}] / [X_{max} - X_{min}]$

  where X is the site raw score and X_{min} and X_{max} are the minimum and maximum site scores of the entire dataset. When standardising scores for ASPM the following minima and maxima are used: %EPT-abundance (0-100), EPT-richness (0-29), MCI (0-200).

- LIFENZ and LIFENZ.W are newly developed hydrological sensitivity indices (Greenwood et al. 2016) for riverine macroinvertebrates based on the equivalent index used in the UK (Extence et al. 1999, Dunbar et al. 2010). There are no thresholds for poor or excellent but the higher the score the more sensitive the fauna is to changes in flow.

Statistical analysis of invertebrate community data

Correlation of indices was performed using Pearson's correlation coefficient because of the large number of zeros (Huson 2007). As indices are only measured once yearly temporal trend analysis simply involved correlating indices with year. To analyze community data collections from each year between 2008 and 2019 were averaged. Community composition was then analyzed with non-metric multi-dimensional scaling ordination (NMDS) using Primer (Anderson et al. 2008). Primer is a statistical software package for undertaking multivariate statistical analyses of community ecology data. Hellinger distance measures on untransformed abundances were used to calculate the NMDS plot. Hellinger distances treat the data as relative abundance and is recommended for biological data (Legendre and Legendre 1998)

Sampling Locations

State of the Environment Monitoring Sites

There are 67 State of the Environment sites scattered throughout Northland (Figure 2), which represent a range of geologies, river orders and land use and includes six reference sites whose catchment comprises at least 85 percent native cover (Table 1). The sites are spread across 10 of 13 freshwater management units (FMU's) with the remaining FMU's only having lake sites. A full list of the study sites is presented in Appendix 1. Site photos are included in Appendix 2.

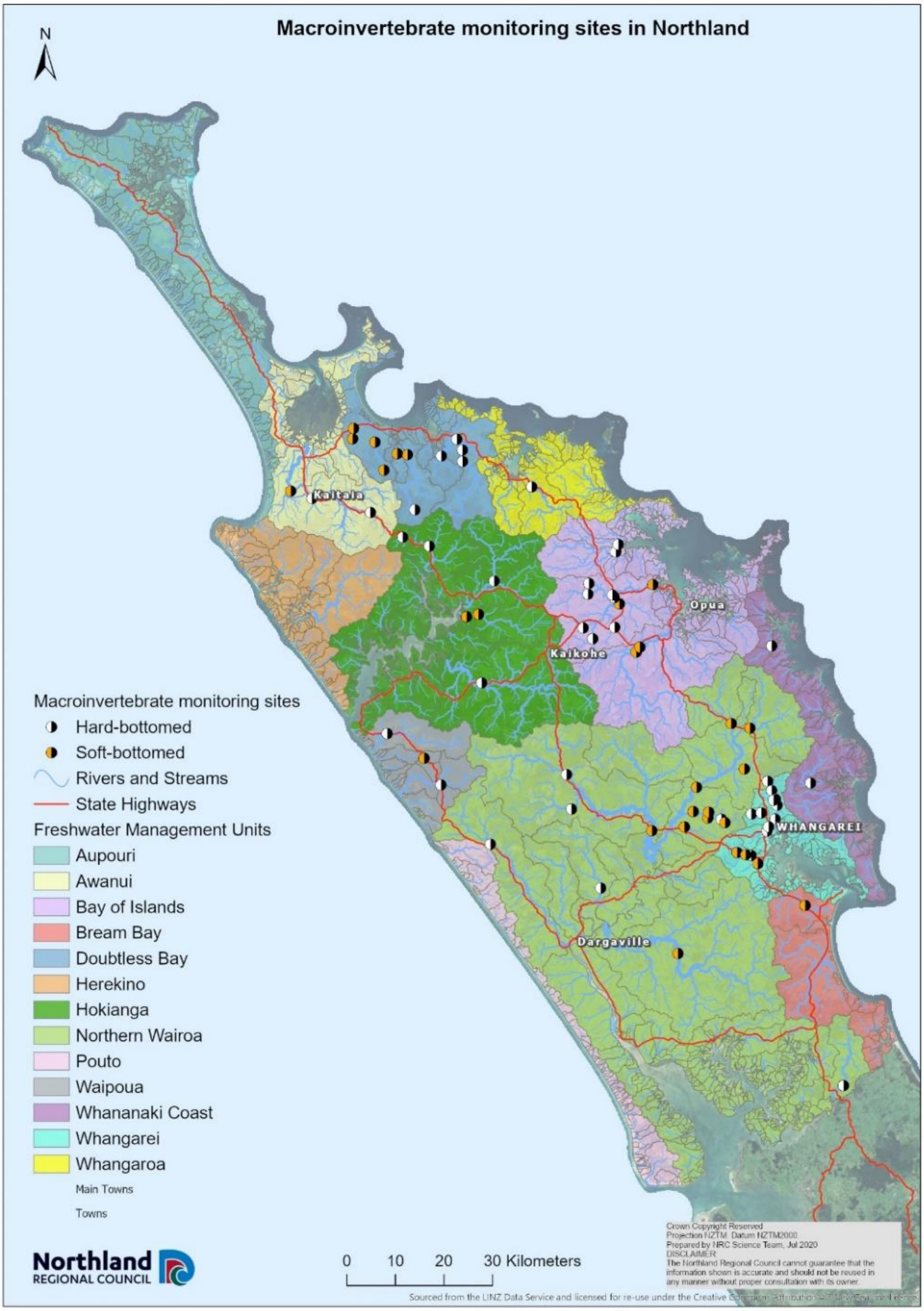

Figure 2 State of the Environment monitoring sites in Northland

Table 1 Number of the 67 SOE sites in groupings from the Freshwater Environments of New Zealand (FENZ) and River Environment Classification (REC) categories.

FENZ class		Stream order		REC Land use		REC geology	
A1	15	1	5	Pasture	50	Soft sediment	18
A2	2	2	4	Exotic forest	4	Volcanic acidic	28
A3	6	3	14	Indigenous forest	9	Hard sediment	21
C4	36	4	20	Urban	3		
C5	4	5	19	Scrub	1		
C6	3	6	5				
C8	1						

Results

Section 1

State of water quality

Macroinvertebrate Community Index (MCI)

Most sites had MCI scores in the intermediate degradation range (Figure 3, Figure 4, Figure 5). There was less range in MCI scores within sites from year to year than for some of the other indices. Between 2009 and 2019 Waipoua at SH12 had the highest MCI of 143 and Wairua at Purua had the lowest 43.

Based on the NPSFM (2020), using a five-year median 37 sites would be classed as D with an MCI below 90, 22 as C with an MCI between 90 and 110, 7 as B with an MCI between 110 and 130 and only 1 an A with an MCI greater than 130 (Table 1).

The reference sites Tapapa at SH1, Waipoua at SH12, Wairau at SH12 and Pukeni at Kanehiana Drive were the only sites with median MCI scores greater than 120. FMUs had significantly different MCIs ($F_{9,502}$ = 9.20, $P<0.001$). This was a result of the Waipoua FMU having a higher median MCI than Awanui, Bay of Islands, Doubtless Bay, Hokianga, Northern Wairoa and Whangarei; and the Hokianga FMU having a higher median MCI than the Bay of Islands, Doubtless Bay, Northern Wairoa, Waipoua and Whangarei FMU.

Table 2 Median biological metrics for the sampled SOE sites collected between 2015 and 2019 (i.e. five-year average required under the NPSFM 2020). An A in the NPSFM is indicated by blue, a B by green, a C by orange and a D by red. The last rows give counts of the number of sites with metrics in each of the four NPSFM categories.

FMU	Site Name	MCI	QMCI	Percent EPT taxa	Percent EPT animals	ASPM
Awanui	Victoria at Victoria Valley Rd	106	4.8	38.1	49.2	0.4
Awanui	Awanui at FNDC	92	4.2	38.9	9.7	0.3
Awanui	Awanui at Waihue Channel	74	2.3	16.7	2.1	0.2
Doubtless Bay	Aurere at Pekerau Rd	64	2.2	1.9	0.3	0.1
Doubtless Bay	Parapara at Parapara Toatoa Rd	89	4.6	33.3	55.1	0.4
Doubtless Bay	Parapara at Taumata Rd	87	2.1	11.1	0.4	0.2
Doubtless Bay	Oruaiti at Sawyer Rd	86	3.7	30.4	18.2	0.3
Doubtless Bay	Stony Creek at Sawyer Rd	90	4.1	31.8	21.0	0.3
Doubtless Bay	Oruaiti at Windust Rd	88	3.9	30.4	6.8	0.2
Doubtless Bay	Kenana at Kenana Rd	91	4.0	30.8	4.8	0.3
Doubtless Bay	Peria at Honeymoon Valley Rd	118	6.6	48.1	59.5	0.5
Doubtless Bay	Oruru at Oruru Rd	91	2.4	25.0	1.4	0.2
Doubtless Bay	Paranui at Paranui Rd	64	3.7	8.3	13.3	0.2
Whangaroa	Kaeo at Dip Rd	93	5.0	25.0	2.4	0.2
Bay of Islands	Kerikeri at Stone Store	80	3.8	27.5	19.5	0.2
Bay of Islands	Waipapa at Waipapa Landing	66	3.0	7.1	1.6	0.1

FMU	Site Name	MCI	QMCI	Percent EPT taxa	Percent EPT animals	ASPM
Bay of Islands	Waitangi at Waimate North Rd	114	6.1	44.6	40.9	0.4
Bay of Islands	Waipapa at Waimate North Rd	90	4.2	34.8	15.0	0.3
Bay of Islands	Waitangi at SH10	94	4.4	44.4	7.0	0.3
Bay of Islands	Waiaruhe D/S Mangamutu Cnfl	97	5.9	43.8	66.5	0.5
Bay of Islands	Pekepeka at Ohaeawai	86	3.1	29.2	6.8	0.2
Bay of Islands	Watercress at SH1	89	4.5	36.8	55.6	0.4
Bay of Islands	Mania at SH10	60	2.8	4.8	11.8	0.2
Bay of Islands	Waiaruhe at Puketona	91	3.1	38.1	11.3	0.3
Bay of Islands	Waitangi at Wakelins	71	1.8	6.8	1.1	0.1
Bay of Islands	Waiharakeke at Stringers Rd	92	4.5	36.2	35.5	0.4
Hokianga	Tapapa at SH1	121	7.0	53.6	67.8	0.6
Hokianga	Mangamuka at Iwitaua Rd	106	5.5	42.9	13.5	0.4
Hokianga	Waipapa at Forest Ranger	108	5.1	46.4	25.5	0.4
Hokianga	Punakitere at Taheke	88	4.2	35.7	38.1	0.4
Hokianga	Utakura at Okaka Rd	66	2.1	7.9	0.4	0.1
Waipoua	Waipoua at SH12	133	7.6	63.3	80.3	0.7
Waipoua	Wairau at SH12	122	6.3	45.0	58.5	0.5

FMU	Site Name	MCI	QMCI	Percent EPT taxa	Percent EPT animals	ASPM
Waipoua	Waimamaku at SH12	94	4.0	23.8	7.1	0.3
Whananaki Coast	Punaruku at Russell Rd	113	5.0	56.7	23.1	0.4
Whananaki Coast	Ngunguru at Coalhill Lane	92	4.6	36.4	19.8	0.3
Northern Wairoa	Whakapara at Cableway	78	2.3	20.0	1.2	0.2
Northern Wairoa	Waiotu at SH1	78	2.2	20.0	1.0	0.2
Northern Wairoa	Mangahahuru at Main Rd	117	5.4	47.4	19.3	0.4
Northern Wairoa	Mangahahuru at Apotu Rd	79	3.2	14.3	3.2	0.2
Northern Wairoa	Wairua at Purua	77	2.2	26.1	0.2	0.2
Northern Wairoa	Mangere at Wood Rd	79	3.9	21.9	2.4	0.2
Northern Wairoa	Mangere at Kara Rd	109	5.2	41.7	19.1	0.4
Northern Wairoa	Mangere at Kokopu Rd	99	2.3	27.8	2.7	0.2
Northern Wairoa	Mangapiu at Kokopu Rd	71	2.7	9.5	2.8	0.1
Northern Wairoa	Mangere at Knight Rd	86	2.2	17.4	0.5	0.2
Northern Wairoa	Waipao at Draffin Rd	109	3.1	45.8	7.6	0.3
Northern Wairoa	Mangakahia at Twin Bridges	88	3.4	25.9	8.3	0.2

FMU	Site Name	MCI	QMCI	Percent EPT taxa	Percent EPT animals	ASPM
Northern Wairoa	Opouteke at Suspension Bridge	82	3.0	31.8	6.1	0.2
Northern Wairoa	Mangakahia at Titoki	95	2.2	37.5	1.5	0.2
Northern Wairoa	Manganui at Mititai Rd	53	2.1	0.0	0.0	0.1
Northern Wairoa	Kaihu at Gorge	86	3.8	38.1	6.5	0.3
Northern Wairoa	Hakaru at Topuni	76	3.6	26.3	5.8	0.2
Whangarei	Mangakino at Mangakino Lane	105	6.0	45.5	56.4	0.5
Whangarei	Mangakino U/S Waitaua Cnfl	93	2.6	22.7	7.2	0.2
Whangarei	Waitaua at Vinegar Hill Rd	80	2.4	14.3	2.2	0.2
Whangarei	Hatea at Whangarei Falls	81	3.8	20.3	3.2	0.2
Whangarei	Hatea at Mair Park	79	3.9	22.7	9.6	0.2
Whangarei	Pukenui at Kanehiana Drive	127	5.8	52.8	50.0	0.6
Whangarei	Waiarohia at Whau Valley	78	3.5	19.0	4.2	0.2
Whangarei	Waiarohia at Second Avenue	77	3.6	12.5	7.6	0.2
Whangarei	Raumanga at Bernard Street	85	4.1	23.0	8.3	0.2
Whangarei	Otaika at Cemetery Rd	88	3.2	27.4	3.7	0.3
Whangarei	Otakaranga at Otaika Valley Rd	58	2.0	4.2	0.5	0.1
Whangarei	Otaika at Otaika Valley Rd	106	4.6	43.8	17.5	0.3
Whangarei	Puwera at SH1	60	2.0	3.8	0.0	0.1

Bream Bay	Ruakaka at Flyger Rd	86	3.6	26.7	10.0	0.2
NPSFM Categories	**A**	1	3			3
	B	7	6			15
	C	22	11			13
	D	37	47			36

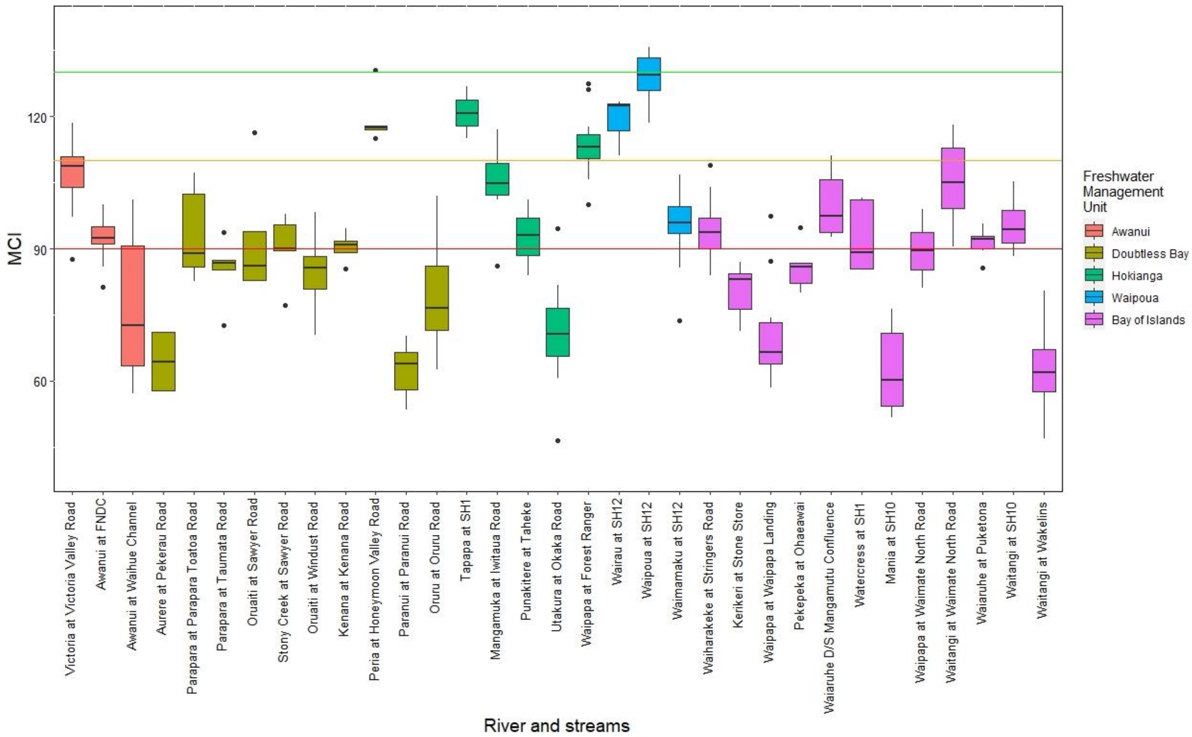

Figure 3 MCI (hard bottom or soft bottom depending on river substrate) collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The green line at MCI = 120 and above corresponds to clean water, the yellow line at MCI = 100 represents mild pollution (above) and moderate pollution (below) and the red line at MCI = 80 and below indicates polluted water.

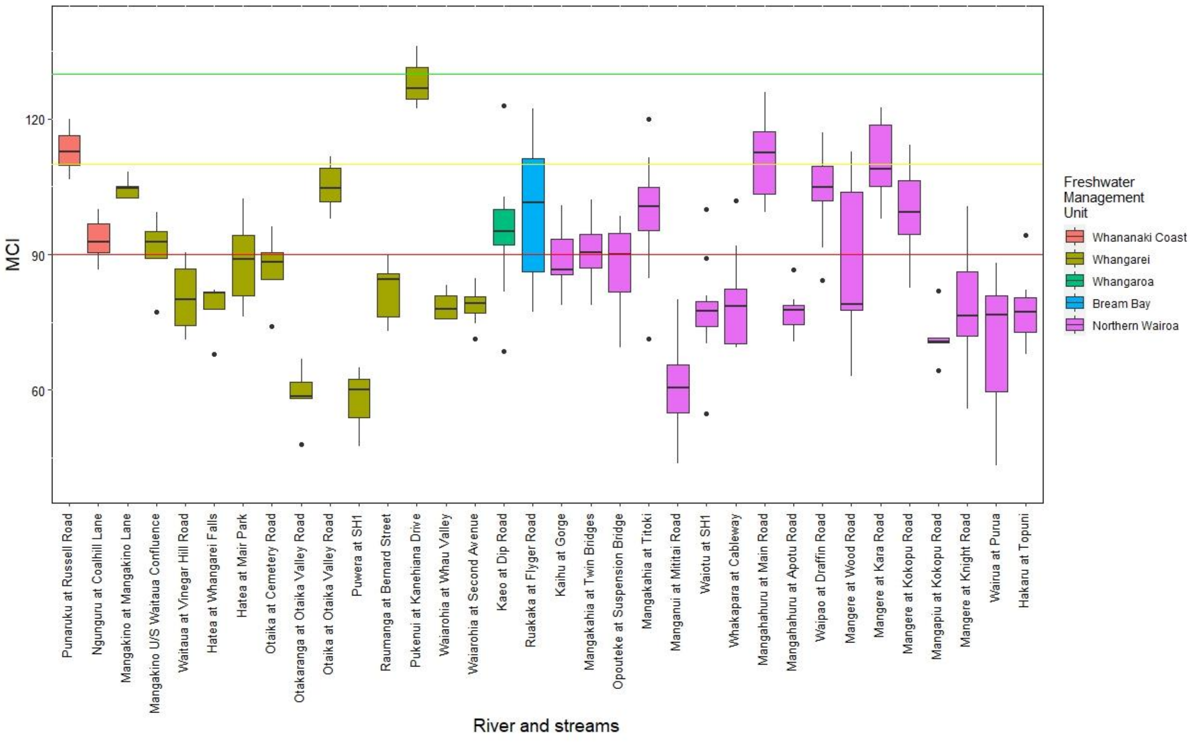

Figure 4 MCI (hard bottom or soft bottom depending on river substrate) collected at sites in the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The green line at MCI = 120 and above corresponds to clean water, the yellow line at MCI = 100 represents mild pollution (above) and moderate pollution (below) and the red line at MCI = 80 and below indicates polluted water.

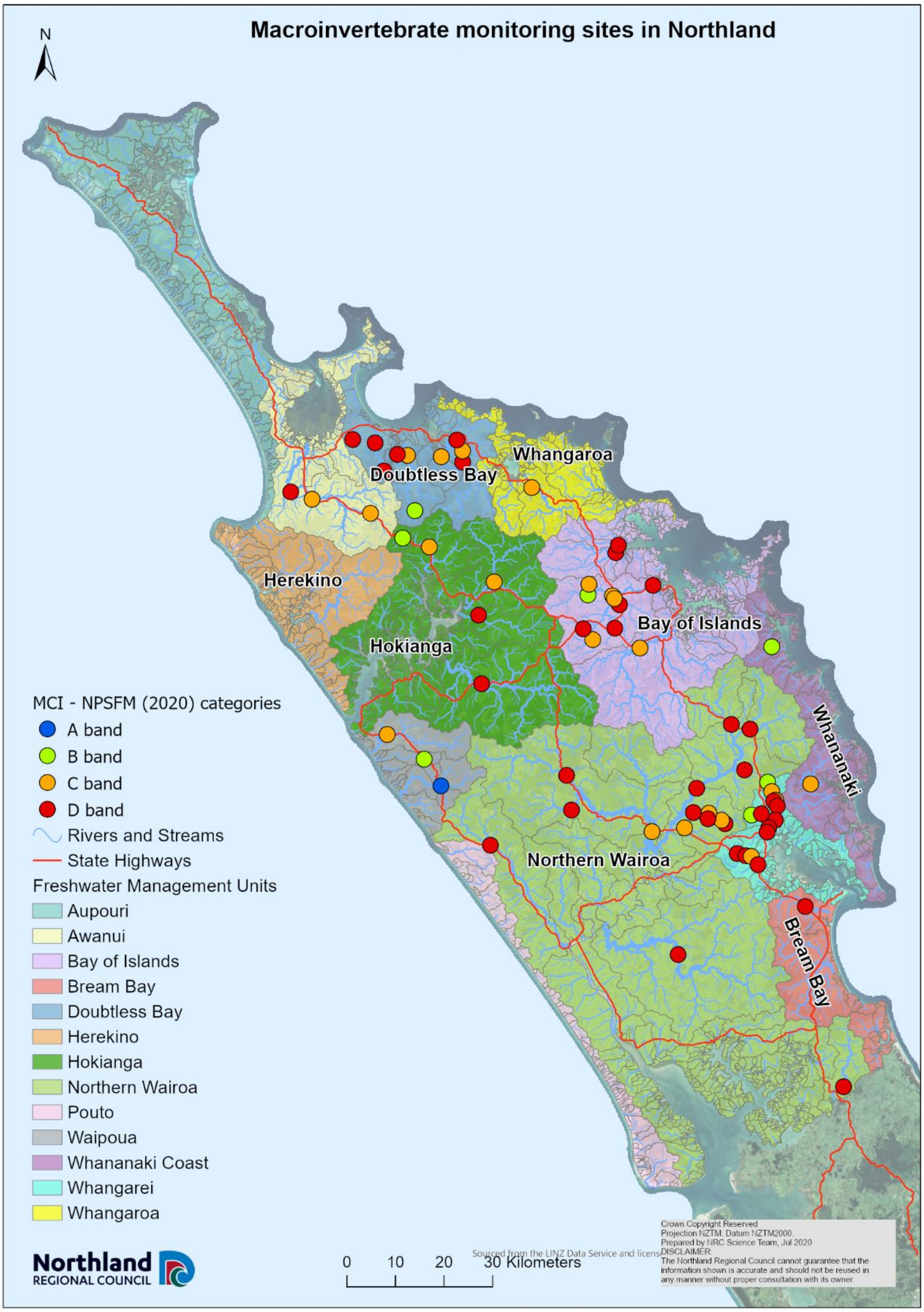

Figure 5 Map of five-year average MCI (hard bottom or soft bottom depending on river substrate) collected at Northland State of the Environment monitoring sites between 2015 and 2019. Sites are colour coded based on their position in the NPSFM (2020) bands.

Semi Quantitative Macroinvertebrate Community Index (SQMCI)

Most sites had SQMCI scores indicative of similar conditions to the MCI predominantly in the intermediate degradation range (Figure 6, Figure 7, Figure 8). The Northern Wairoa FMU did, however, have more sites assessed as degraded than in other FMUs.

Between 2009 and 2019 six of the 67 sites had median SQMCIs greater than 6, 7 had medians between 6 and 5, 16 had SQMCI’s between 5 and 4 and 38 had SQMCIs lower than (or equal to) 4. Based on the NPSFM (2020) 47 sites would be classed as D, 11 as C, 6 as B and 3 an A.

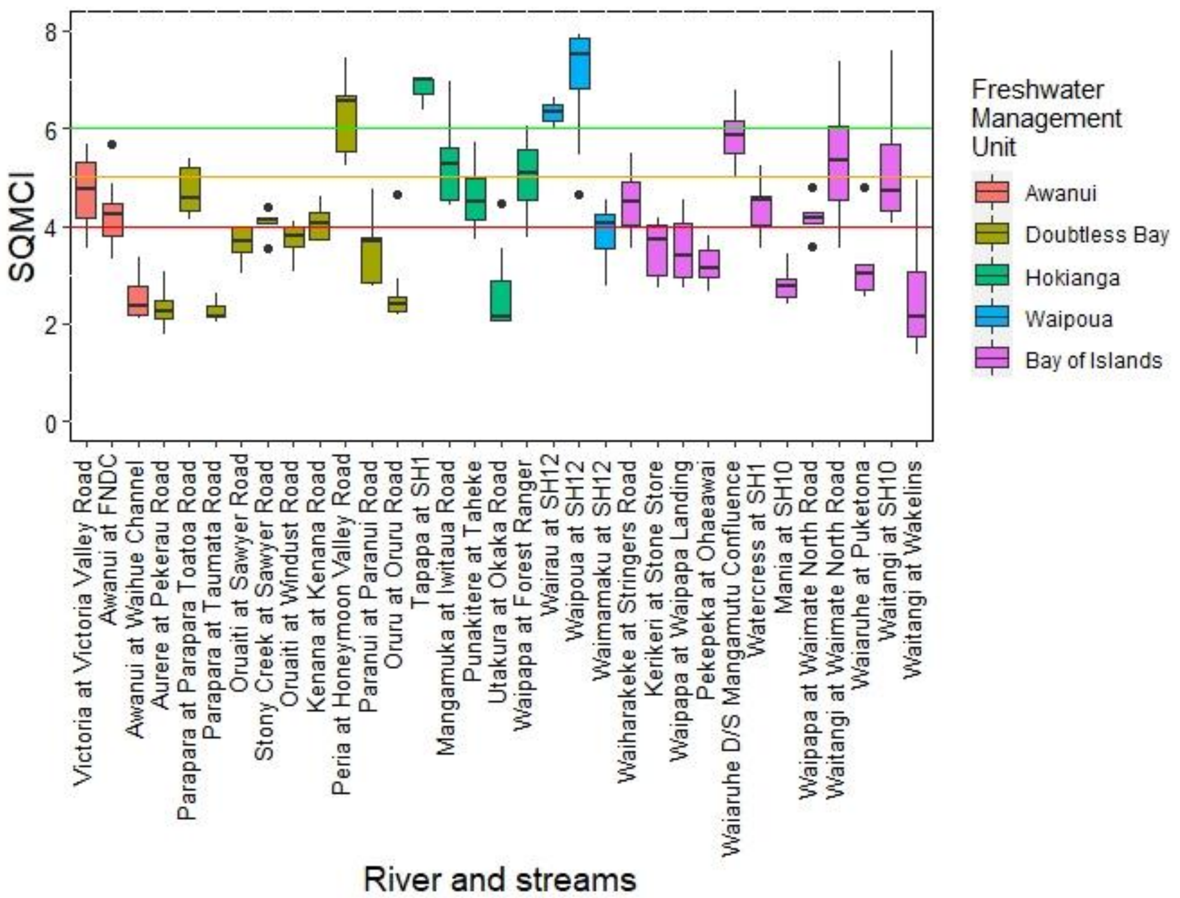

Figure 6 SQMCI (hard bottom or soft bottom depending on river substrate) collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The green line at SQMCI = 6 and above corresponds to clean water, the yellow line at SQMCI = 5 represents mild pollution (above) and moderate pollution (below) and the red line at SQMCI = 4 and below indicates polluted water.

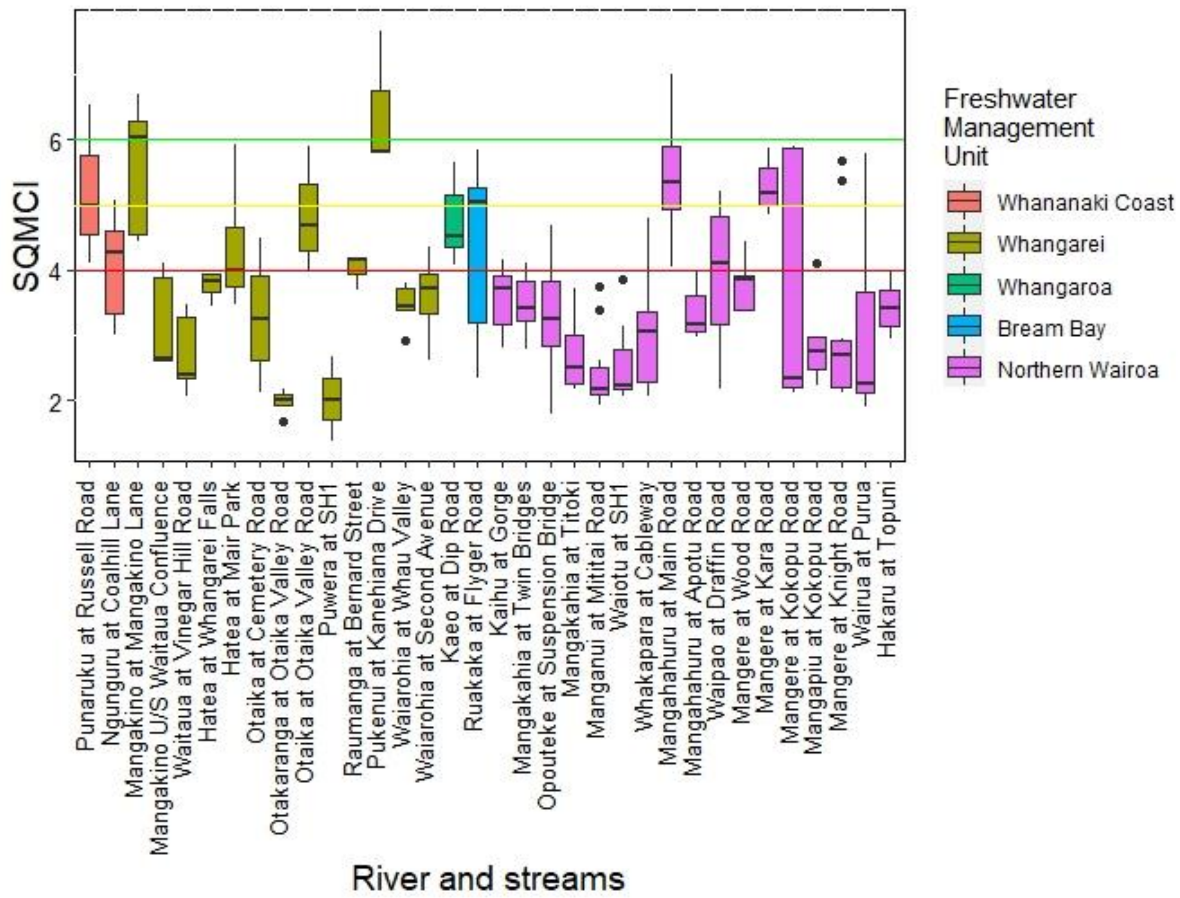

Figure 7 SQMCI (hard bottom or soft bottom depending on river substrate) collected at sites in the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The green line at SQMCI = 6 and above corresponds to clean water, the yellow line at SQMCI = 5 represents mild pollution (above) and moderate pollution (below) and the red line at SQMCI = 4 and below indicates polluted water.

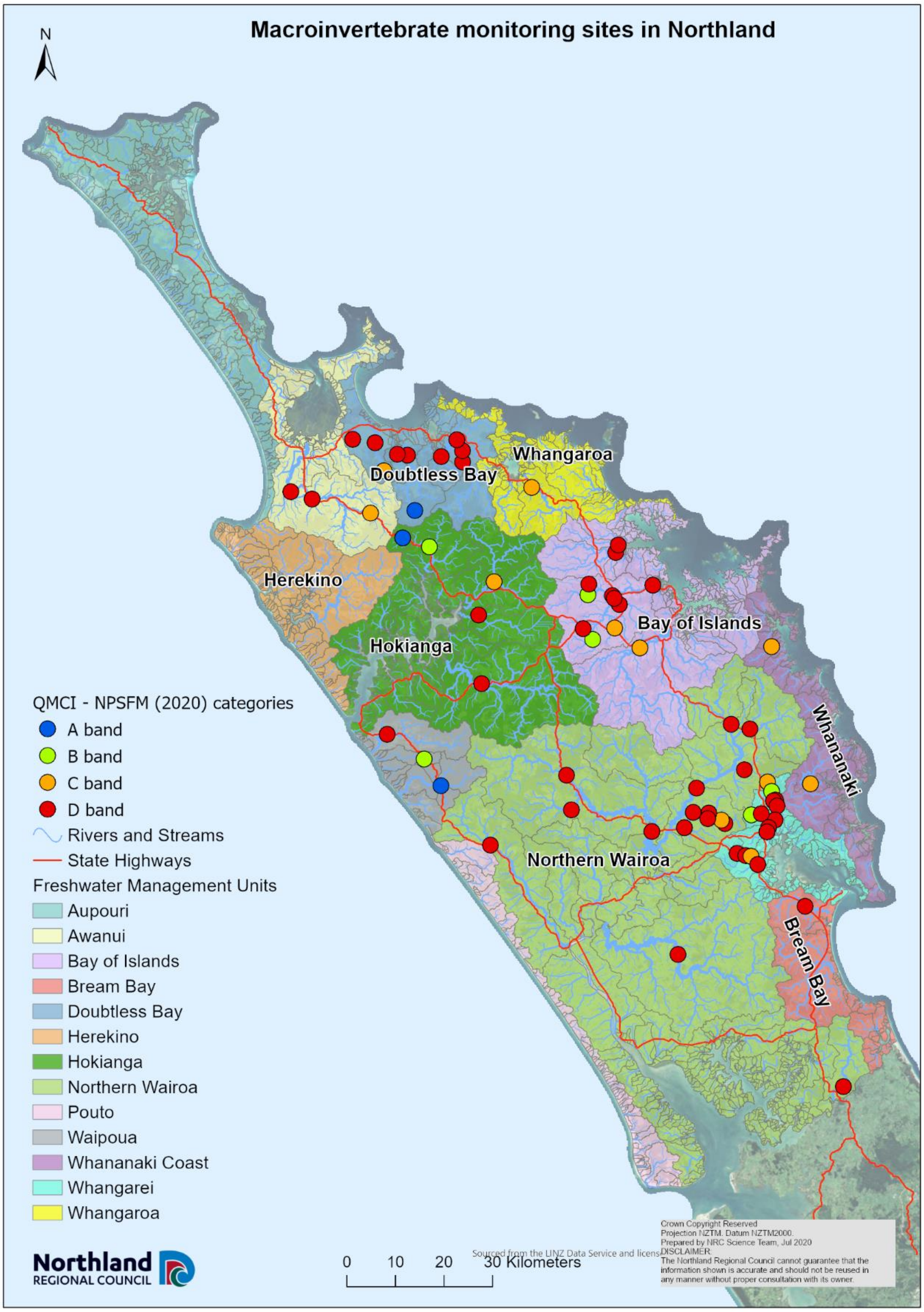

Figure 8 Map of five-year average SQMCI (hard bottom or soft bottom depending on river substrate) collected at Northland State of the Environment monitoring sites between 2015 and 2019. Sites are colour coded based on their position in the NPSFM (2020) bands.

Percent EPT (Ephemeroptera, Plecoptera, Trichoptera)

Percent of EPT animals ranged from 0 at many sites to 80% at Waipoua at SH12 (Figure 9, Figure 10). There were no obvious differences in EPT between FMUs.

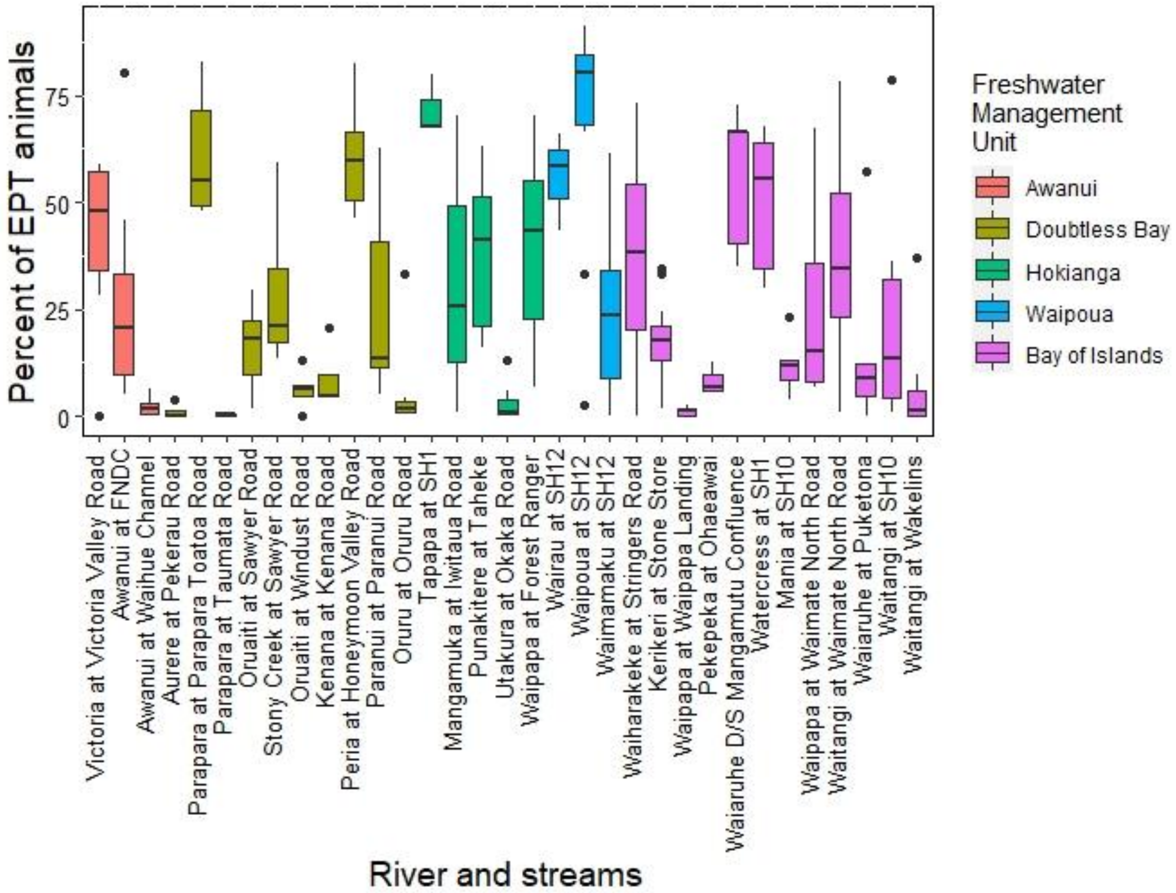

Figure 9 Percent EPT animals collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range.

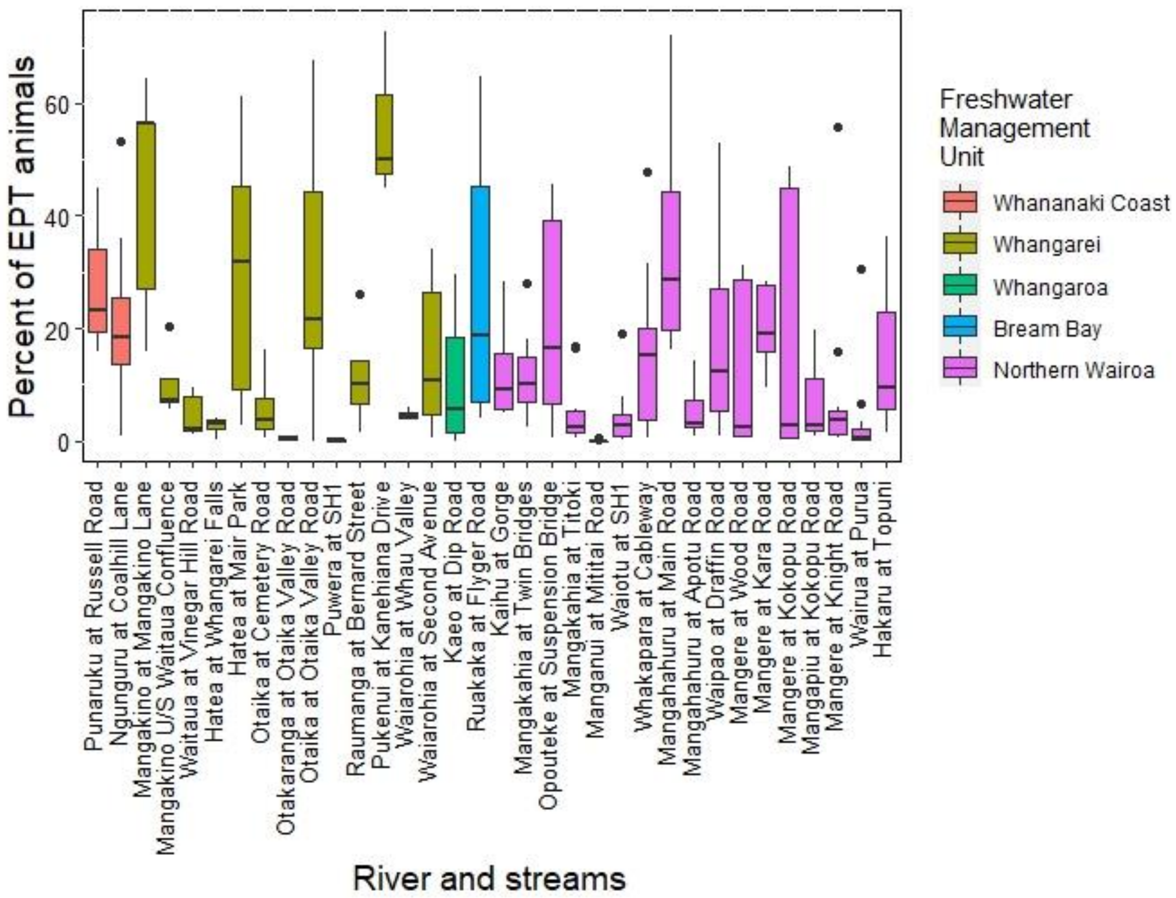

Figure 10 Percent EPT animals collected at sites in the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range.

Average Score per Metric

Three of the 67 sites had median ASPM sites classed as an A in the NPSFM (2020), 15 would be a B, 13 would be a C and 36 a D between 2009 and 2019 (Figure 11, Figure 12, Figure 13).

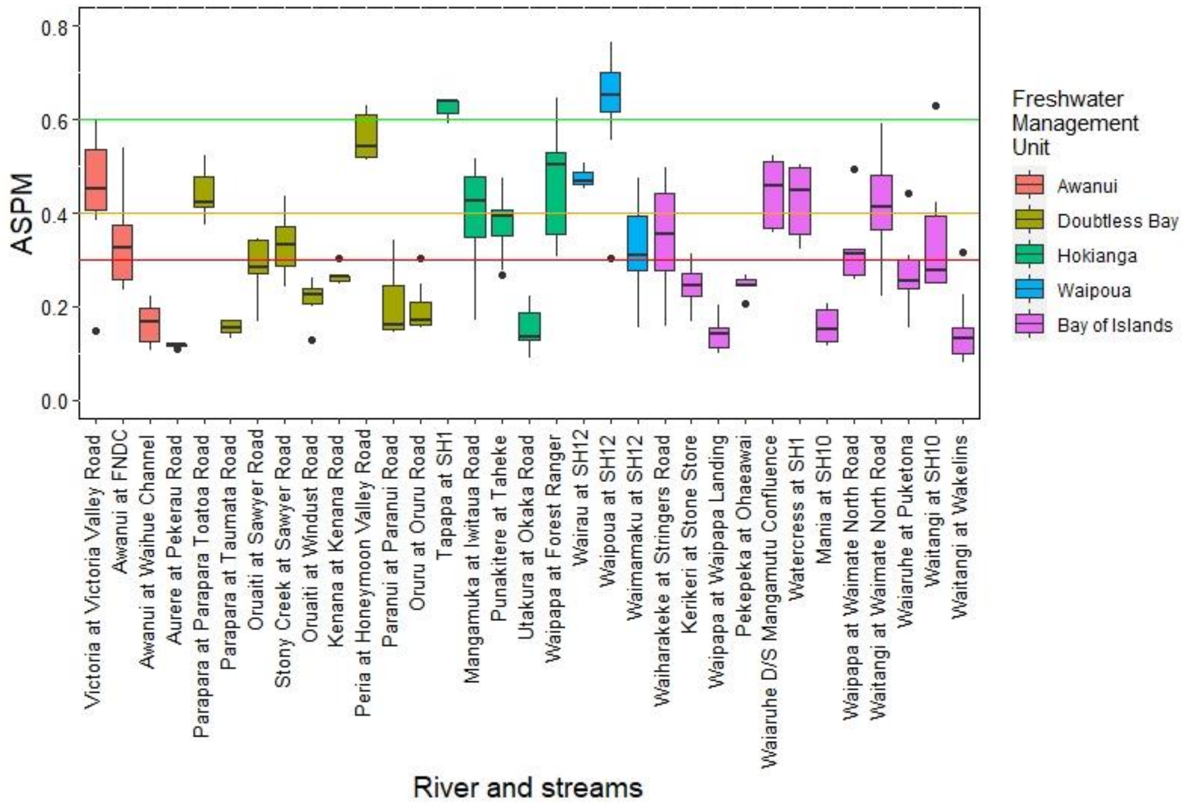

Figure 11 Average Score per Metric collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range.

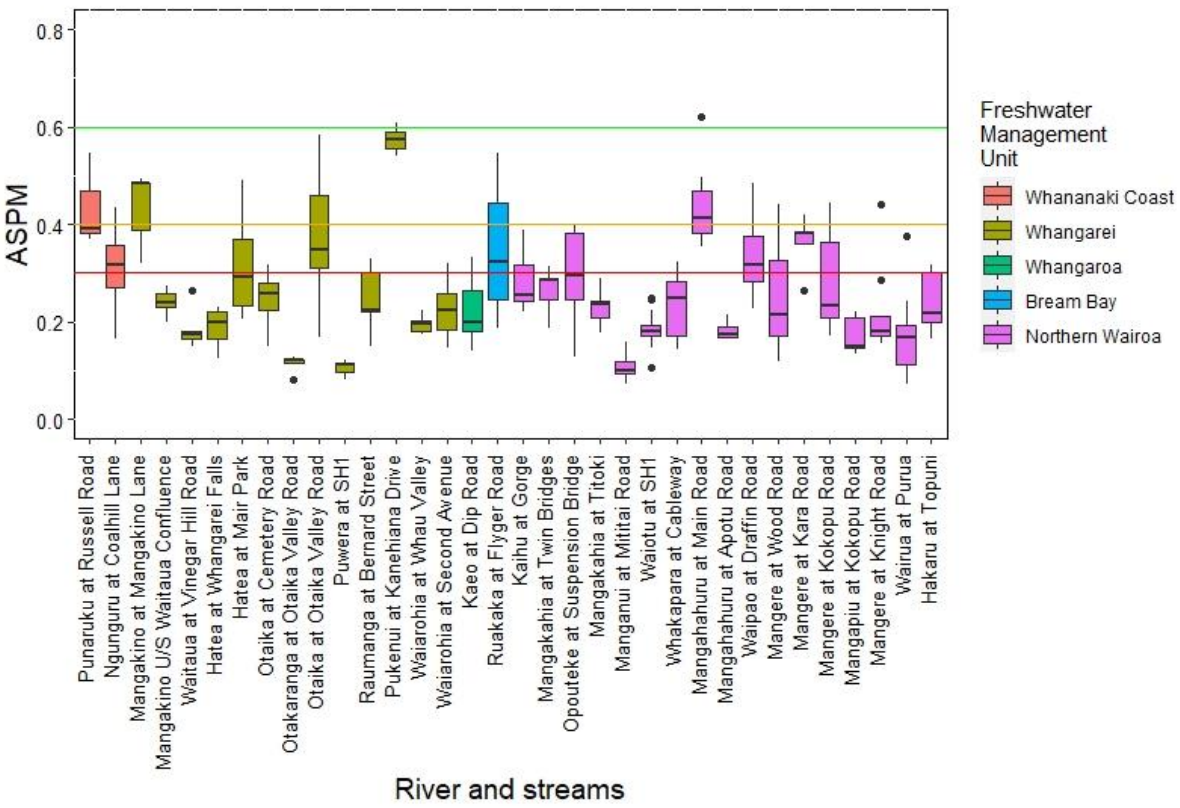

Figure 12 Average Score per Metric collected at sites in the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range.

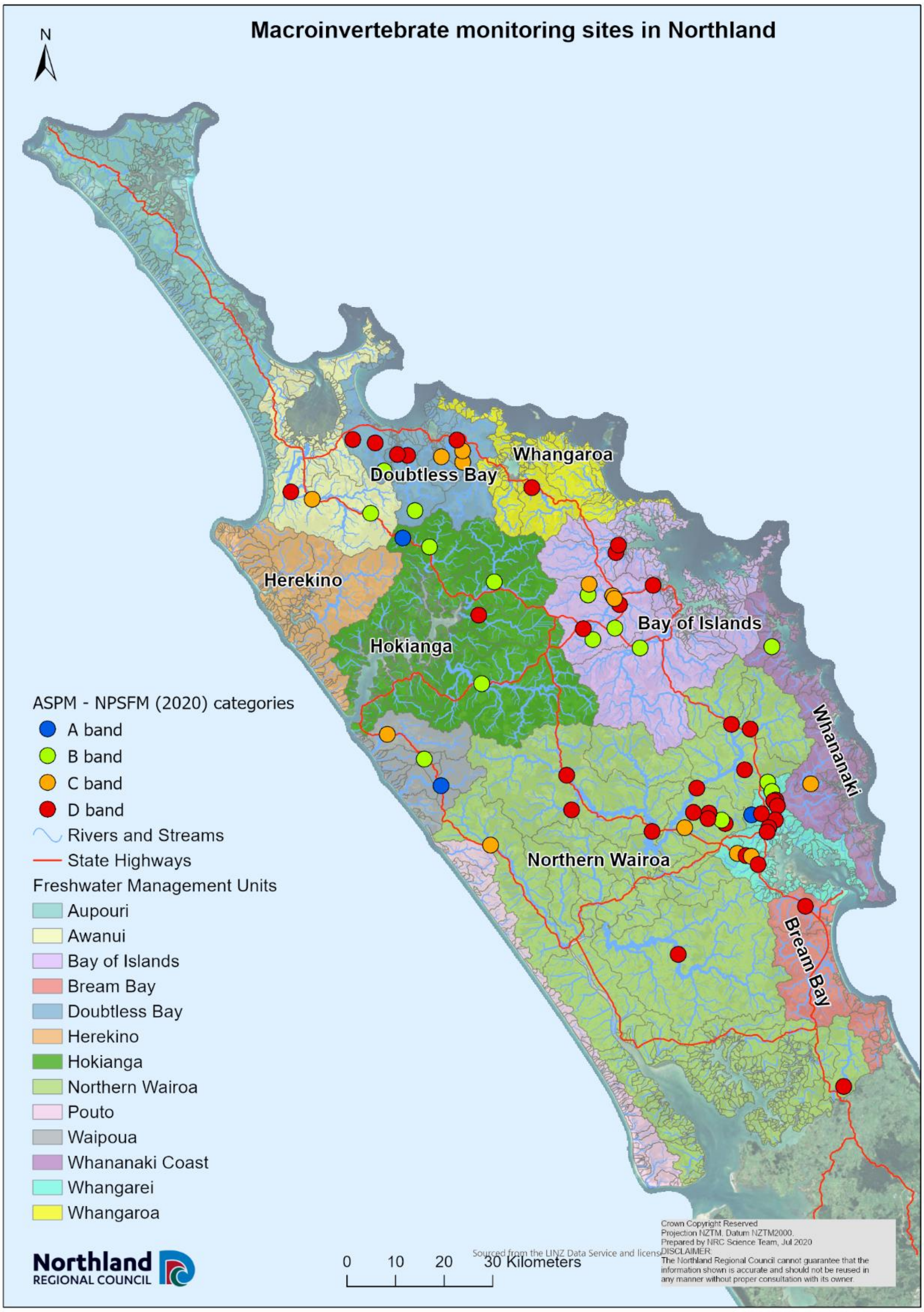

Figure 13 Map of five-year average ASPM collected at Northland State of the Environment monitoring sites between 2015 and 2019. Sites are colour coded based on their position in the NPSFM (2020) bands.

LIFENZ a hydrological sensitivity index of riverine macroinvertebrates

The LifeNZ index, where higher scores indicate ecological communities with greater flow, is presented in Figure 14 and. There is considerable variation within Freshwater Management Units.

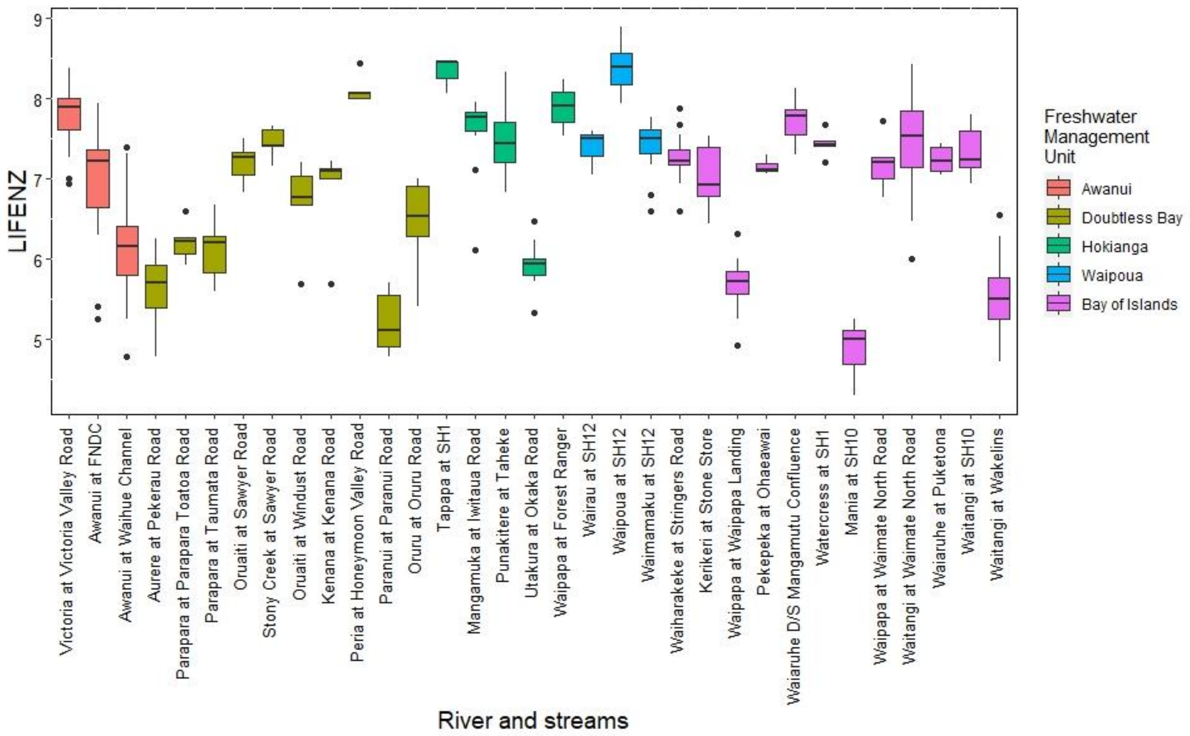

Figure 14 LIFENZ for invertebrates collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The higher the score the more sensitive the community is to flow reductions at a site.

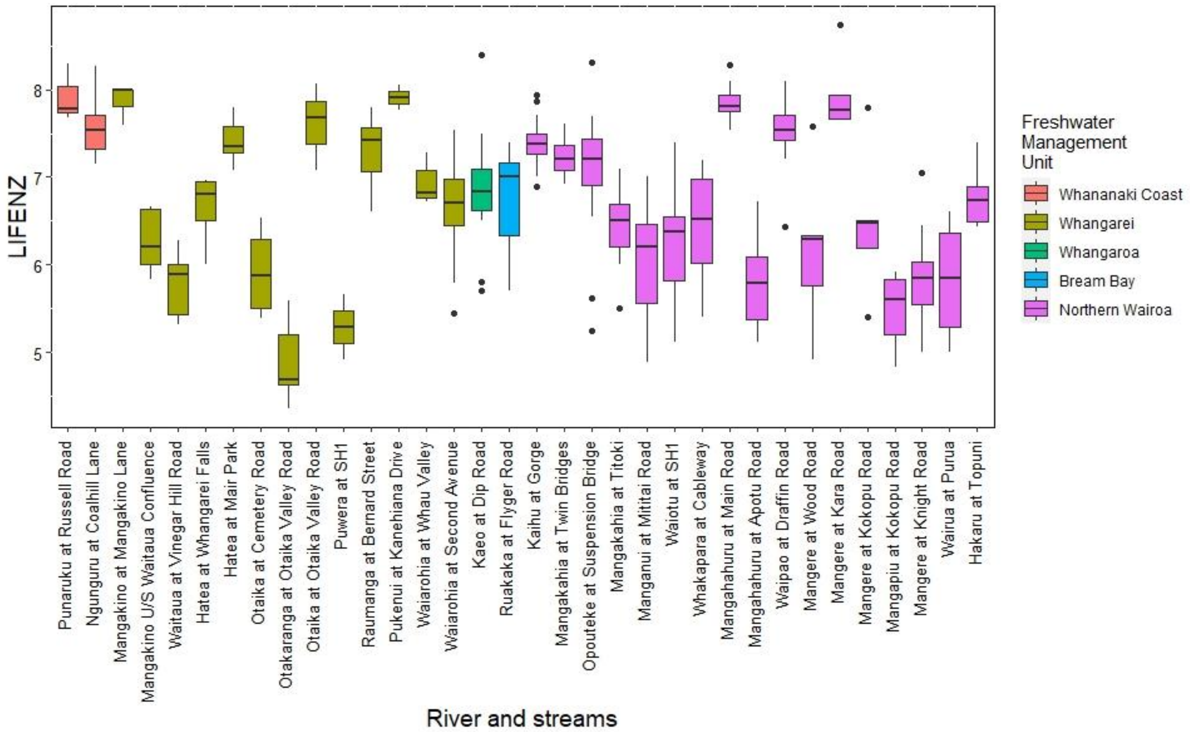

Figure 15 LIFENZ for invertebrates collected at sites in the the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The higher the score the more sensitive the community is to flow reductions at a site.

LIFENZ.W a velocity preference weighted hydrological sensitivity index of riverine macroinvertebrates

The flow weighted LifeNZ.W index for the study sites, is presented in Figure 16 and Figure 17. The index values seem very similar to those for the LifeNZ index for each sites with considerable variation within Freshwater Management Units.

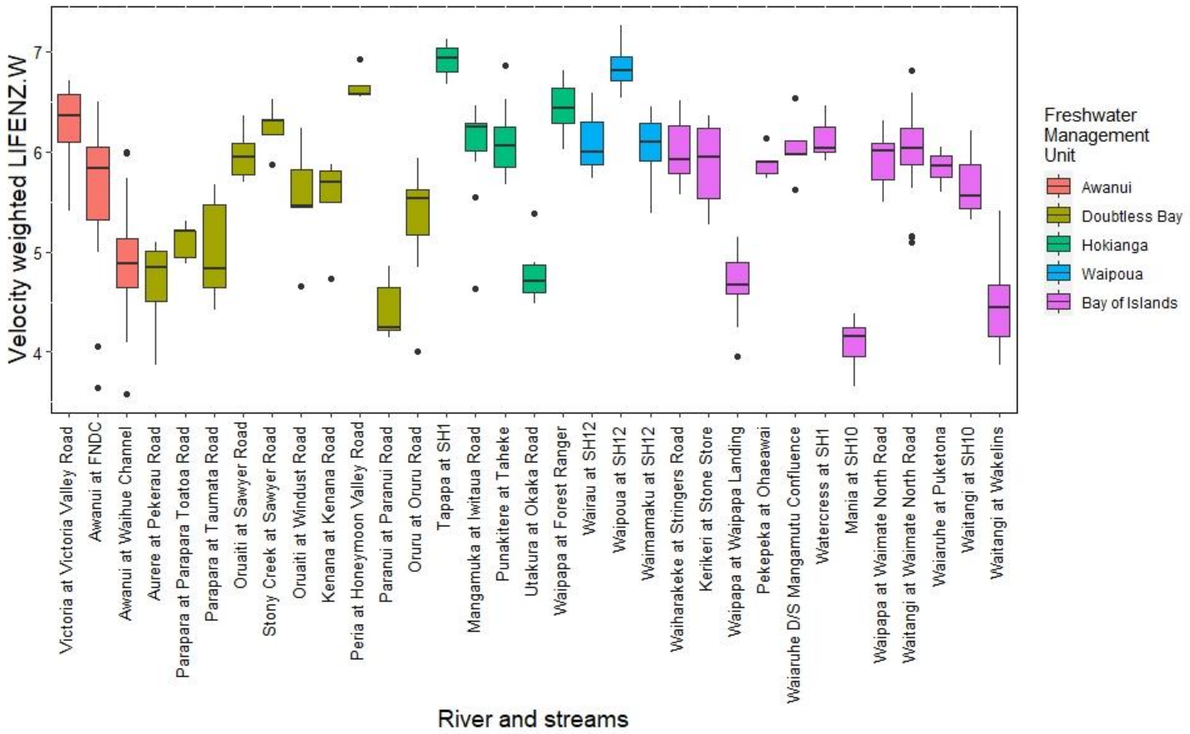

Figure 16 Velocity preference weighted LIFENZ for invertebrates collected at sites in the Awanui, Doubtless Bay, Hokianga, Waipoua and Bay of Islands freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The higher the score the more sensitive the community is to flow reductions at a site.

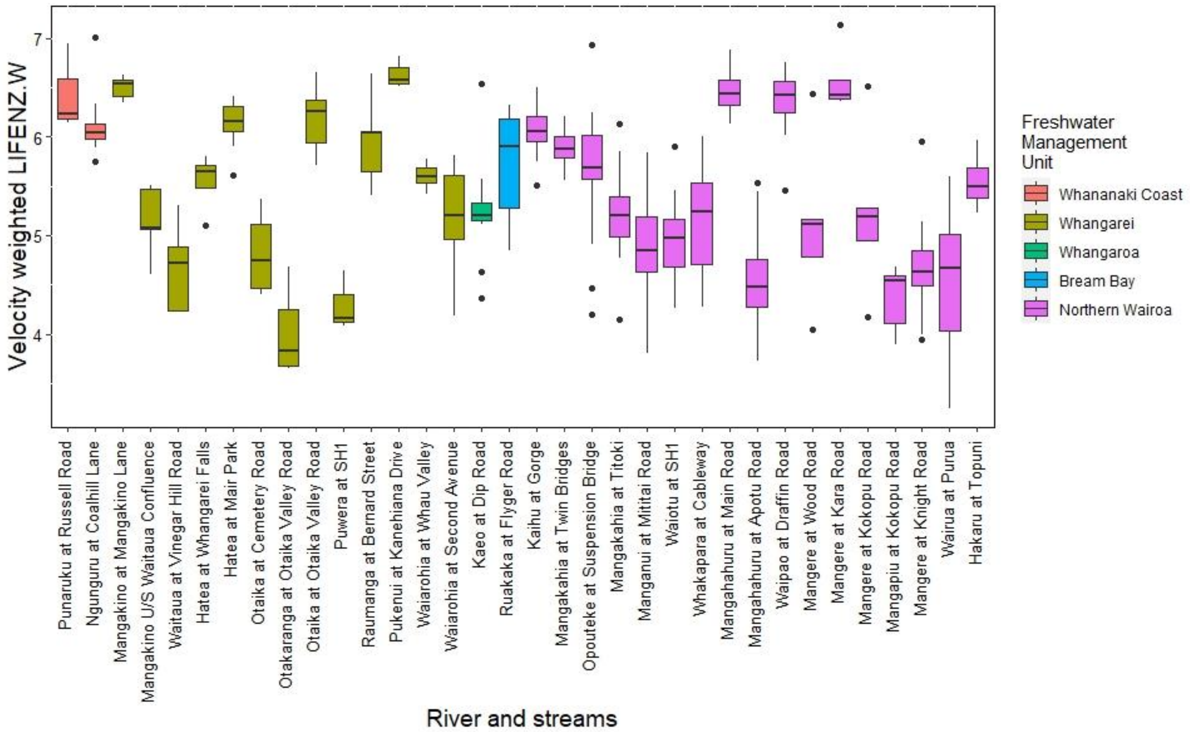

Figure 17 Velocity preference weighted LIFENZ for invertebrates collected at sites in the Whananaki Coast, Whangarei, Whangaroa, Bream Bay and Northern Wairoa freshwater management units between 2009 and 2019. Boxes represent the 25th and 75th percentile with the central bar of the box the median. Whiskers are the maximum and minimum excluding outliers. Outliers are dots outside 1.5 x interquartile range. The higher the score the more sensitive the community is to flow reductions at a site.

Temporal trends in biological indices

One site of the 32 sites with a long enough record to assess temporal change, Waitangi at Waimate North Road, exhibited an increase in SQMCI over the last 10 years (Table 3). Thirteen sites had significant declines in MCI, SQMCI or EPT animals. Of the two reference sites with records of significant length Waipoua at SH12 exhibited no change with time, but Waipapa at Forest Ranger had a decline in EPT animals.

Table 3 Correlation coefficient between biological indices and time for samples collected between 2009 and 2019. Significant correlations are indicated in bold and grey cell colour.

Freshwater Management Unit	Site Name	Number of years	MCI	SQMCI	Percent EPT animals	Number of taxa
Awanui	Victoria at Victoria Valley Rd	11	-0.11	0.15	0.04	0.24
Awanui	Awanui at FNDC	11	-0.04	-0.21	-0.49	0.36
Awanui	Awanui at Waihue Channel	11	0.04	**-0.58**	-0.17	0.44
Doubtless Bay	Oruru at Oruru Rd	11	0.41	-0.33	-0.28	0.37
Whangaroa	Kaeo at Dip Rd	11	-0.11	-0.03	-0.28	-0.07
Bay of Islands	Kerikeri at Stone Store	12	0.03	0.39	-0.04	-0.04
Bay of Islands	Waipapa at Waipapa Landing	11	-0.32	**-0.71**	0.17	**0.67**
Bay of Islands	Waitangi at Waimate North Rd	12	0.15	**0.62**	0.00	0.15
Bay of Islands	Waitangi at Wakelins	10	0.32	-0.09	0.05	-0.10
Bay of Islands	Waiharakeke at Stringers Rd	10	-0.22	-0.18	-0.13	0.11
Hokianga	Mangamuka at Iwitaua Rd	11	-0.21	-0.33	**-0.77**	0.05
Hokianga	Waipapa at Forest Ranger	11	-0.38	-0.33	**-0.69**	-0.39
Hokianga	Punakitere at Taheke	11	-0.42	0.03	0.07	0.50

Hokianga	Utakura at Okaka Rd	10	-0.46	-0.13	0.06	0.49
Waipoua	Waipoua at SH12	11	0.33	0.22	0.16	-0.36
Waipoua	Waimamaku at SH12	11	**-0.56**	0.20	-0.38	-0.41
Northern Wairoa	Whakapara at Cableway	11	**-0.70**	**-0.59**	-0.49	0.24
Northern Wairoa	Waiotu at SH1	11	0.19	-0.16	-0.32	**0.79**
Northern Wairoa	Mangahahuru at Main Rd	11	0.29	-0.21	-0.50	-0.06
Northern Wairoa	Mangahahuru at Apotu Rd	11	0.26	0.32	-0.16	0.40
Northern Wairoa	Wairua at Purua	11	0.07	-0.04	0.01	**0.58**
Northern Wairoa	Mangere at Knight Rd	11	0.06	-0.40	-0.14	0.54
Northern Wairoa	Waipao at Draffin Rd	11	0.25	-0.46	-0.25	0.35
Northern Wairoa	Mangakahia at Twin Bridges	11	0.04	**-0.77**	-0.61	0.01
Northern Wairoa	Opouteke at Suspension Bridge	11	**-0.72**	-0.30	**-0.71**	0.28
Northern Wairoa	Mangakahia at Titoki	11	0.04	**-0.77**	-0.61	0.01
Northern Wairoa	Manganui at Mititai Rd	11	-0.49	**-0.69**	-0.41	0.06
Northern Wairoa	Kaihu at Gorge	11	-0.25	0.33	-0.25	-0.36
Northern Wairoa	Hakaru at Topuni	11	**-0.65**	0.02	-0.66	-0.33

Whangarei	Hatea at Mair Park	11	**-0.55**	-0.35	-0.50	0.09
Whangarei	Waiarohia at Second Avenue	11	-0.35	0.08	-0.19	0.24
Bream Bay	Ruakaka at Flyger Rd	11	**-0.83**	-0.39	-0.13	0.28

Analysis of invertebrate community data

The ordination of invertebrate communities was a strong one with a stress of 0.14. Amongst potential grouping of invertebrate communities at the study sites land use and substrate type formed the most distinctive groups (Figure 18). Indigenous forest sites are to the left of axis one with pasture sites towards the left. There was a significant difference in communities between landuse ($F_{4,58}$ =1.85, P=0.03), substrate type ($F1_{,58}$ =4.28, P=0.002) but there was no interaction ($F_{3,58}$ =1.85, P=0.10). Within the pasture site group those with hard substrates were towards the left and those with soft sediments to the right. Freshwater management unit, FENZ class, REC network position, REC geology and order did not represent distinctive groupings or gradients.

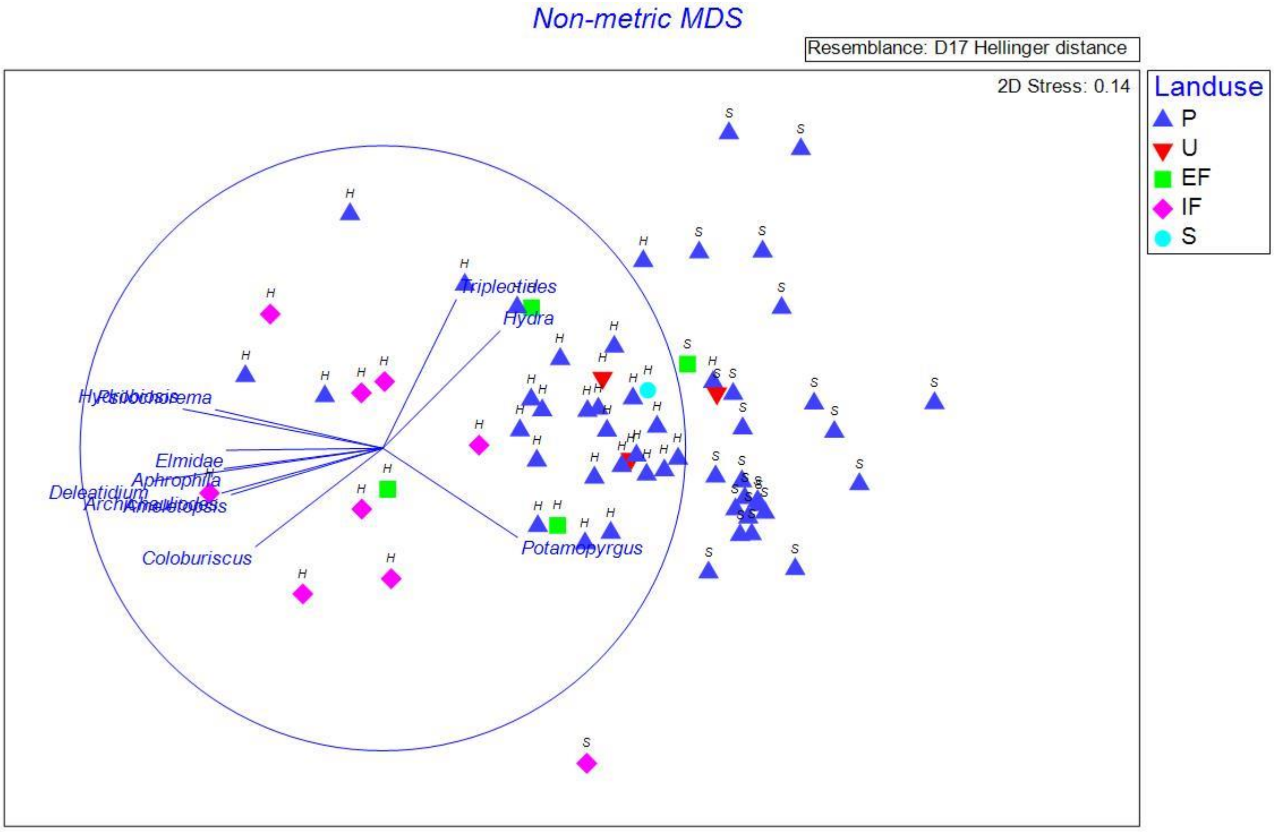

Figure 18 Nonmetric multidimensional scaling of average invertebrate communities collected at study sites between 2008 and 2019. The closer the sites too each other the more similar they are in composition. Landuse types P=pasture, U=urban, EF=exotic forest, IF=indigenous forest and S=scrub. The S and H next to symbols indicate soft or hard bottom streams.

Invertebrates associated with the communities for the indigenous forest sites were *Deleatidium, Coloburiscus, Archicauliodes, Aphrophila, Elmidae, Hydrobiosis* and *Psilocorhema*, to the left. *Triplectides* and *Hydra* were associated with pasture sites towards the upper right and the mollusc *Potamopygrus* with sites towards the bottom right.

GIS variables (from FENZ and REC) and habitat variables measured concurrently with invertebrate collections (averaged measures for 2014 to 2019) correlated with axis one and two of the NMDS are presented in Table 4. Deposited fine sediment (assessed with several metrics) was most strongly associated with axis one, with sites with high levels of deposited sediment to the right of axis one. Axis two was not strongly associated with any measure variable.

Table 4 Correlation of habitat variables with NMDS axes. Correlations greater than 0.65 are indicated in bold.

	NMDS axis 1	NMDS axis 2
Order	0.04	-0.13
Catchment area	0.17	-0.10
RHA Deposited sediment	**-0.71**	-0.03
RHA Invertebrate habitat diversity	**-0.66**	-0.08
RHA Invertebrate habitat abundance	**-0.73**	-0.12
RHA Fish cover diversity	**-0.64**	-0.07
RHA Fish cover abundance	-0.55	0.03
RHA Hydraulic heterogeneity	**-0.74**	-0.10
RHA Bank erosion	-0.35	0.08
RHA Bank vegetation	-0.51	-0.03
RHA riparian width	-0.37	-0.10
RHA riparian shade	-0.19	-0.15
RHA Total	-0.69	-0.08
width	0.02	0.18
depth	0.63	0.00
Temperature	0.30	0.32
Conductivity	0.30	-0.03
pH	-0.02	0.08
Percent Bedrock	0.00	0.13
Percent Boulder	0.21	-0.01
Percent Large Cobble	-0.42	-0.06
Percent Small Cobble	0.20	-0.14
Percent Gravel	0.35	-0.15
Percent Sand	0.47	0.01
Percent Silt	**0.68**	0.02
Clean Percent Periphyton cover	0.31	-0.08
Film Percent Periphyton cover	-0.61	-0.10
Sludge Percent Periphyton cover	-0.12	0.25
Mat Percent Periphyton cover	-0.20	-0.01
Fil. Slimy % Periphyton cover	0.00	0.00
Fil. Coarse % Periphyton cover	0.04	0.06

Macrophyte Percent cent Cover (riffle)	-0.15	0.04
Macrophyte Percent cent Cover (run)	0.49	0.17
Macrophyte Percent cent Cover (pool)	0.28	0.01
Deposited Sediment Riffle	0.03	-0.17
Deposited Sediment Run	0.47	0.04
Deposited Sediment pool	0.01	-0.20
Riffle habitat length (m)	-0.30	-0.01
Run habitata length (m)	-0.06	-0.18
Pool habitat length (m)	-0.08	-0.07
Deposited sediment measured in 2019	**0.66**	0.03
Distance to sea.	0.19	-0.15
Impervious	0.18	0.24
NaturalCover	-0.53	-0.17
LogNConcentration	0.63	0.03
DownstreamDamEffect	0.07	0.04
CoalEffect	0.03	0.10
MineEffect	-0.14	0.01
FishEffect	0.01	0.08
SegJanAirT	0.15	0.43
SegMinTNorm	-0.14	-0.23
SegFlow	0.14	-0.10
SegLowFlow	0.12	-0.07
SegFlow4th	0.10	-0.06
SegFlowVariability	-0.14	-0.01
SegSlope	-0.34	-0.10
SegSlopeSqrt	-0.34	-0.11
SegRipShade	-0.28	-0.09
SegHisShade	-0.16	0.11
SegRipNative	-0.35	-0.24
SegCluesN	0.49	-0.01
SegCluesLogN	0.63	0.03
DSDist2Coast	0.19	-0.15
DSAvgSlope	-0.07	0.07

DSAvgSlopeSqrt	-0.09	0.07
DSMaxLocalSlope	-0.41	-0.10
DSDam	-0.08	-0.06
USAvgTNorm	0.37	-0.05
USDaysRain	-0.30	0.23
USAvgSlope	-0.42	-0.06
USCalcium	0.36	-0.08
USHardness	-0.51	-0.02
USPhosporus	-0.23	-0.03
USPeat	0.14	-0.10
USLake	-0.04	0.10
USWetland	-0.12	0.12
USIndigFor	-0.53	-0.25
USNative	-0.53	-0.19
USPasture	0.55	0.16
ReachSed	-0.53	-0.11
ReachHab	-0.44	-0.20
DRP_State	0.44	-0.09
ECOLI_State	0.46	0.14
NO3N_State	0.41	0.07
TP_State	0.57	-0.05
FRE3	-0.19	0.17
Mean Flow Cumecs	0.14	-0.10
Mean Annual Flood Cumecs	0.15	-0.10
MALF Cumecs	0.09	-0.09

Invertebrate community changes with time

Examination of changes in invertebrate communities with time (in ordination space) for sites with greater than ten years of data, does not give any indication that in the years with high

NZDI values (2010, 2013 and 2017) invertebrate communities are any different to other years when NZDI values were low (Figure 19 – Figure 33).

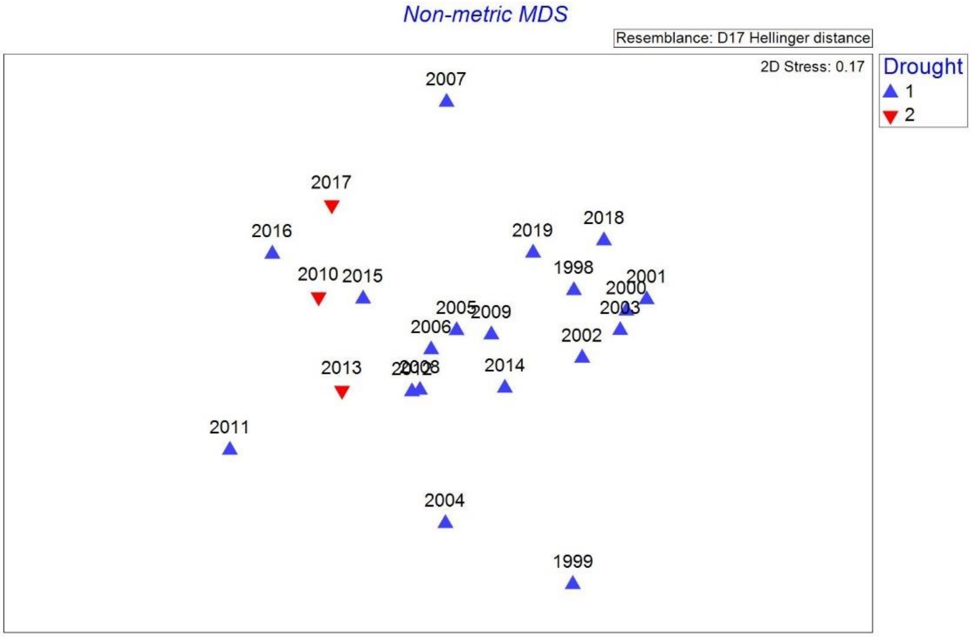

Figure 19 Temporal changes in invertebrate communities at Mangahahuru at Apotu Road. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

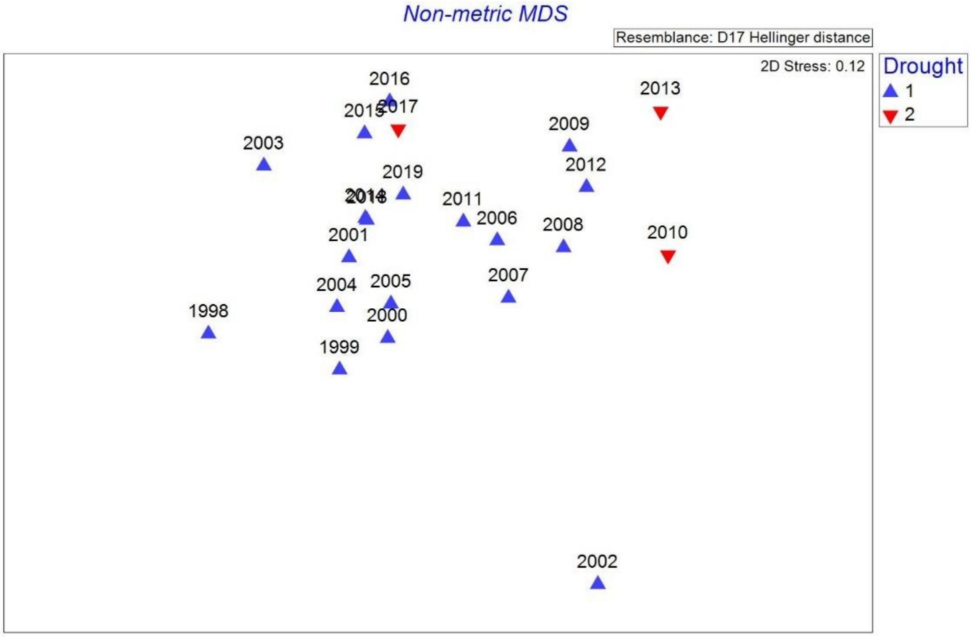

Figure 20 Temporal changes in invertebrate communities at Awanui at FNDC. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

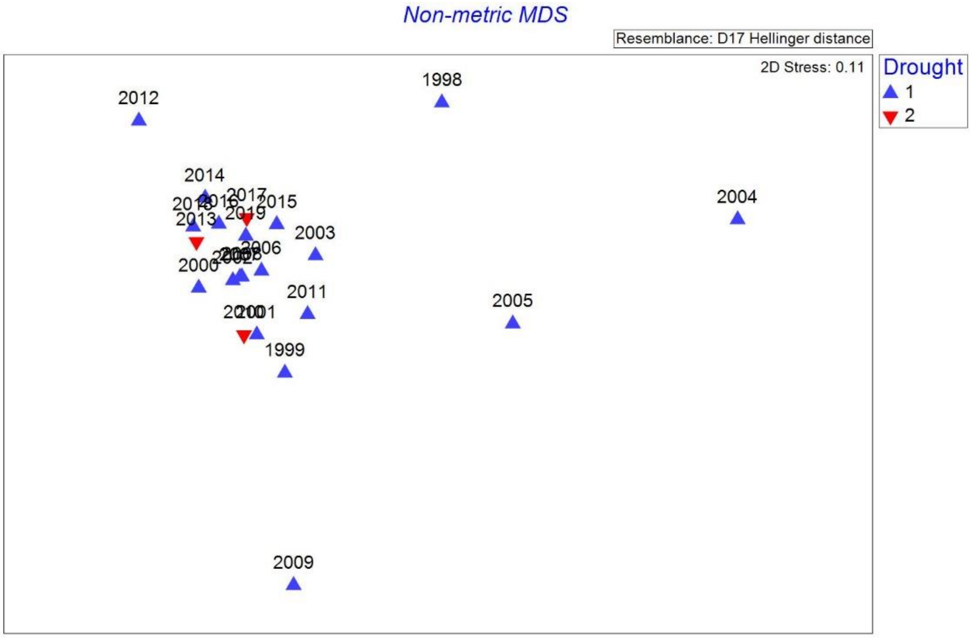

Figure 21 Temporal changes in invertebrate communities at Awanui at Waihue Channel. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

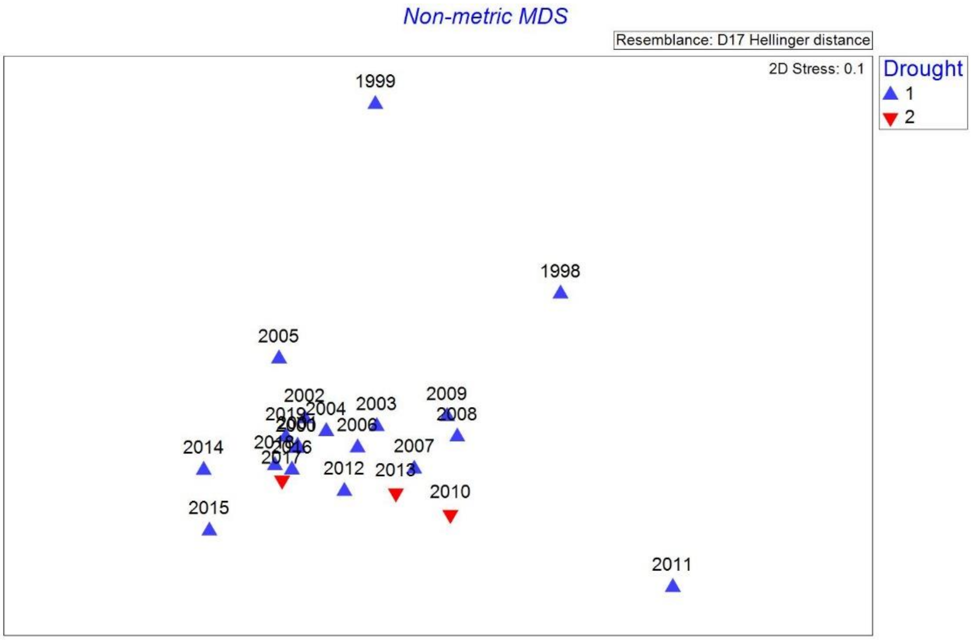

Figure 22 Temporal changes in invertebrate communities at Mangakahia at Titoki. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

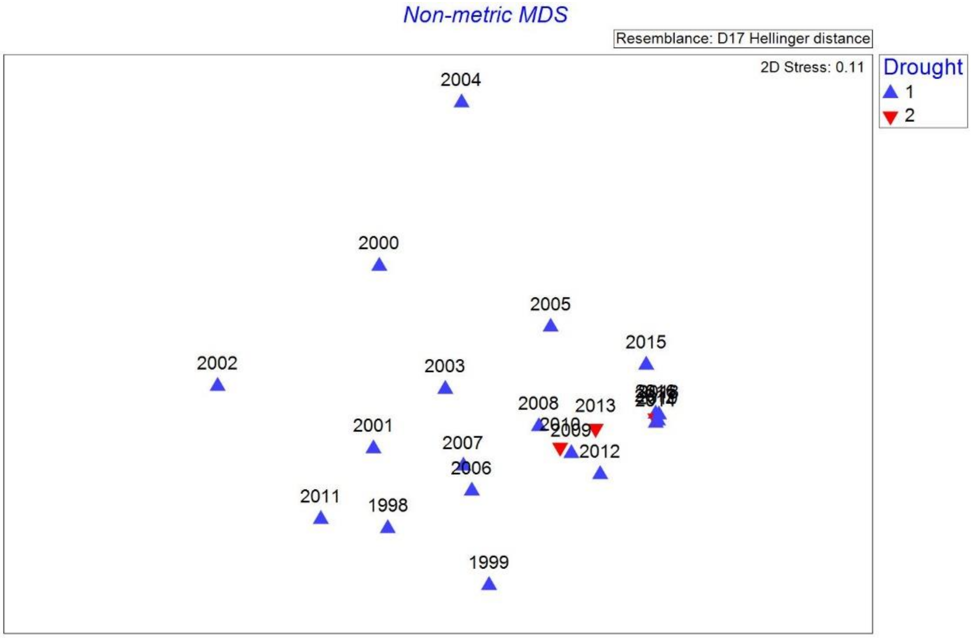

Figure 23 Temporal changes in invertebrate communities at Mangere at Knight Road. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

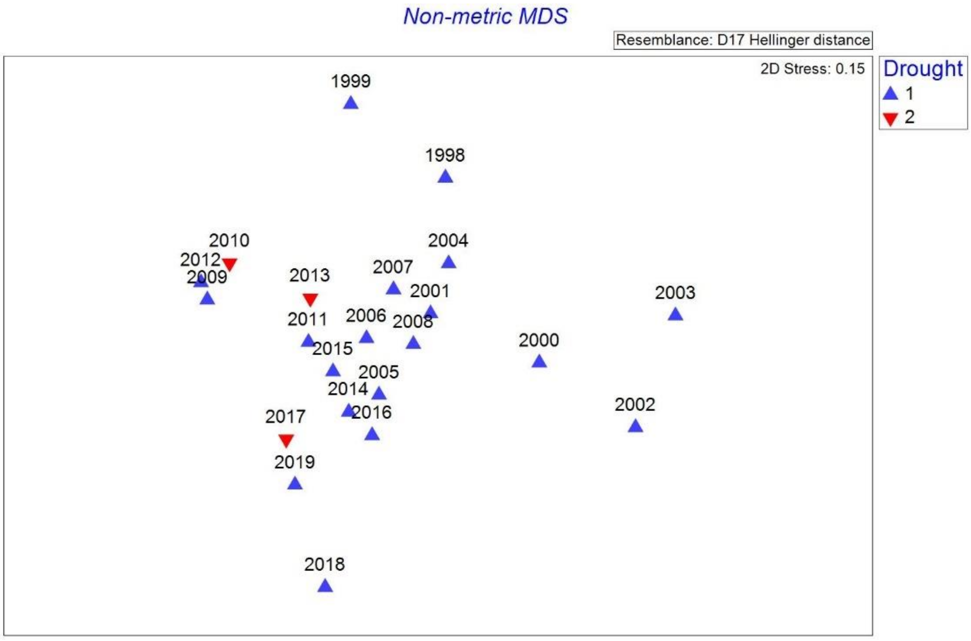

Figure 24 Temporal changes in invertebrate communities at Waipapa at Forest Ranger. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

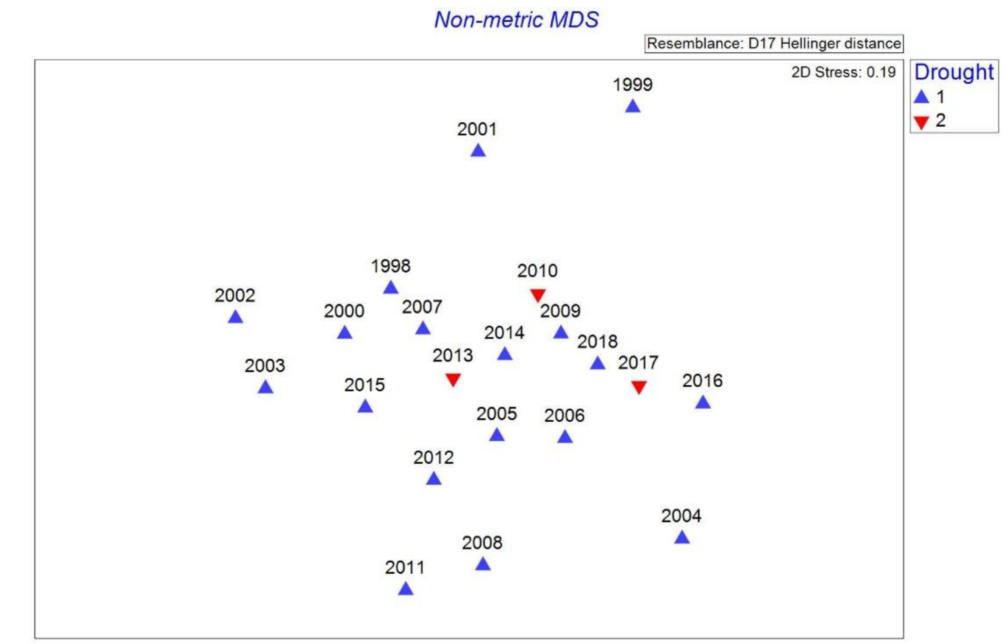

Figure 25 Temporal changes in invertebrate communities at Waitangi at Wakelins. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

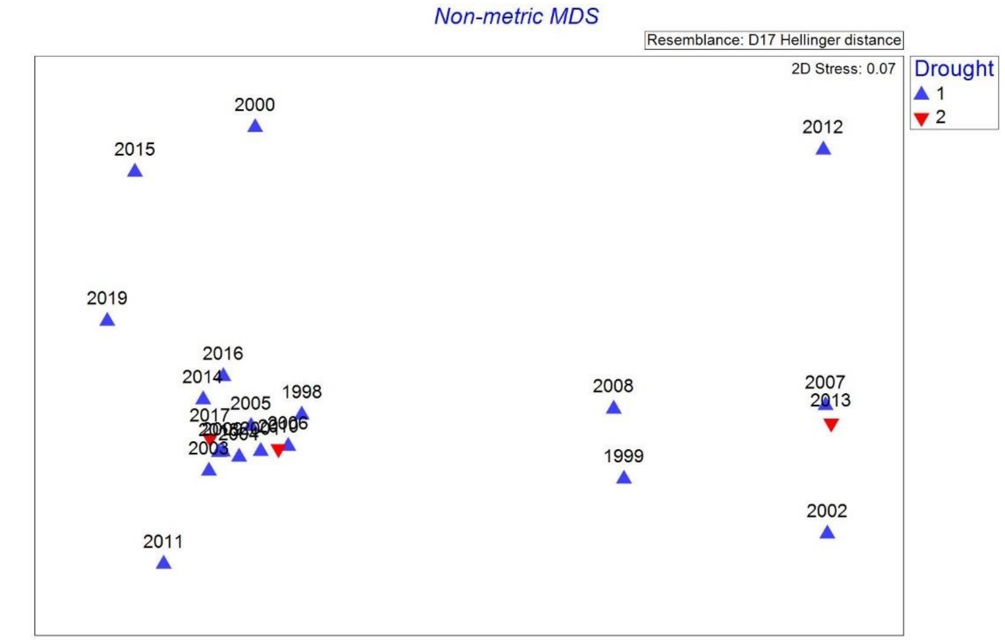

Figure 26 Temporal changes in invertebrate communities at Wairua at Purua. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

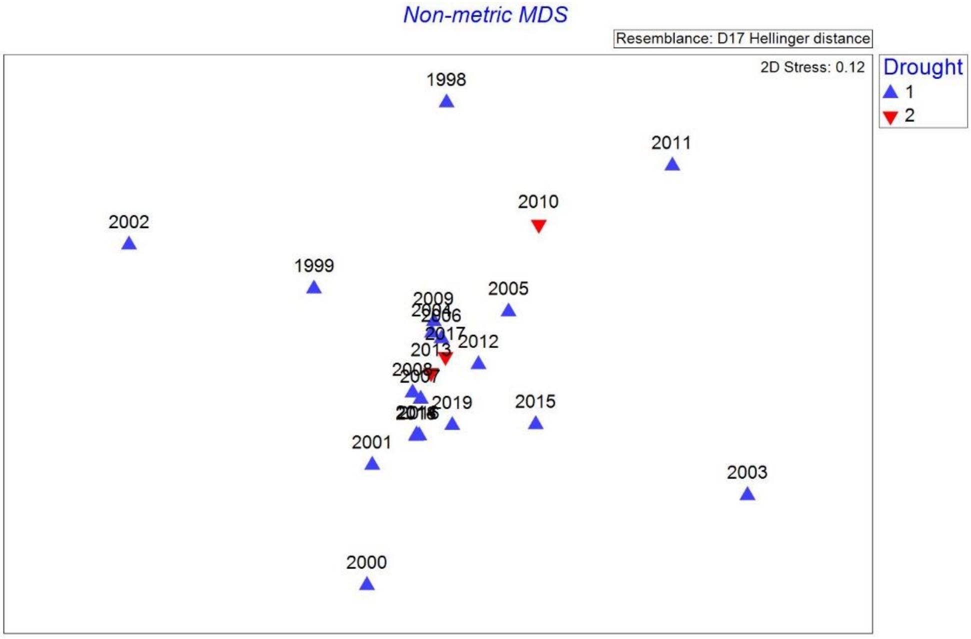

Figure 27 Temporal changes in invertebrate communities at Whakapara at Cableway. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

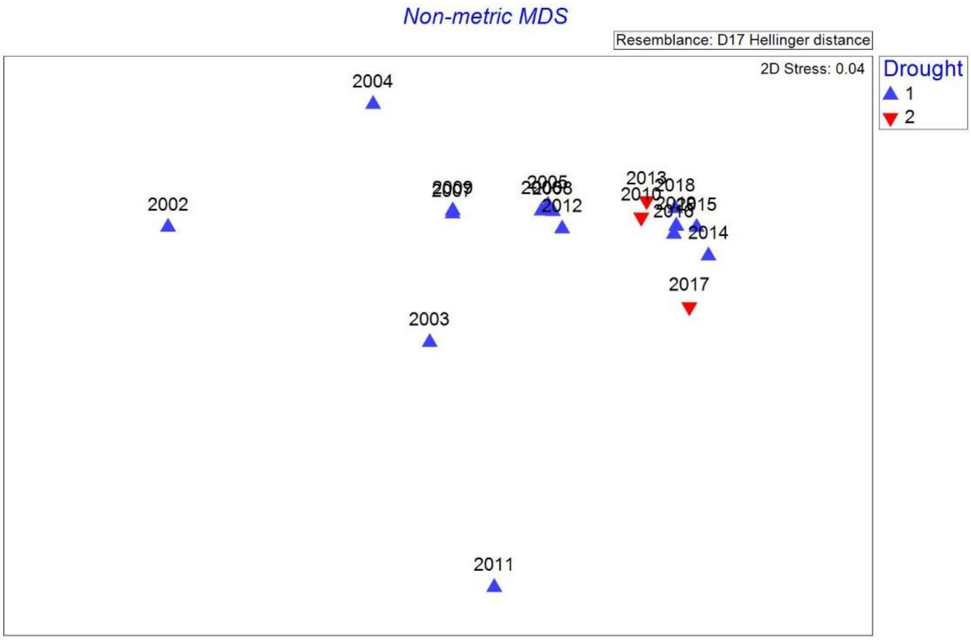

Figure 28 Temporal changes in invertebrate communities at Manganui at Mititai Road. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

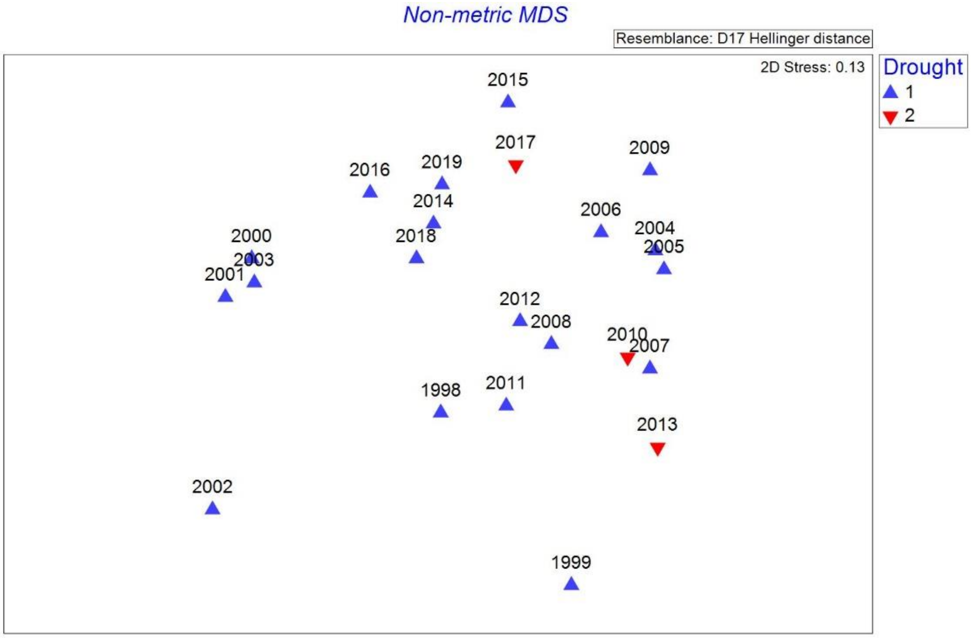

Figure 29 Temporal changes in invertebrate communities at Opouteke at Suspension Bridge. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

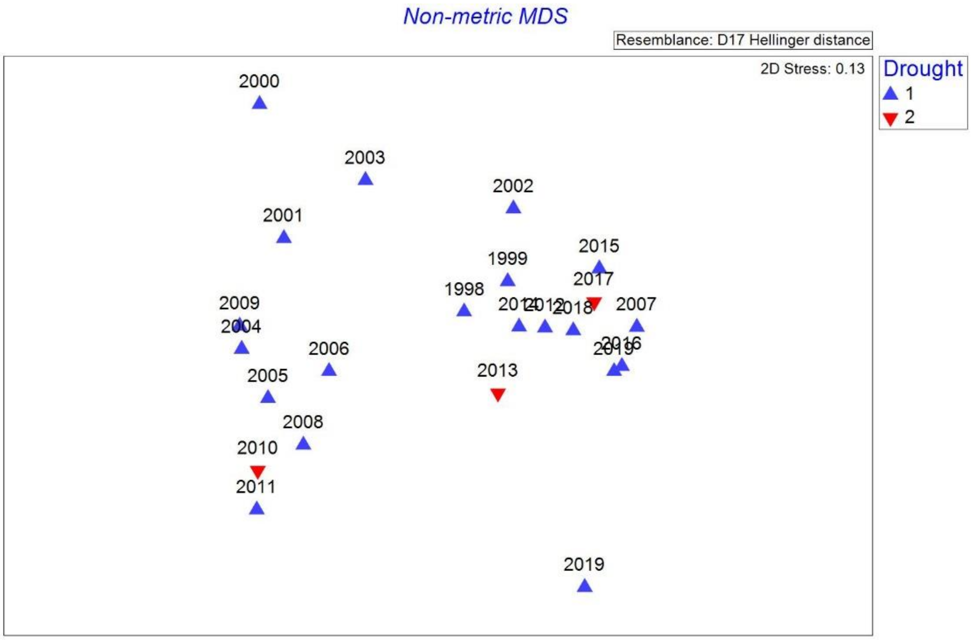

Figure 30 Temporal changes in invertebrate communities at Waitangi at Waimate North Road. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

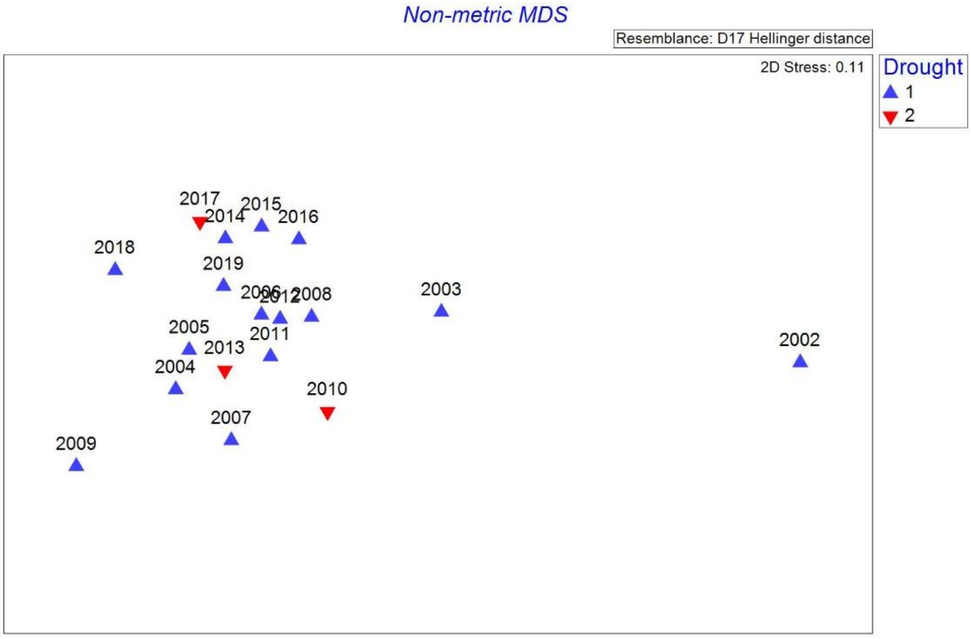

Figure 31 Temporal changes in invertebrate communities at Punakitere at Taheke. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

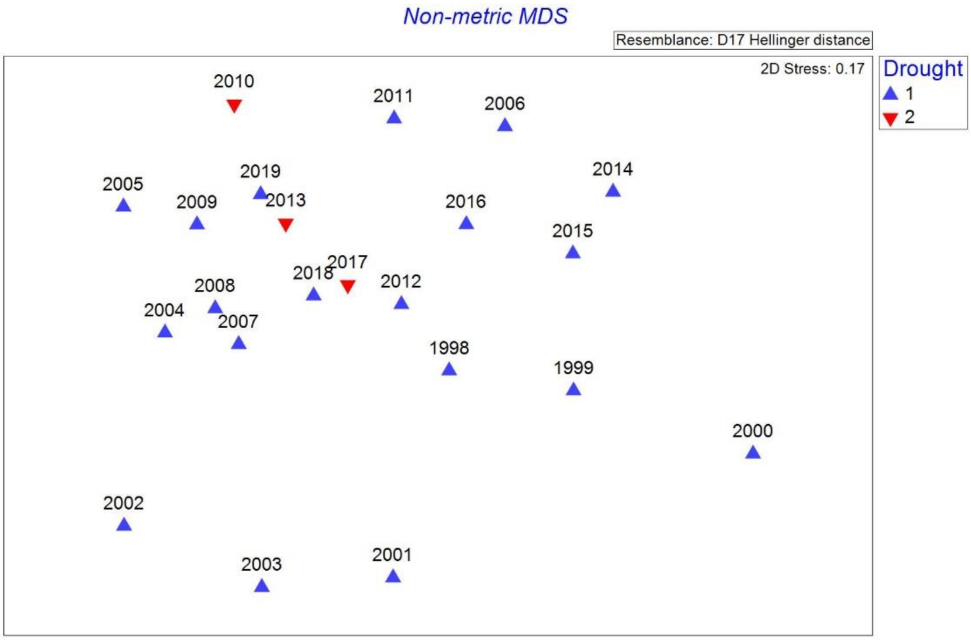

Figure 32 Temporal changes in invertebrate communities at Victoria at Victoria Valley Road. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

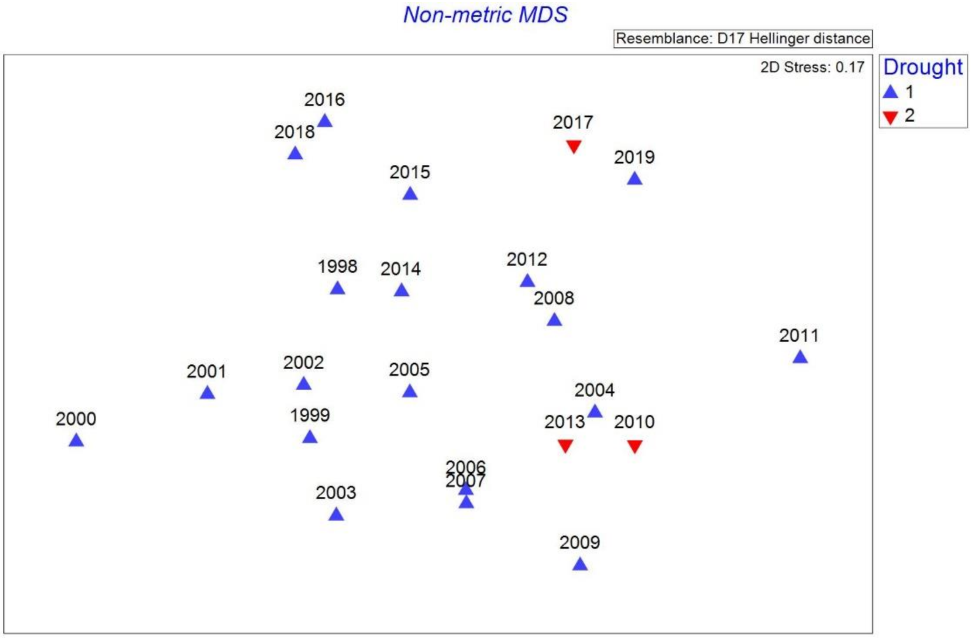

Figure 33 Temporal changes in invertebrate communities at Waiarohia at Second Avenue. Drought 1 = NZDI > 1.6, drought 2 NZDI < 1.6.

Section 2

Relationship between drought and biological indices

The macroinvertebrate data used here was not targeted for drought monitoring. This analysis is interim to investigate any potential relationships prior to analysis of the targeted monitoring of 22 sites in 2020 in report two.

The New Zealand Drought Index (NZDI)

The New Zealand Drought Index (NZDI), is a climate data-based indicator of drought based on four commonly-used climatological drought indicators: the Standardised Precipitation Index, the Soil Moisture Deficit, the Soil Moisture Deficit Anomaly, and the Potential Evapotranspiration Deficit (Mol et al. 2017, NIWA 2017). The index is calculated daily for 2007 onwards; we used the maximum value at any time throughout the year for assessment against the biotic indices. Higher values of NZDI indicate more severe drought effects. There are separate estimates for the Far North, Whangarei and Kaipara regions.

Correlations between the biological indices recorded at study sites between 2007 and 2019 are presented in Table 5. The most notable point is that there are very few significant correlations, although the records for many sites (n = 3 – 5) are probably too short to have much certainty in high NZDI values having no effect.

The LifeNZ index was negatively correlated with the NZDI at Manganui at Mititai Road and Kenana at Kenana Road. This means the index declined as the drought effect increased. This is illustrated in Figure 34.

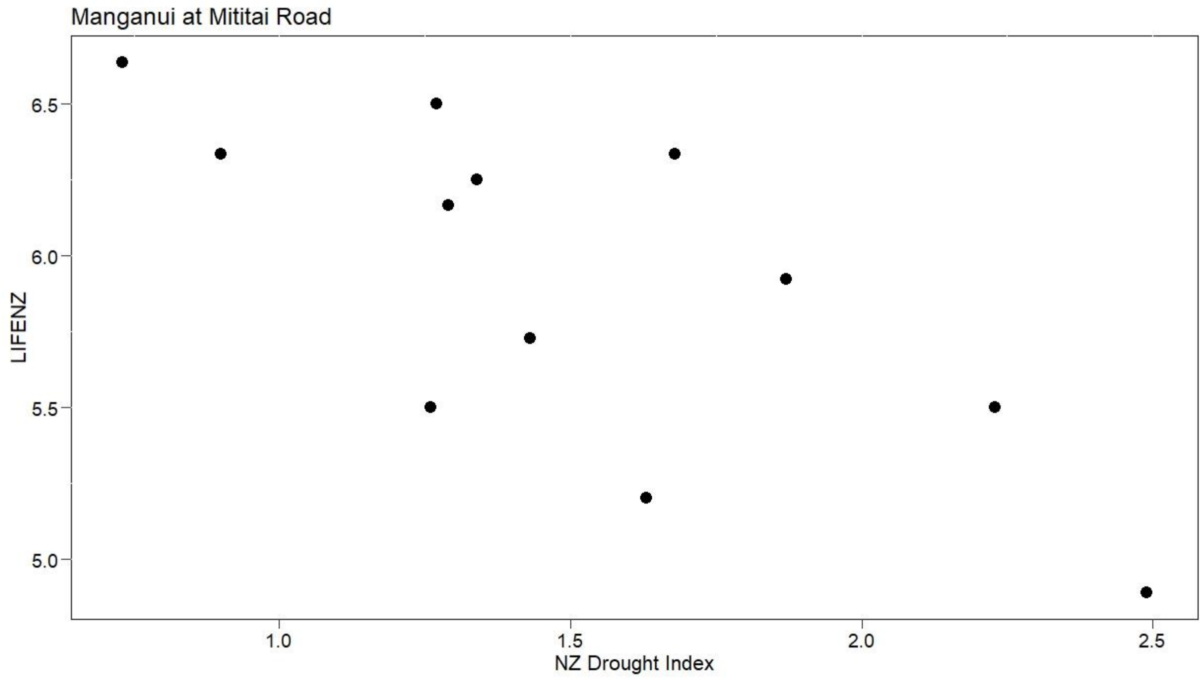

Figure 34 LifeNZ index as a function of the NZDI at Manganui at Mititai road.

Interestingly the LifeNZ index was also positively correlated with Parapara at Taumata Road.

The LifeNZ.W index was negatively correlated with the NZDI at Mangahahuru at Apotu Road and Kenana at Kenana Road and positively correlated at Watercress at SH1.

The MCI index was negatively correlated with the NZDI at Mangere at Kokopu Road, Kaeo at Dip Road, Parapara at Parapara Toatoa Road, Tapapa at SH1, Wairau at SH12, and positively at Hatea at Whangarei Falls and Otaika at Cemetery Road.

The SQMCI index was negatively correlated with the NZDI at Mangahahuru at Apotu Road, Hatea at Whangarei Falls, Kenana at Kenana Road, Pekepeka at Ohaeawai, Tapapa at SH1, and positively Punaruku at Russell Road.

The number of taxa was positively correlated with the NZDI at eight sites, but negatively correlated at Tapapa at SH1 and Wairau at SH12.

The percent EPT animals was also positively correlated with the NZDI at four sites.

Table 5 Correlation coefficient between biological index and New Zealand Drought Index for that Northland region. Significant correlations are indicated in bold and grey cell colour.

Site names	Site	Number of years	LIFENZ	LIFENZ.W	MCI	SQMCI	Percent EPT animals	Number of taxa
Waiharakeke at Stringers Road	100007	12	0.57	0.54	0.25	0.40	0.26	0.17
Hatea at Mair Park	100194	11	0.34	0.33	0.12	0.51	0.34	0.10
Mangahahuru at Main Road	100237	13	0.26	0.14	0.33	0.21	0.36	0.40
Mangahahuru at Apotu Road	100281	13	-0.53	**-0.56**	0.38	**-0.65**	-0.30	0.24
Awanui at FNDC	100363	13	0.37	0.32	0.02	0.07	0.17	0.23
Awanui at Waihue Channel	100370	13	-0.08	0.04	-0.36	-0.03	0.22	0.36
Mangakahia at Titoki	101038	13	-0.32	-0.37	-0.01	0.01	0.10	-0.02
Waipapa at Waipapa Landing	101524	12	0.09	0.20	-0.09	0.11	-0.10	-0.10
Kerikeri at Stone Store	101530	13	0.00	0.04	-0.21	0.10	0.16	-0.49
Mangere at Knight Road	101625	13	0.22	0.19	-0.01	-0.38	-0.37	-0.29
Mangapiu at Kokopu Road	101626	5	-0.48	-0.46	0.02	0.69	**0.84**	**0.88**
Waipapa at Forest Ranger	101751	13	-0.34	-0.46	-0.36	-0.21	0.31	0.26
Waitangi at Wakelins	101752	12	-0.22	-0.16	-0.22	-0.16	0.01	-0.13
Wairua at Purua	101753	13	0.14	0.17	0.12	-0.27	-0.24	-0.16
Mangere at Kara Road	102106	5	-0.15	-0.22	0.27	-0.64	0.26	**0.76**
Mangere at Kokopu Road	102109	5	0.03	0.01	**-0.92**	-0.59	-0.56	0.73
Waiotu at SH1	102248	13	-0.26	-0.24	-0.42	-0.49	-0.25	-0.03
Whakapara at Cableway	102249	13	0.20	0.11	0.12	0.26	0.20	-0.10
Kaihu at Gorge	102256	13	0.19	-0.01	0.16	-0.16	-0.07	0.31
Manganui at Mititai Road	102257	**13**	**-0.74**	-0.55	-0.20	-0.57	-0.45	0.03
Opouteke at Suspension Bridge	102258	13	0.18	0.09	0.21	-0.23	0.09	0.42
Kaeo at Dip Road	102674	13	-0.55	-0.53	**-0.59**	-0.01	0.12	0.12
Waitangi at Waimate North Road	103178	14	-0.20	-0.06	0.19	-0.19	0.03	0.23
Waipoua at SH12	103304	13	-0.45	-0.33	-0.22	-0.02	0.03	0.46
Ruakaka at Flyger Road	105008	13	0.03	-0.03	-0.10	0.05	0.00	0.29

Punakitere at Taheke	105231	13	0.04	0.10	0.01	-0.19	-0.12	-0.11
Victoria at Victoria Valley Road	105532	13	-0.25	-0.27	-0.07	-0.42	-0.19	-0.06
Hatea at Whangarei Falls	105972	4	0.77	0.83	**0.90**	**-0.91**	0.71	0.77
Waiarohia at Whau Valley	107773	5	-0.16	0.11	-0.70	0.27	0.56	0.42
Waiarohia at Second Avenue	108359	13	0.27	0.20	0.04	0.02	0.33	0.04
Waitaua at Vinegar Hill Road	108738	5	-0.71	-0.78	-0.52	0.02	-0.20	0.16
Waipao at Draffin Road	108941	12	-0.16	-0.15	-0.15	0.33	-0.13	0.14
Mangamuka at Iwitaua Road	108978	12	0.11	0.03	0.13	-0.01	0.15	0.13
Oruru at Oruru Road	108979	12	0.32	0.25	0.01	-0.11	-0.16	-0.51
Utakura at Okaka Road	109020	11	0.03	-0.23	0.35	0.10	0.08	-0.30
Hakaru at Topuni	109021	12	-0.24	-0.35	-0.06	-0.44	0.46	0.08
Mangakahia at Twin Bridges	109096	12	0.03	-0.11	0.02	0.00	0.50	-0.10
Waimamaku at SH12	109098	12	0.10	0.05	-0.09	-0.39	0.27	0.16
Mangere at Wood Road	109166	5	-0.18	-0.14	-0.03	-0.46	-0.14	0.56
Mangakino at Mangakino Lane	109795	5	0.23	-0.61	0.10	0.72	**0.76**	0.64
Mangakino U/S Waitaua Confluence	109982	5	-0.32	-0.59	0.52	-0.13	-0.37	**0.93**
Otaika at Otaika Valley Road	110431	8	0.00	-0.17	0.60	0.51	0.53	0.44
Ngunguru at Coalhill Lane	110603	8	0.10	-0.10	0.63	-0.26	0.02	0.24
Aurere at Pekerau Road	304587	4	-0.79	-0.89	-0.26	-0.47	-0.61	0.77
Waiaruhe at Puketona	304589	6	-0.31	-0.03	0.18	-0.05	-0.09	-0.18
Waitangi at SH10	304595	6	0.20	-0.16	-0.40	-0.22	-0.23	-0.24
Parapara at Taumata Road	304597	**5**	**0.90**	0.68	-0.52	-0.30	-0.02	**0.94**
Parapara at Parapara Toatoa Road	304599	5	0.42	0.56	**-0.77**	-0.69	-0.55	0.43
Oruaiti at Windust Road	304641	6	-0.05	0.00	-0.06	0.59	-0.25	-0.05
Raumanga at Bernard Street	304709	5	0.55	0.52	0.10	0.37	-0.16	0.56
Kenana at Kenana Road	306635	**5**	**-0.92**	**-0.89**	-0.73	**-0.78**	-0.70	**0.83**
Mania at SH10	306639	5	-0.53	-0.53	-0.36	-0.25	-0.47	0.54

Peria at Honeymoon Valley Road	306641	5	-0.09	-0.12	-0.01	-0.20	-0.22	-0.49
Pekepeka at Ohaeawai	306643	5	0.26	0.20	0.34	**-0.89**	-0.43	0.61
Watercress at SH1	306655	5	0.65	**0.90**	0.75	0.31	0.46	0.02
Waiaruhe D/S Mangamutu Confluence	306661	5	0.21	-0.16	-0.53	-0.17	0.01	-0.66
Paranui at Paranui Road	306665	5	0.31	-0.05	0.27	-0.49	-0.39	0.65
Oruaiti at Sawyer Road	306673	5	0.44	0.66	-0.40	-0.20	0.70	**0.79**
Stony Creek at Sawyer Road	306675	5	0.49	0.19	0.23	-0.16	-0.63	**0.79**
Otakaranga at Otaika Valley Road	306863	5	-0.53	-0.57	0.61	0.36	0.30	0.70
Otaika at Cemetery Road	306865	4	0.51	0.52	**0.90**	0.76	0.52	**0.92**
Waipapa at Waimate North Road	306915	5	0.17	0.30	0.40	0.07	0.02	0.41
Pukenui at Kanehiana Drive	312177	3	0.37	0.99	-0.46	-0.14	-0.32	0.71
Tapapa at SH1	313165	3	0.81	0.47	**-0.99**	**-0.92**	-0.10	**-1.00**
Wairau at SH12	313168	3	0.87	1.00	**-0.90**	0.38	**0.94**	**-0.93**
Punaruku at Russell Road	313171	3	-0.68	-0.83	0.67	1.00	**0.99**	**0.99**
Puwera at SH1	315381	3	-0.62	-0.02	0.74	0.35	**0.96**	**0.93**

Of the sites that showed a significant correlation between the NZDI none of them showed a consistent effect across a variety of indices

The Standardised Discharge Index (SDI)

The Standardised Precipitation Index (SPI) and Standardised Discharge Index (SDI) have been calculated by Hoa Pham for the Northland region. They provide a higher resolution of potential drought impacts for individual sites rather than the more region wide NZDI.

The LifeNZ and LifeNZ.W index was negatively correlated with the SDI at Utakura at Okaka Road (Table 6).

The MCI and SQMCI index were both negatively correlated with the SDI at Mangakahia at Twin Bridges

The number of taxa was negatively correlated with the SDI at Mangakahia at Twin Bridges.

The percent EPT animals was also negatively correlated with the SDI at Mangahahuru at Main Road and Utakura at Okaka Road. It was positively correlated at Waitangi at Waimate North Road and Mangamuka at Iwitaua Road.

Table 6 Correlation coefficient between biological index and Standardised Discharge Index. Significant correlations are indicated in bold and grey cell colour.

Site names	Site	Number of years	LIFENZ	LIFENZ.W	MCI	SQMCI	Percent EPT animals	Number of taxa
Waiharakeke at Stringers Road	100007	7	-0.46	-0.49	-0.24	-0.62	0.14	0.30
Mangahahuru at Main Road	100237	5	0.71	-0.69	0.40	0.00	**-0.82**	-0.46
Awanui at FNDC	100363	16	0.42	0.41	0.31	0.30	0.44	0.22
Mangakahia at Titoki	101038	14	0.46	-0.16	0.47	0.31	-0.20	0.29
Waipapa at Waipapa Landing	101524	7	-0.06	-0.59	0.08	-0.21	-0.20	0.15
Kerikeri at Stone Store	101530	6	0.35	-0.64	0.01	-0.23	-0.26	-0.28
Mangere at Knight Road	101625	18	0.28	0.51	0.12	0.04	0.30	-0.32
Waipapa at Forest Ranger	101751	15	0.25	-0.08	0.11	0.15	-0.22	-0.03
Waitangi at Wakelins	101752	14	-0.16	0.10	0.27	0.16	-0.27	-0.22
Wairua at Purua	101753	16	-0.29	0.08	-0.36	-0.47	-0.11	-0.08
Waiotu at SH1	102248	10	0.45	0.00	0.25	0.20	0.18	0.20
Whakapara at Cableway	102249	15	0.13	0.05	-0.22	-0.26	0.23	-0.21
Kaihu at Gorge	102256	10	0.39	0.19	-0.18	-0.07	0.01	-0.47

Manganui at Mititai Road	102257	13	-0.27	-0.10	-0.06	-0.08	0.04	0.18
Opouteke at Suspension Bridge	102258	18	0.43	0.23	0.31	0.19	0.30	-0.03
Kaeo at Dip Road	102674	6	0.71	-0.42	-0.45	-0.49	-0.05	-0.39
Waitangi at Waimate North Road	103178	9	0.39	0.60	-0.27	-0.44	**0.79**	0.40
Waipoua at SH12	103304	6	0.26	-0.25	-0.50	-0.61	-0.10	0.01
Ruakaka at Flyger Road	105008	6	0.09	-0.32	-0.34	-0.63	0.22	0.33
Punakitere at Taheke	105231	14	0.15	0.23	0.39	0.39	0.16	-0.24
Victoria at Victoria Valley Road	105532	5	0.24	0.44	0.22	0.41	0.54	0.75
Waiarohia at Second Avenue	108359	14	0.33	0.15	0.26	0.23	0.03	-0.30
Mangamuka at Iwitaua Road	108978	7	-0.06	0.60	0.27	0.20	**0.77**	-0.20
Oruru at Oruru Road	108979	6	0.37	0.02	0.57	0.44	0.08	-0.01
Utakura at Okaka Road	109020	6	**-0.87**	**-0.80**	0.32	0.59	**-0.76**	-0.09
Mangakahia at Twin Bridges	109096	6	0.46	0.42	**-0.90**	**-0.75**	-0.44	**-0.80**
Waimamaku at SH12	109098	9	0.44	0.03	0.21	0.30	0.26	0.59

Discussion

The primary focus of this report was to assess the current state and trends in ecological health of invertebrate communities in 67 streams and rivers monitored by Northland Regional Council. However, this report also explored the potential for using State of the Environment data collected annually in Northland to assess impacts of drought on riverine ecological health. Northland has experienced droughts in recent history in 2010, 2013 and 2017 (based on the NZDI) with potential adverse impacts on the aquatic communities of its rivers and streams. State of the environment monitoring is usually collected in early summer (January and February) before the most pronounced effects of drought are likely to occur. Despite this there seemed to be some suggestion that biological indices at several sites did change in response to drought in more severe drought years. Interestingly, the flow focused biological indices LifeNZ and LifeNZ.W index did not demonstrate as much of a change in response to drought as some of the other metrics. This suggests that perhaps changes in flow are not directly affecting invertebrate communities but impacting other environmental variables such as sediment levels, periphyton abundance or nutrient levels that in turn impact the invertebrates. Hopefully the more targeted monitoring in the next phase of the project will provide some enlightenment on this.

However, in contrast to drought, pastoral land use and deposited fine sediment appears to be having the largest detrimental impact on invertebrate communities in these streams and rivers. Invertebrate communities were distinctive between pasture and indigenous forest land use and between soft and hard substrate streams. Deposited fine sediment seemed to be the habitat variable most strongly correlated with these differences in invertebrate communities. Furthermore, many sites had biological metrics indicative of a D class based on the current NPSFM (2020) and several also showed declining trends of those indices. The Waipoua FMU sites seem to stand out as being in better condition than those elsewhere in the region, although even here Waimamaku at SH12 has a declining MCI.

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Appendix 1 Study site characteristics

Site Name	Easting	Northing	NZ Reach ID	FENZ Level Two	Order	Geology	Landcover	Network_poistion	Catchment_area
Aurere at Pekerau Road	1633460	6125736	1002569	A3	2	SS	P	LO	8757900
Awanui at FNDC	1625095	6113439	1004333	C4	5	SS	P	HO	219430848
Awanui at Waihue Channel	1620713	6114952	1004083	C4	5	VA	P	HO	72207904
Hakaru at Topuni	1734514	5992515	1026482	A1	5	SS	P	HO	82141304
Hatea at Mair Park	1720440	6047390	1018018	C4	4	VA	U	MO	42845772
Hatea at Whangarei Falls	1720854	6050268	1017464	C4	4	VA	P	MO	29501100
Kaeo at Dip Road	1670326	6115833	1003935	C4	5	SS	P	HO	98159376
Kaihu at Gorge	1661819	6042219	1019201	C6	5	VA	P	HO	115255808
Kenana at Kenana Road	1651704	6122183	1003041	C4	4	VA	S	MO	35686800
Kerikeri at Stone Store	1687631	6102447	1006289	C4	5	VA	P	HO	98720984

Mangahahuru at Apotu Road	1714117	6057720	1015857	A1	4	HS	P	MO	43820100
Mangahahuru at Main Road	1718886	6055192	1016447	A1	3	HS	EF	MO	22048200
Mangakahia at Titoki	1695063	6045019	1018598	C4	6	VA	P	HO	810098112
Mangakahia at Twin Bridges	1677496	6056596	1015928	C4	6	VA	P	HO	244237488
Mangakino at Mangakino Lane	1719727	6053270	1016854	C4	2	HS	EF	LO	8574300
Mangakino U/S Waitaua Confluence	1720522	6051489	1017040	C4	3	HS	EF	MO	13598100
Mangamuka at Iwitaua Road	1649247	6103622	1006091	C4	4	VA	IF	MO	36738900
Manganui at Mititai Road	1700451	6019713	1023188	A1	6	SS	P	HO	408979776
Mangapiu at Kokopu Road	1706588	6047656	1018071	A2	1	SS	P	LO	421200
Mangere at Kara Road	1709388	6047363	1018129	A1	4	HS	P	MO	17234100
Mangere at Knight Road	1703586	6048948	1017791	A1	5	SS	P	HO	75920416
Mangere at Kokopu Road	1706785	6048813	1017835	A1	5	HS	P	HO	49440600

Mangere at Wood Road	1710121	6046658	1018299	A1	4	HS	P	MO	15092100
Mania at SH10	1688381	6091736	1008424	A1	1	VA	P	LO	551700
Ngunguru at Coalhill Lane	1727725	6054828	1016568	C4	4	HS	P	MO	44561700
Opouteke at Suspension Bridge	1678503	6049460	1017632	C6	5	VA	EF	HO	108436480
Oruaiti at Sawyer Road	1656099	6121066	1003228	C4	5	SS	P	HO	96890400
Oruaiti at Windust Road	1654905	6125633	1002580	C4	6	VA	P	HO	156565856
Oruru at Oruru Road	1644747	6122468	1002906	C4	5	VA	P	HO	91675824
Otaika at Cemetery Road	1712613	6040509	1019551	C4	3	VA	P	MO	10524600
Otaika at Otaika Valley Road	1715492	6039912	1019622	C4	4	HS	P	MO	35777700
Otakaranga at Otaika Valley Road	1714396	6040056	1019608	C4	3	HS	P	MO	13271400
Paranui at Paranui Road	1642652	6122666	1003015	A3	3	SS	P	MO	13878000
Parapara at Parapara Toatoa Road	1639905	6119265	1003476	A3	4	SS	P	MO	10611900

Parapara at Taumata Road	1638075	6125035	1002684	A3	4	SS	P	MO	27765900
Pekapeka at Ohaeawai	1680918	6086769	1009371	C6	3	VA	P	MO	11205000
Peria at Honeymoon Valley Road	1646259	6111088	1004660	C4	4	VA	IF	MO	15403500
Pukenui at Kanehiana Drive	1715556	6048444	1017957	C5	2	HS	IF	LO	2936700
Punakitere at Taheke	1660001	6075453	1011729	C4	5	SS	P	HO	325731744
Punaruku at Russell Road	1719724	6083074	1010009	C4	3	HS	IF	MO	19533600
Puwera at SH1	1716889	6038226	1019956	A3	3	HS	P	MO	14127300
Raumanga at Bernard Street	1718764	6044939	1020313	A1	1	SS	P	LO	445500
Ruakaka at Flyger Road	1726626	6029623	1021503	A3	4	SS	P	MO	47529900
Stony Creek at Sawyer Road	1656071	6123396	1002927	C4	5	VA	P	HO	52802100
Tapapa at SH1	1643757	6105452	1005772	C5	3	VA	IF	MO	8056800
Utakura at Okaka Road	1659392	6089568	1008814	C4	4	SS	P	MO	110136592

Victoria at Victoria Valley Road	1637132	6110554	1004839	C4	4	VA	IF	MO	26883000
Waiarohia at Second Avenue	1719097	6045830	1018445	C4	3	HS	U	MO	18511200
Waiarohia at Whau Valley	1717592	6048676	1017919	A1	2	HS	P	LO	2564100
Waiaruhe at Puketona	1687317	6093000	1008155	C4	5	HS	P	HO	173059328
Waiaruhe R at DS of Mangamutu Stm Confluence	1682883	6084542	1009776	C4	4	SS	P	MO	36615600
Waiharakeke at Stringers Rd	1692604	6082806	1011114	C4	1	SS	P	LO	324900
Waimamaku at SH12	1640566	6065018	1014099	C4	5	VA	P	HO	102546000
Waiotu at SH1	1711403	6067089	1013585	A1	5	HS	P	HO	121155320
Waipao at Draffin Road	1701772	6045796	1018522	A1	4	VA	P	MO	36763200
Waipapa at Forest Ranger	1662582	6096421	1007423	C4	5	SS	IF	HO	121107600
Waipapa at Waimate North Road	1682092	6095939	1007584	C5	3	VA	P	MO	8250300
Waipapa at Landing	1688150	6103986	1006063	C4	1	VA	P	LO	314614.16

Waipoua at SH12	1651633	6054443	1016579	C5	4	VA	IF	MO	16278300
Wairau at SH12	1648179	6059938	1015357	C8	3	VA	IF	MO	9096300
Wairua at Purua	1704273	6053948	1016617	A2	6	HS	P	HO	544650560
Waitangi at SH10	1686945	6093559	1008099	C4	4	VA	P	MO	82986296
Waitangi at Waimate North Road	1681894	6093741	1008027	C4	4	VA	P	MO	50526000
Waitangi at Wakelins	1695269	6095708	1007625	C4	5	HS	P	HO	300543232
Waitaua at Vinegar Hill Road	1720111	6051298	1017317	C4	3	VA	U	MO	12492900
Watercress at SH1	1687416	6086899	1009281	A1	3	HS	P	MO	12123900
Whakapara at Cableway	1715259	6066116	1013917	A1	5	HS	P	HO	164852096

Appendix 2 Photographs of the Northland Regional Council SoE macroinvertebrate monitoring sites.

Awanui FMU

Figure 35 Victoria at Victoria Valley Road

Figure 33: Awanui at FNDCl

Figure 36: Awanui at Waihue Channel

Doubtless Bay FMU

Figure 37 Oruaiti at Windust Road

Figure 38 Oruru at Oruru Road

Hokianga FMU

Figure 39 Mangamuku at Iwitaua Road

Figure 40 Punakitere at Taheke

Figure 41 Utakura near Horeke Road

Figure 40 Waipapa at Forest Ranger

Waipoua FMU

Figure 42 Waipoua at SH12 Bridge

Figure 43 Waimamaku at SH12

Northern Wairoa FMU

Figure 45 Kaihu at Gorge

Figure 44 Mangakahia at Twin Bridges

Figure 47 Opouteke at Suspension Bridge

Figure 46Mangakahia at Titoki

Figure 48 Manganui at Mitaitai Road

Figure 49 Waiotu at SH1 Bridge

Figure 50 Whakapara at Cableway

Figure 51 Mangahahuru at end of Main Road

Figure 53 Mangahahuru at Apotu Raod

Figure 52 Waipao at Draffin Road

Figure 55 Mangere at Knight Road

Figure 54 Wairua at Purua

Figure 56 Hakaru at Topuni Farm

Whangarei FMU

Figure 58 Hatea at Mair Park

Figure 57 Otaika at Otaika Road

Figure 59 Raumanga at Bernard Street

Figure 60 Waiarohia at Second Avenue

Whangaroa FMU

Figure 61 Kaeo at Dip Road Bridge

Bream Bay FMU

Figure 62 Ruakaka at Flyger Road

Bay of Islands FMU

Figure 64 Waiharakeke at Stringers Road

Figure 63 Kerikeri at Stone Store

Figure 65 Waipapa at Landing Bridge

Figure 66Waiaruhe D/S Manganutu confluence

Figure 68 Watercress at SH!

Figure 67 Waitangi at Waimate Road

Figure 70 Waiaruhe at Puketona

Figure 69 Waitangi at SH10 Bridge

Figure 71 Waitangi at Watea

Appendix 3 Data collected at 22 sites in March 2020 during the Northland drought that will be resampled in 2020 as a focused assessment of potential drought effects.

Note 1: Collected by Steve Pohe, Pohe Environmental (1-10) or NRC staff (11-22) following Stark et al. (2001) Protocol C1, modified by collecting only 5 sampling unit efforts instead on 10 (NRC sampling instructions).

Note 2: Processed by Steve Pohe, Pohe Environmental following Stark et al. (2001) Protocol P3, counting all individuals retained in stacked 8, 2 & 0.5 mm Endecotts sieves, and identified under dissecting microscope (7.5–60x).

Note 3: Exuviae, pupa, empty cases and terrestrial additions not included in counts.

Note 4: Species list and tolerance values based on Stark et al. 2001. 1 Additions by Stark & Maxted 2007. 2 Further additions, including bold blue tolerance values, by Pohe Environmental, based on professional judgement.

Sample number			**1**	**2**	**3**	**4**	**5**	**6**
Site name			Kauritutahi at McBeth Road	Waipapa Stream at Wiroa Road	Waitaraire Stream at Bridge 5	Ahuroa at Piroa Falls (Waipu Gorge Road)	Waiariki Northern Dam (Puhipuhi Road)	Waiotu at top of Tapuhi Road
NRC site number								
Collection date			23/03/2020	24/03/2020	24/03/2020	23/03/2020	23/03/2020	23/03/2020
Sample type			Kicknet	Kicknet	Kicknet	Kicknet	Kicknet	Kicknet
Substrate			5 Cobble–Pebble	5 Cobble–Mud	5 Pebble–Gravel	5 Pebble–Gravel	5 Cobble	5 Pebble–Gravel
TAXA	Tolerance values							
INSECTA	HB	SB [1]						
Ephemeroptera								
Acanthophlebia cruentata	7	9.6						9
Ameletopsis perscitus	10	10.0						1

Atalophlebioides cromwelli	9	4.4						
Austroclima sepia	9	6.5	4					
Coloburiscus humeralis	9	8.1	13			1		34
Deleatidium angustum	8	5.6						3
Deleatidium cerinum	8	5.6						9
Deleatidium fumosum	8	5.6						
Deleatidium lillii	8	5.6	26					105
Mauiulus aquilus	5	4.1	7					26
Mauiulus luma	5	4.1	12					
Neozephlebia scita	7	7.6						
Nesameletus ornatus	9	8.6						
Zephlebia indet.	7	8.8				1		
Zephlebia dentata	7	8.8	13					25
Zephlebia spectabilis	7	8.8						
Zephlebia tuberculata	7	8.8	2		4			1
Zephlebia versicolor	7	8.8	10					9
Plecoptera								
Austroperla cyrene	9	8.4						1
Megaloptera								
Archichauliodes diversus	7	7.3	3	5	3	7	8	78
Odonata								
Adversaeshna brevistyla (= *Aeshna*)	5	1.4		1				
Antipodochlora braueri	6	6.3						
Hemicordulia australiae	5	0.4						3
Tramea loweii [2]	**5**	**6.0**						
Xanthocnemis zealandica	5	1.2		4				
Hemiptera								
Microvelia	5	4.6		1				
Sigara	5	2.4		5				
Coleoptera								

Elmidae #1 (Fig. 187 of Winterbourn et al. 2006)	6	7.2	3	1	171	42		155
Elmidae #2 (Fig. 188 of Winterbourn et al. 2006)	6	7.2					1	
Hydraenidae	8	6.7						19
Ptilodactylidae	8	7.1						
Diptera								
Aphrophila	5	5.6						
Austrosimulium	3	3.9	6	158	82	1	3	112
Chironominae [2]	**2**	**4.7**	16	1	6	18	1	
Dolichopodidae	3	8.6						
Empididae	3	5.4						
Ephydridae	4	1.4						
Eriopterini	9	7.5						6
Hexatomini	5	6.7						
Limonia	6	6.3		1				
Maoridiamesa	3	4.9				1		
Mischoderus (Tanyderidae)	4	5.9						
Muscidae	3	1.6	1					
Orthocladiinae	2	3.2	2	29	37	12		4
Paradixa	4	8.5						
Paralimnophila	6	7.4					1	
Tabanidae	3	6.8						
Tanypodinae	5	6.5		2	3			
Trichoptera								
Beraeoptera	8	7.0						
Costachorema	7	7.2						
Helicopsyche	10	8.6						
Hudsonema amabile	6	6.5	2			7		
Hydrobiosis	5	6.7	3	1		1		2
Hydropsyche - Aoteapsyche	4	6.0	42	6	5	12	6	1
Neurochorema	6	6.0						
Olinga	9	7.9	213					3

Oxyethira	2	1.2	22	44	59	24		5
Paroxyethira	2	3.7	3		6	1		1
Polyplectropus	8	8.1						1
Psilochorema	8	7.8	1					2
Pycnocentria	7	6.8	9			1		3
Pycnocentrodes	5	3.8	103		24	44		1
Triplectides dolichos / obsoletus	5	5.7						2
Collembola	6	5.3	4	22	1			
Acarina	5	5.2	1	9				
CRUSTACEA								
Amarinus (= *Halicarcinus*) [1]	**3**	5.1	12					
Amphipoda indet.	5	5.5		1				
Copepoda	5	2.4		1				
OSTRACODA	3	1.9		7	4			
Paracalliope [1]	5	**5.5**	177					
Paranephrops	5	8.4	1	1				
Paratya	5	3.6			1			
MOLLUSCA								
Ferrissia (= *Gundlachia*)	3	2.4	17	1	5	1		22
Gyraulus	3	1.7			4			
Latia	3	6.1	8			1		
Lymnaeidae, *Austropeplea tomentosa* [2]	**3**	**1.2**			2			
Lymnaeidae, *Galba truncatula* [2]	**3**	**1.2**						
Lymnaeidae, *Pseudosuccinea columella* [2]	**3**	**1.2**		1	1			
Physidae, *Physa acuta* (= *Physella*)	3	0.1		1	2		1	
Sphaeriidae	3	2.9						
Tateidae, *Halopyrgus pupoides* [2]	**4**	**2.1**						

Tateidae, *Potamopyrgus antipodarum*	4	2.1	485	213	358	641		12
HIRUDINEA	3	1.2		2	7			
NEMATODA	3	3.1	1	1				
NEMERTEA	3	1.8						
OLIGOCHAETA	1	3.8	62	63	3	3	6	3
PLATYHELMINTHES	3	0.9	12	35	10	6	1	4
Full count total			1296	617	798	825	28	662
Taxonomic richness			34	28	23	20	9	32
MCI value			99.4	81.4	73.9	84.0	77.8	119.4
QMCI value			5.05	3.26	4.06	4.06	4.11	6.02
EPT* count			15	2	3	7	1	19
%EPT*			44.1	7.1	13.0	35.0	11.1	59.4

Sample number			**7**	**8**	**9**	**10**	**11**	**12**
Site name			Takahue River at Saddle Road	Victoria River trib at Ratea	Pukepoto Stream at Kaitaia-Awaroa Rd	Ahuroa R. at Braigh Flats	Mangahahuru at Main Road	Ngunguru at Coalhill Lane
NRC site number							100237	110603
Collection date			24/03/2020	24/03/2020	24/03/2020	23/03/2020	16/03/2020	16/03/2020
Sample type			Kicknet	Kicknet	Kicknet	Kicknet	Kicknet	Kicknet
Substrate			5 Cobble–Pebble	5 Pebble–Cobble	5 Pebble–Gravel	5 Pebble–Gravel	Hard-bottomed	Hard-bottomed
TAXA	Tolerance values							
INSECTA	HB	SB [1]						
Ephemeroptera								
Acanthophlebia cruentata	7	9.6		1				
Ameletopsis perscitus	10	10.0						
Atalophlebioides cromwelli	9	4.4						
Austroclima sepia	9	6.5		2	26			

Coloburiscus humeralis	9	8.1		99			61	
Deleatidium angustum	8	5.6						
Deleatidium cerinum	8	5.6						
Deleatidium fumosum	8	5.6			1			
Deleatidium lillii	8	5.6		3	19		2	1
Mauiulus aquilus	5	4.1					12	1
Mauiulus luma	5	4.1		10	5			
Neozephlebia scita	7	7.6		5				
Nesameletus ornatus	9	8.6		25				
Zephlebia indet.	7	8.8						
Zephlebia dentata	7	8.8		1	74	12	36	1
Zephlebia spectabilis	7	8.8		1				
Zephlebia tuberculata	7	8.8		1	12	3	12	
Zephlebia versicolor	7	8.8						1
Plecoptera								
Austroperla cyrene	9	8.4						
Megaloptera								
Archichauliodes diversus	7	7.3	4	23		14	73	7
Odonata								
Adversaeshna brevistyla (= *Aeshna*)	5	1.4						
Antipodochlora braueri	6	6.3				1	2	
Hemicordulia australiae	5	0.4						
Tramea loweii [2]	**5**	**6.0**			2			
Xanthocnemis zealandica	5	1.2	1					
Hemiptera								
Microvelia	5	4.6						
Sigara	5	2.4						
Coleoptera								
Elmidae #1 (Fig. 187 of Winterbourn et al. 2006)	6	7.2		7	89	7	96	10
Elmidae #2 (Fig. 188 of Winterbourn et al. 2006)	6	7.2		1				

Hydraenidae	8	6.7					4	
Ptilodactylidae	8	7.1						
Diptera								
Aphrophila	5	5.6		2				
Austrosimulium	3	3.9		22	54	2	13	1
Chironominae [2]	**2**	**4.7**	13	6	3	3	3	1
Dolichopodidae	3	8.6						
Empididae	3	5.4		1				
Ephydridae	4	1.4	7					
Eriopterini	9	7.5					5	
Hexatomini	5	6.7						
Limonia	6	6.3						
Maoridiamesa	3	4.9						
Mischoderus (Tanyderidae)	4	5.9					4	
Muscidae	3	1.6	9					
Orthocladiinae	2	3.2	71	4	3	3	4	8
Paradixa	4	8.5					1	
Paralimnophila	6	7.4						
Tabanidae	3	6.8		1				
Tanypodinae	5	6.5						
Trichoptera								
Beraeoptera	8	7.0						
Costachorema	7	7.2						
Helicopsyche	10	8.6						
Hudsonema amabile	6	6.5			9		1	
Hydrobiosis	5	6.7		1				
Hydropsyche - Aoteapsyche	4	6.0		29	12	1	25	
Neurochorema	6	6.0		3				
Olinga	9	7.9		13	13		1	
Oxyethira	2	1.2	28	12	58	3	4	9
Paroxyethira	2	3.7	12	2	15			1
Polyplectropus	8	8.1						

Psilochorema	8	7.8					1	
Pycnocentria	7	6.8		4	2	6	12	
Pycnocentrodes	5	3.8	18	7	40	3	2	
Triplectides dolichos / obsoletus	5	5.7				1	4	
Collembola	6	5.3						
Acarina	5	5.2	1				1	
CRUSTACEA								
Amarinus (= *Halicarcinus*) [1]	**3**	5.1						
Amphipoda indet.	5	5.5						
Copepoda	5	2.4						
OSTRACODA	3	1.9			1			
Paracalliope [1]	5	**5.5**				129		7
Paranephrops	5	8.4						
Paratya	5	3.6						
MOLLUSCA								
Ferrissia (= *Gundlachia*)	3	2.4	2	1	2	1		1
Gyraulus	3	1.7						
Latia	3	6.1	1	1		21	12	
Lymnaeidae, *Austropeplea tomentosa* [2]	**3**	**1.2**	12					
Lymnaeidae, *Galba truncatula* [2]	**3**	**1.2**	8					
Lymnaeidae, *Pseudosuccinea columella* [2]	**3**	**1.2**						13
Physidae, *Physa acuta* (= *Physella*)	3	0.1				1	1	18
Sphaeriidae	3	2.9					1	
Tateidae, *Halopyrgus pupoides* [2]	**4**	**2.1**	1					
Tateidae, *Potamopyrgus antipodarum*	4	2.1	141	103	145	113	83	1617
HIRUDINEA	3	1.2			4	3		1

NEMATODA	3	3.1					1	
NEMERTEA	3	1.8	1					
OLIGOCHAETA	1	3.8	10		3	6	2	8
PLATYHELMINTHES	3	0.9		3	6			
Full count total			340	394	598	333	479	1706
Taxonomic richness			18	31	24	20	30	18
MCI value			67.8	106.5	95.0	85.0	103.3	81.1
QMCI value			3.18	5.98	4.92	4.57	5.93	3.98
EPT* count			1	16	11	6	12	4
%EPT*			5.6	51.6	45.8	30.0	40.0	22.2
* Excludes *Oxyethira* & *Paroxyethira* (Hydroptilidae).								

Sample number			**13**	**14**	**15**	**16**	**17**	**18**
Site name			Punaruku at Russell Road	Mangere at Kara Road	Awanui at FNDC	Pekapeka at Ohaeawai	Victoria at Victoria Valley Road	Waiaruhe d/s of Mangamutu confluence
NRC site number			313171	102106	100363	306643	105532	306661
Collection date			16/03/2020	16/03/2020	16/03/2020	16/03/2020	16/03/2020	16/03/2020
Sample type			Kicknet	Kicknet	Kicknet	Kicknet	Kicknet	Kicknet
Substrate			Hard-bottomed	Hard-bottomed	Hard-bottomed	Hard-bottomed	Hard-bottomed	Hard-bottomed
TAXA	Tolerance values							
INSECTA	HB	SB [1]						
Ephemeroptera								
Acanthophlebia cruentata	7	9.6	8					
Ameletopsis perscitus	10	10.0						
Atalophlebioides cromwelli	9	4.4						
Austroclima sepia	9	6.5		3				
Coloburiscus humeralis	9	8.1	6	110		6		
Deleatidium angustum	8	5.6		24				2

Deleatidium cerinum	8	5.6	15					24
Deleatidium fumosum	8	5.6						
Deleatidium lillii	8	5.6	9					
Mauiulus aquilus	5	4.1		32				2
Mauiulus luma	5	4.1		3	1			
Neozephlebia scita	7	7.6						
Nesameletus ornatus	9	8.6						
Zephlebia indet.	7	8.8						
Zephlebia dentata	7	8.8		98				
Zephlebia spectabilis	7	8.8						
Zephlebia tuberculata	7	8.8	1	4	1	4		
Zephlebia versicolor	7	8.8		1				
Plecoptera								
Austroperla cyrene	9	8.4						
Megaloptera								
Archichauliodes diversus	7	7.3	18	26		3	2	43
Odonata								
Adversaeshna brevistyla (= *Aeshna*)	5	1.4						
Antipodochlora braueri	6	6.3	1					
Hemicordulia australiae	5	0.4						
Tramea loweii [2]	**5**	**6.0**						
Xanthocnemis zealandica	5	1.2						
Hemiptera								
Microvelia	5	4.6						
Sigara	5	2.4						
Coleoptera								
Elmidae #1 (Fig. 187 of Winterbourn et al. 2006)	6	7.2	460	54		3		84
Elmidae #2 (Fig. 188 of Winterbourn et al. 2006)	6	7.2						
Hydraenidae	8	6.7	7	1				
Ptilodactylidae	8	7.1	1					

Diptera								
Aphrophila	5	5.6	2					
Austrosimulium	3	3.9	1	24			2	1
Chironominae [2]	**2**	**4.7**	25	2	2	2	5	2
Dolichopodidae	3	8.6	1					
Empididae	3	5.4						
Ephydridae	4	1.4						
Eriopterini	9	7.5	3	2	1			
Hexatomini	5	6.7						1
Limonia	6	6.3						
Maoridiamesa	3	4.9						
Mischoderus (Tanyderidae)	4	5.9	1	1				
Muscidae	3	1.6	1				1	
Orthocladiinae	2	3.2	4			7	17	5
Paradixa	4	8.5						
Paralimnophila	6	7.4						
Tabanidae	3	6.8	2					1
Tanypodinae	5	6.5	1		1			
Trichoptera								
Beraeoptera	8	7.0						
Costachorema	7	7.2						
Helicopsyche	10	8.6						
Hudsonema amabile	6	6.5		6		4		1
Hydrobiosis	5	6.7	9			1		2
Hydropsyche - Aoteapsyche	4	6.0	62	1		20		54
Neurochorema	6	6.0	4					
Olinga	9	7.9	68					
Oxyethira	2	1.2	9			12	19	
Paroxyethira	2	3.7				10	11	
Polyplectropus	8	8.1						
Psilochorema	8	7.8	16	2				1
Pycnocentria	7	6.8	18	9		6	2	4

Pycnocentrodes	5	3.8	7	2	2	23	2	1
Triplectides dolichos / obsoletus	5	5.7					1	
Collembola	6	5.3						
Acarina	5	5.2	1					
CRUSTACEA								
Amarinus (= *Halicarcinus*) [1]	**3**	5.1						
Amphipoda indet.	5	5.5						
Copepoda	5	2.4						
OSTRACODA	3	1.9						
Paracalliope [1]	5	**5.5**		8				
Paranephrops	5	8.4						
Paratya	5	3.6						
MOLLUSCA								
Ferrissia (= *Gundlachia*)	3	2.4	3	12		1		
Gyraulus	3	1.7					1	
Latia	3	6.1				1		
Lymnaeidae, *Austropeplea tomentosa* [2]	**3**	**1.2**	7				1	
Lymnaeidae, *Galba truncatula* [2]	**3**	**1.2**						
Lymnaeidae, *Pseudosuccinea columella* [2]	**3**	**1.2**						
Physidae, *Physa acuta* (= *Physella*)	3	0.1						2
Sphaeriidae	3	2.9						
Tateidae, *Halopyrgus pupoides* [2]	**4**	**2.1**						
Tateidae, *Potamopyrgus antipodarum*	4	2.1	38	72	31	84	160	2
HIRUDINEA	3	1.2			1		1	
NEMATODA	3	3.1						
NEMERTEA	3	1.8	1					

OLIGOCHAETA	1	3.8	14	6		2		
PLATYHELMINTHES	3	0.9						
Full count total			824	503	40	189	225	232
Taxonomic richness			34	24	8	17	14	18
MCI value			104.7	115.8	100.0	88.2	72.9	101.1
QMCI value			5.85	6.39	4.18	4.20	3.58	5.75
EPT* count			12	13	3	7	3	9
%EPT*			35.3	54.2	37.5	41.2	21.4	50.0
* Excludes *Oxyethira* & *Paroxyethira* (Hydroptilidae).								

Sample number			**19**	**20**	**21**	**22**
Site name			Waitangi at Waimate North Road	Mangamuka at Iwitaua	Tangowahine at Tangowahine Road	Tapapa at SH1
NRC site number			103178	108978	322490	313165
Collection date			16/03/2020	16/03/2020	23/03/2020	16/03/2020
Sample type			Kicknet	Kicknet	Kicknet	Kicknet
Substrate			Hard-bottomed	Hard-bottomed	Hard-bottomed	Hard-bottomed
TAXA	Tolerance values					
INSECTA	HB	SB [1]				
Ephemeroptera						
Acanthophlebia cruentata	7	9.6				2
Ameletopsis perscitus	10	10.0				
Atalophlebioides cromwelli	9	4.4				4
Austroclima sepia	9	6.5				
Coloburiscus humeralis	9	8.1	1			33
Deleatidium angustum	8	5.6				
Deleatidium cerinum	8	5.6	8			
Deleatidium fumosum	8	5.6				

Deleatidium lillii	8	5.6				7
Mauiulus aquilus	5	4.1	6			
Mauiulus luma	5	4.1				1
Neozephlebia scita	7	7.6				2
Nesameletus ornatus	9	8.6				1
Zephlebia indet.	7	8.8				
Zephlebia dentata	7	8.8	3			1
Zephlebia spectabilis	7	8.8				1
Zephlebia tuberculata	7	8.8	1			
Zephlebia versicolor	7	8.8				1
Plecoptera						
Austroperla cyrene	9	8.4				
Megaloptera						
Archichauliodes diversus	7	7.3	18	6		21
Odonata						
Adversaeshna brevistyla (= *Aeshna*)	5	1.4				
Antipodochlora braueri	6	6.3				
Hemicordulia australiae	5	0.4				
Tramea loweii [2]	**5**	**6.0**				
Xanthocnemis zealandica	5	1.2				
Hemiptera						
Microvelia	5	4.6				
Sigara	5	2.4				
Coleoptera						
Elmidae #1 (Fig. 187 of Winterbourn et al. 2006)	6	7.2	93	75	10	27
Elmidae #2 (Fig. 188 of Winterbourn et al. 2006)	6	7.2				
Hydraenidae	8	6.7				1
Ptilodactylidae	8	7.1				1
Diptera						
Aphrophila	5	5.6				

Austrosimulium	3	3.9	4	2	6	5
Chironominae [2]	**2**	**4.7**	1	23		9
Dolichopodidae	3	8.6				
Empididae	3	5.4				
Ephydridae	4	1.4				
Eriopterini	9	7.5				
Hexatomini	5	6.7				
Limonia	6	6.3				
Maoridiamesa	3	4.9				2
Mischoderus (Tanyderidae)	4	5.9				
Muscidae	3	1.6				
Orthocladiinae	2	3.2	6	85	1	5
Paradixa	4	8.5				
Paralimnophila	6	7.4				
Tabanidae	3	6.8				
Tanypodinae	5	6.5				
Trichoptera						
Beraeoptera	8	7.0				26
Costachorema	7	7.2				1
Helicopsyche	10	8.6				1
Hudsonema amabile	6	6.5	3	6		
Hydrobiosis	5	6.7				
Hydropsyche - Aoteapsyche	4	6.0	2	1		23
Neurochorema	6	6.0				
Olinga	9	7.9				27
Oxyethira	2	1.2		12	5	
Paroxyethira	2	3.7		5	4	
Polyplectropus	8	8.1				
Psilochorema	8	7.8				
Pycnocentria	7	6.8	18	3		4
Pycnocentrodes	5	3.8	1	8		45
Triplectides dolichos / obsoletus	5	5.7				

Collembola	6	5.3				
Acarina	5	5.2				
CRUSTACEA						
Amarinus (= *Halicarcinus*) [1]	**3**	5.1				
Amphipoda indet.	5	5.5			44	
Copepoda	5	2.4				
OSTRACODA	3	1.9	23			
Paracalliope [1]	5	**5.5**			33	
Paranephrops	5	8.4				
Paratya	5	3.6				
MOLLUSCA						
Ferrissia (= *Gundlachia*)	3	2.4	4	2		4
Gyraulus	3	1.7				
Latia	3	6.1				
Lymnaeidae, *Austropeplea tomentosa* [2]	**3**	**1.2**		1		
Lymnaeidae, *Galba truncatula* [2]	**3**	**1.2**				
Lymnaeidae, *Pseudosuccinea columella* [2]	**3**	**1.2**				
Physidae, *Physa acuta* (= *Physella*)	3	0.1	1	4	1	
Sphaeriidae	3	2.9				
Tateidae, *Halopyrgus pupoides* [2]	**4**	**2.1**				
Tateidae, *Potamopyrgus antipodarum*	4	2.1	2	295	616	543
HIRUDINEA	3	1.2		5	1	
NEMATODA	3	3.1				
NEMERTEA	3	1.8				
OLIGOCHAETA	1	3.8	2		6	
PLATYHELMINTHES	3	0.9				

Full count total	197	533	727	798
Taxonomic richness	19	16	11	27
MCI value	96.8	77.5	65.5	126.7
QMCI value	5.54	3.87	4.07	4.79
EPT* count	9	4	0	17
%EPT*	47.4	25.0	0.0	63.0
* Excludes *Oxyethira* & *Paroxyethira* (Hydroptilidae).				