Determinates of benthic invertebrate community structure in small Kaipara streams

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Abstract

Land use effects on stream health has become a major issue in New Zealand water management. Much of this focus has been targeted at the intensification of dairy farming, however there are other land use practices that can have detrimental effects on stream health. I evaluated the effect of multiple land use activities on the ecological health of small streams in the greater Auckland/South Kaipara region of New Zealand. All, but one of the streams were moderately to severely degraded with communities dominated by Amphipoda, Oligochaeta, Ostracoda, P. *antipodarum* and *Chironomidae*. The degree of degradation was negatively associated with the percentage of catchment in native forest. However, this reduced ecological health was not directly linked with any single environmental variable affected by land use change. This would make any potential restoration or mitigation plans for these streams extremely challenging as multiple drivers must be addressed.

Key Words

Auckland; community; drivers; freshwater; health; invertebrates; small stream; South Kaipara; water quality.

Introduction

The effects of agricultural intensification on the ecological health of biological communities in New Zealand's rivers and streams has become an increasingly topical and contentious issue of public and government concern (Parlimentary Commissioner for the Environment, 2013; Joy, 2015; Kerr, Hughey & Cullen, 2016; Death, 2017). However, agricultural intensification, principally in the dairy industry, is just one of many catchment and riparian land use activities degrading riverine health including urbanisation, industrialisation, sheep and beef farming, horticulture and plantation forestry (MacLeod & Moller, 2006; Larned *et al.*, 2004; Monaghan *et al.*, 2007). While these may affect less length of New Zealand rivers than intensive livestock farming (Dymond *et al.*, 2013; Collins, Elliott & Adams, 2005) the per reach effects of these activities can be far more damaging locally (Larned *et al.*, 2016).

The impacts of deforestation from land use change include excessive periphyton growth, fluctuations in dissolved oxygen (DO)(Harding, 2003) and pH, pesticide use, and extensive macrophyte growth (Quinn & Gilliland, 1989). Indirect effects of land use changes include reduced groundwater recharging (Neill *et al.*, 2006), increased runoff (Ralph *et al.*, 1994; Sweeney *et al.*, 2004), decreased bank stability (Allan & Castillo, 2007; Sweeney *et al.*, 2004), and lower carbon:nitrogen (C:N) ratios (Davies *et al.*, 2005; Neill *et al.*, 2006). Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa, indicative of good water quality, which rely on biofilms for browsing, are often replaced by species tolerant of eutrophication, macrophytes, and/or high periphyton biomass (Collier & Winterbourn, 2000; Cox & Rutherford, 2000; Quinn *et al.*, 1994; Rutherford *et al.*, 1997).

Increased sediment entering streams can result in mechanical damage and burial of taxa (Dewson, James & Death, 2007a), increased habitat homogenisation (through filling of interstitial spaces) (Quinn *et al.*, 1992), and the transfer of phosphorus and bacteria from cultivated or sewage treated land into streams (McDowell & Wilcock, 2007; Dymond *et al.*, 2013; Reddy, Khaleel & Overcash, 1981). Taxa shift away from EPT dominant communities to predominantly Oligochaete, Crustacea, Mollusca, Diptera and Coleoptera larval assemblages (Collier & Winterbourn, 2000).

Flow regimes may be altered by deforestation, including increased velocity (Walsh, Fletcher & Ladson, 2005) and volume of runoff (Bunn & Arthington, 2002). This increased force and volume of water entering streams results in morphological changes (incision and erosion) to banks and channelization of streambeds (Collier & Winterbourn, 2000; Poff *et al.*, 1997). This flashiness (Leopold, 1968; Walsh *et al.*, 2005; Schueler, 1994) perturbs invertebrate communities through higher peak flows and a greater volume of water reaching streams in a reduced timeframe, mobilising substrate and inducing drift (Bunn & Arthington, 2002; Death & Winterbourn, 1995). Habitats disturbed by higher peak flows are characterised by low species diversity, with species unable to tolerate high velocities lacking and Orthoclad chironomids dominating (Jalon *et al.*, 1994; Munn & Brusven, 1991). In contrast, artificially reduced base flows, related to water abstraction for irrigation in agrarian areas, decrease velocity, depth, and wetted width, impacting filter feeders and piercers (notably *Aoteapsyche* and *Oxyethira*) due to their reliance on substrate stability, depth and velocity (Hynes & Hynes, 1970; Dewson, James & Death, 2007c; Dewson, James & Death, 2007b).

Not surprisingly, there has been a tendency for studies of the effects of land use on stream health to be focused in areas with the greatest levels of agricultural intensification, for example, Waikato (Death & Collier, 2010), Manawatu (Death & Joy, 2004; Joy & Death, 2003; Death *et al.*, 2015), Canterbury (Harding, Winterbourn & McDiffett, 1997; Harding, 2003), and Otago (Magbanua *et al.*, 2010; Matthaei *et al.*, 2006). Areas of New Zealand where dairy farming does not dominate the landscape have been less well investigated for linkages between in-stream health and surrounding land use. Furthermore, although Regional Environment Agencies monitor water quality and ecological health in rivers and streams throughout New Zealand, they focus on the larger rivers where determining causal drivers is more difficult.

In this study, I investigated the effects of land use on macroinvertebrate communities in small streams in the South Kaipara and Waitakere regions of New Zealand where a wide variety of land uses potentially effect river health. The land uses in the area include: intensive dairy farming; lifestyle blocks; small scale sheep and beef farming; vineyards and horticulture; undisturbed forest remnants; plantation forests; small townships; and larger urban areas. This area borders on the rapidly expanding metropolis of Auckland and is increasingly under threat from urban development (Gluckman, 2017).

Study area

The Auckland region covers 4,894 km^2 and is situated in the north-west of New Zealand's North Island between 36.4^o and 37^o S and is bordered on the west by the Tasman sea, the Hauraki Gulf in the east and Northland to the north (Stats New Zealand, 2010). South Kaipara is a peninsula bordered by the Tasman Sea to the west, the Kaipara Harbour to the north and east, and the Waitakere Ward and Ranges to the south (Piggot *et al.*, 1978). The peninsula is defined by Holocene dunes on the west coast, extending eastward inland to high plateaus and terraced steps which terminate in cliffs above the Kaipara Harbour which is surrounded by extensive mudflats. The terraced plateaus contain at least 35 small dune lakes which are heavily polluted by nutrients. Aside from Holocene and Pleistocene sands, estuarine clays and alluvium with thin peat cover are the dominant soil types found in the district (Brothers, 1954).

The Waitakere Ward to the south contains the Waitakere volcano and Ranges (up to 474 m in altitude) with steep cliffs along the west coast (Stats New Zealand, 2010). A primary feature of this area is the 14,899-ha protected land parcel (Auckland Centennial Memorial Park) containing one of the largest remaining podocarp-broadleaf and kauri forest remnants in the Auckland region (Auckland Council, 2013; Auckland Council District Plan, 2011). Surrounding the park, urban intensification continues as the population of Auckland City grows and the eastern boundary merges into Auckland City. The Waitakere Ranges receive the highest rate of rainfall for the region, about 2000 mm per annum with the rest of the area averaging 800-1000 mm per annum. Much of the Auckland region has been heavily developed (urban) with less central areas containing suburban townships, lifestyle blocks, various farming (dairy, beef and sheep, horticulture), and plantation forests (Brothers, 1954).

Methods

Study sites

The Auckland Council monitor 76 sites in the region from 6, 100-group level Freshwater Ecosystems of New Zealand classes (Leathwick *et al.*; Leathwick & Winterbourn, 1984) (Table 1). For my study, I selected 17 streams to sample in the Southern Kaipara region in proportion to Freshwater Ecosystems of New Zealand (FENZ) database (Leathwick *et al.*, 2010b) classes present in the region, but not sampled by Auckland Council (Table 1, Fig. 1). Streams within the Auckland city limits were omitted.

Table 1. The 76 streams currently monitored by Auckland City Council and the 17 small Kaipara streams sampled in December 2016 and the corresponding FENZ 100-level classes they belong to.

FENZ 100-level Class	Number of Auckland city council sites	Kaipara sites
C1	0	1
C4	13	0
C5	12	0
C6	4	0
A1	32	9

A2	5	6
A3	10	0
A4	0	1

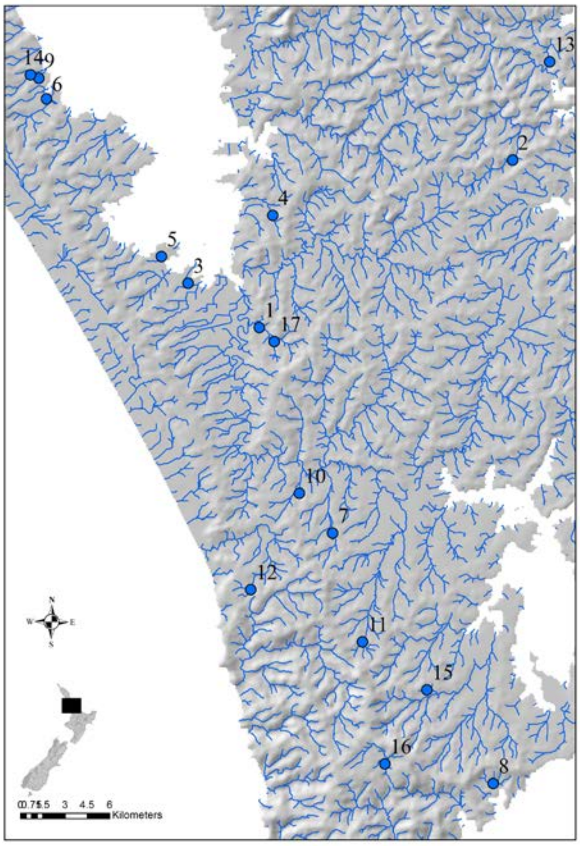

Figure 1. Map of the 17 small streams sampled in Kaipara in December 2016.

Invertebrate collection

Macroinvertebrates were sampled once during the Austral Summer (December) 2016. Three replicates of 0.3 m^2 D-net samples (0.5 mm mesh, 30 cm wide opening) were collected per site (Stark *et al.*, 2001), approximately 25 m apart. Riffles were preferentially sampled when present and samples were stored in 70-80% isopropanol (Stark *et al.*, 2001). Processing of invertebrates was performed in the lab where they were removed from samples using a 500 μm sieve, enumerated and identified to the lowest possible taxonomic level using keys in Winterbourn, Gregson and Dolphin (2006) and Chapman, Lewis and Winterbourn (2011).

Physicochemical characteristics

Concurrent with invertebrate sampling, chemical and physical characteristics of each reach were measured. Conductivity (automatically adjusted to 25^{o}C) and water temperature were measured with a EuTech Instruments Oaktron meter. A filtered 500 ml water sample was collected and frozen for laboratory analysis of total oxidised nitrogen, ammonia, nitrite, nitrate, and dissolved reactive phosphorus (Appendix 1).

Reach depth and velocity were measured in the centre of the channel with a velocity head rod at five equidistant points. Width was measured in the same manner, with a measuring tape, along the length of the reach. Substrate embeddedness was ranked on a scale from 1-4 (1 representing loosely packed and 4, hard packed clay/silt). Habitat types (pool, riffle, run) were visually assessed as percent abundance across the sample area. Presence of periphyton and/or macrophytes was visually assessed as percent of reach covered by each. Area covered by any in-stream large debris, fallen trees or decomposing remains was estimated as a percentage of reach affected. Surrounding land use (urban, pasture), riparian growth (native, exotic, grasses), and manmade alterations (such as bridges, concrete channels, or drains) were also recorded.

Data analysis

Patterns in community composition were assessed using non-metric multidimensional scaling (NMDS), on log (x+1) transformed data using the Bray Curtis distance measure with the Vegan package (Oksanen *et al.*, 2007) in R (R Core Team, 2013). Biological and environmental variables were ordinated and projected onto the NMDS plot with the maximum correlation calculated (with envfit) for the corresponding communities and (Oksanen *et al.*, 2007; R Core Team, 2013).

Along with the field collected habitat data GIS environmental data on nutrients, flow regime, catchment geology and topography, temperature and shading, MCI and deposited sediment for each sampled reach were also examined for correlations with biological communities . Modelled nutrient, MCI and *E. coli* were sourced from (Unwin & Larned, 2013), flow data from (Booker & Woods, 2014), catchment geology, topography and temperature from the FENZ database (Leathwick *et al.*, 2010b), and modelled sediment data from (Clapcott, Goodwin & Snelder, 2103).

Results

Community composition

Ninety-three taxa were collected from the 17 streams (Fig. 2). About half of these were found at less than 6% of the sites. *Oligochaeta* (present at 94% of sites) were the most commonly found taxa across all sites. The amphipods *Paracalliope* (71%), Paraleptamphopidae (35%), and *Phreatogammarus* (29%) were present at 88% of the sites, followed by *Potamopyrgus antipodarum* (82%), *Acari* (71%), Orthocladiinae (71%), Ostracoda (59%), *Oxyethria albiceps* (53%), and *Tanypodinae* (53%). Numerically abundant taxa at individual sites were primarily Amphipoda (15 sites), *P. antipodarum* (14 sites), Orthocladiinae (12 sites), Ostracoda (10 sites), Tanypodinae (9 sites), and Simuliidae (8 sites). Ephemeroptera, Plecoptera, and Trichoptera taxa were present at 65% of the sites with the greatest abundance (composing 43% of the taxa present) at site 16 and accounting for 60% of the total individuals at that site.

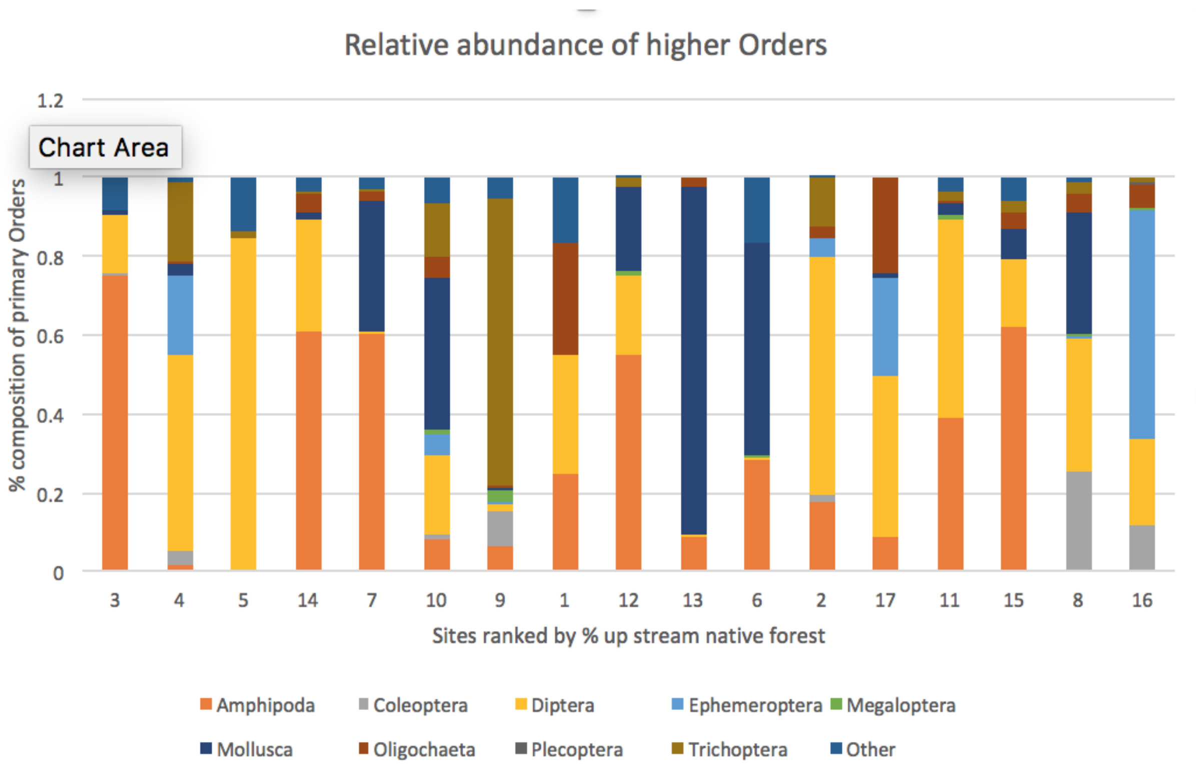

Figure 2. Relative abundance of higher order taxa ranked by percentage of upstream native forest collected at each of the 17 Kaipara streams in December 2016.

The NMDS ordination had a stress of 0.16 indicating a significant repeatable pattern of sample relationships (Fig. 3). Sites increase in ecological condition from the top to the bottom of axis 2. Of the 25 biological and environmental variables measured and the 53 GIS sourced (Table 2); percent of the stream which was run or riffle, streambed type, and stock access were most strongly correlated with patterns in community composition (Table 3). Soft-bottomed sites, with stock access and more runs were the most heavily degraded. In contrast, streams with more riffles, rocky, embedded substrate and no stock presence had a better ecological health.

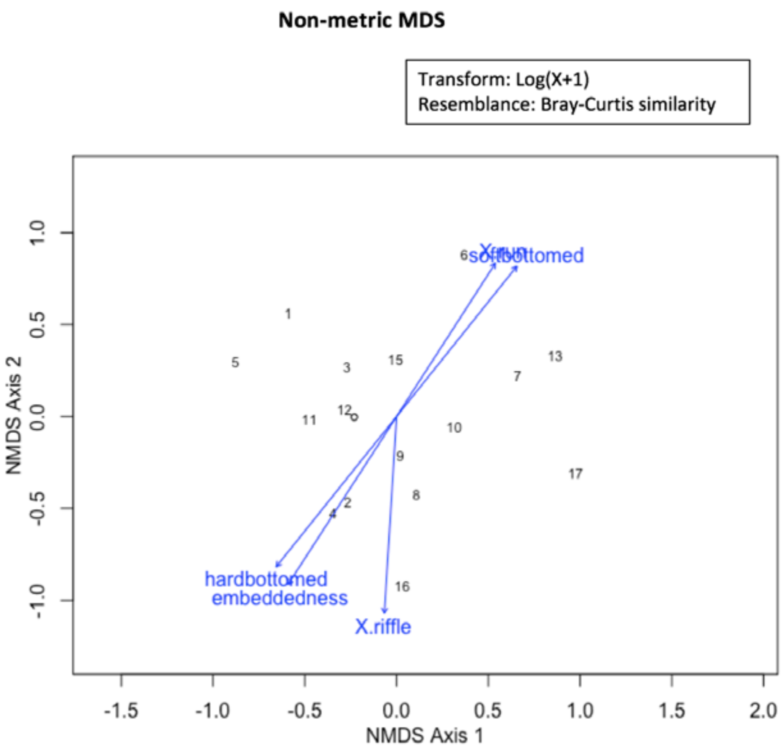

Figure 3. NMDS of invertebrate communities collected at 17 Kaipara streams in December 2016, with significant biological and environmental variables overlaid.

Table 2. Kaipara stream sample site coordinates (NZ Transverse Mercator 2000), biological and physicochemical variables.

Site	TON	Ammonia	width	depth	Nitrite	Nitrate	DRP	North	East	Cond	Temp	V	E	Soft	Hard	%ripar	USNative	%riffle	%run	%pool	%peri	%mac	Stock	%Odebris	ind.	MCI	%IndEPT	%taxaEPT	simpsons	BergerParker	QMCI
1	0.02	0.14	2.80	53.00	0.01	0.01	0.01	1730232	5940227	159.00	22.10	1	1	1	0	0.20	0.16	0.00	1.00	0.00	0.00	0.07	0	0.10	215	100	0.00	0.00	0.21	0.28	2.88
2	0.22	0.09	0.90	37.00	0.00	0.22	0.03	1747274	5951491	47.00	22.40	3	3	0	1	0.00	0.30	0.33	0.33	0.33	0.60	0.00	0	0.05	1952	104	0.13	0.28	0.39	0.60	3.11
3	0.01	0.06	0.80	10.70	0.00	0.01	0.02	1725445	5943201	315.00	22.90	3	3	0	1	0.40	0.00	0.00	1.00	0.00	1.00	0.80	0	0.00	1049	69	0.00	0.00	0.42	0.63	4.21
4	0.07	0.05	0.56	5.70	0.00	0.07	0.02	1731134	5947762	241.00	17.70	3	3	0	1	0.20	0.28	0.30	0.70	0.00	0.30	0.00	0	0.00	855	108	0.27	0.29	0.23	0.44	3.70
5	0.00	0.03	1.40	24.00	0.00	0.00	0.02	1723642	5944997	1628.00	24.90	2	3	0	1	0.00	0.00	0.00	0.20	0.80	0.10	0.05	0	0.00	224	118	0.01	0.08	0.33	0.54	2.17
6	0.01	0.06	2.40	80.00	0.00	0.01	0.03	1715919	5955599	329.00	28.40	2	1	1	0	0.00	0.22	0.00	1.00	0.00	0.05	0.00	0	0.05	895	66	0.00	0.00	0.35	0.54	4.20
7	0.00	1.06	0.60	10.00	0.00	0.00	0.03	1735162	5926395	0.26	17.00	1	1	1	0	0.00	0.13	0.00	1.00	0.00	0.00	1.00	1	0.00	313	116	0.00	0.00	0.30	0.38	4.06
8	0.05	0.02	0.80	9.00	0.00	0.05	0.02	1745968	5909554	2.00	18.40	2	3	0	1	0.40	0.74	0.50	0.50	0.00	0.00	0.50	0	0.00	181	81	0.04	0.25	0.21	0.31	3.85
9	0.01	0.05	0.70	14.30	0.00	0.01	0.01	1715399	5956997	259.00	26.90	1	3	0	1	0.10	0.00	0.00	1.00	0.00	0.20	1.00	0	0.00	1281	79	0.10	0.04	0.52	0.71	2.74
10	0.14	0.04	0.51	8.40	0.00	0.14	0.02	1732924	5929080	0.20	14.50	2	1	1	0	1.00	0.14	0.00	1.00	0.00	0.05	0.00	1	0.10	75	101	0.19	0.22	0.18	0.39	4.23
11	0.07	0.05	3.65	150.00	0.00	0.07	0.01	1737181	5919069	167.00	22.20	2	3	0	1	0.10	0.48	0.00	1.00	0.00	0.00	0.60	0	0.00	1577	76	0.10	0.09	0.26	0.39	3.45
12	0.09	0.01	1.86	24.20	0.00	0.05	0.02	1729661	5922593	2.38	19.40	2	1	1	0	0.00	0.19	0.00	0.70	0.30	0.30	0.20	0	0.00	5602	90	0.00	0.09	0.22	0.32	3.62
13	0.02	0.09	12.00	200.00	0.01	0.01	0.02	1749777	5958094	496.00	22.80	2	1	1	0	1.00	0.22	0.00	1.00	0.00	0.00	0.05	1	0.10	299	80	0.00	0.00	0.78	0.88	3.92
14	0.16	0.09	1.20	15.00	0.00	0.22	0.00	1714837	5957216	238.00	18.90	2	1	1	0	0.10	0.12	0.00	0.70	0.30	0.20	0.50	1	0.20	1310	101	0.00	0.09	0.38	0.58	4.20
15	0.01	0.03	2.00	54.30	0.00	0.01	0.01	1741515	5915844	187.00	20.80	1	1	1	0	0.30	0.70	0.00	1.00	0.00	0.25	0.00	0	0.30	751	116	0.00	0.00	0.41	0.62	2.99
16	0.00	0.02	1.80	31.00	0.00	0.00	0.01	1738688	5910863	0.00	16.70	3	4	0	1	0.40	1.00	0.90	0.10	0.00	0.05	0.00	0	0.10	299	113	0.60	0.43	0.21	0.27	5.41
17	0.02	0.08	0.80	12.00	0.00	0.02	0.01	1731237	5939278	342.00	21.00	2	1	1	0	0.10	0.31	0.00	1.00	0.00	0.10	0.30	1	0.05	159	97	0.25	0.14	0.22	0.28	4.27

Table 3. Correlation of biological and physicochemical measures with NMDS axis scores for invertebrate samples collected in 17 Kaipara streams in December 2016 (bold indicates significant values).

Biological Measures	NMDS1	NMDS2	(r)
Individuals	-1	-0.07	0.56
MCI	-0.42	-0.91	0.46
QMCI	0.82	-0.58	**0.038**
EPT Individuals	0.16	-0.99	**0.002**
EPT Taxa	-0.08	-1	**0.001**
Simpsons	0.61	0.8	0.26
Berger-Parker	0.25	0.97	0.42
Physicochemical Measure			
Total Organic Nitrogen	-0.49	-0.87	0.38
Ammonia	0.87	0.5	0.35
Nitrite	0.23	0.97	0.33
Nitrate	-0.48	-0.88	0.43
Dissolved Reactive Phosphorus	0.78	0.63	0.28
Width	0.65	0.76	0.3
Depth	0.4	0.92	0.31
Northing	0.54	-0.84	0.27
Easting	0.08	1	0.45
Conductivity	-0.65	0.76	0.24
Temperature	-0.23	0.97	0.08
Velocity	-0.29	-0.96	0.11
Embeddedness	-0.54	0.84	**0.002**
Soft-bottom	0.63	0.78	**0.006**
Hard-bottom	-0.63	-0.78	**0.006**
% Riparian Cover	0.99	-0.13	0.34
Upstream Indigenous Cover	0.29	-0.96	0.26
Upstream Native Cover	0.17	-0.99	0.12
% Riffle	-0.06	-1	**0.002**
% Run	0.54	0.84	**0.008**
% Pool	-0.99	0.13	0.09
% Periphyton	-0.97	0.26	0.52
% Macrophyte	1	-0.07	0.93
Stock Access	1	0.1	**0.021**
% Organic Debris	0.5	0.87	0.79

QMCI, EPT(taxa) and EPT(individuals) at a site all increased as the percentage of native forest in the upstream catchment increased, but only the last variable was significant (Fig. 4 -6). Streams with less than 80% of native forest in the catchment appear most degraded.

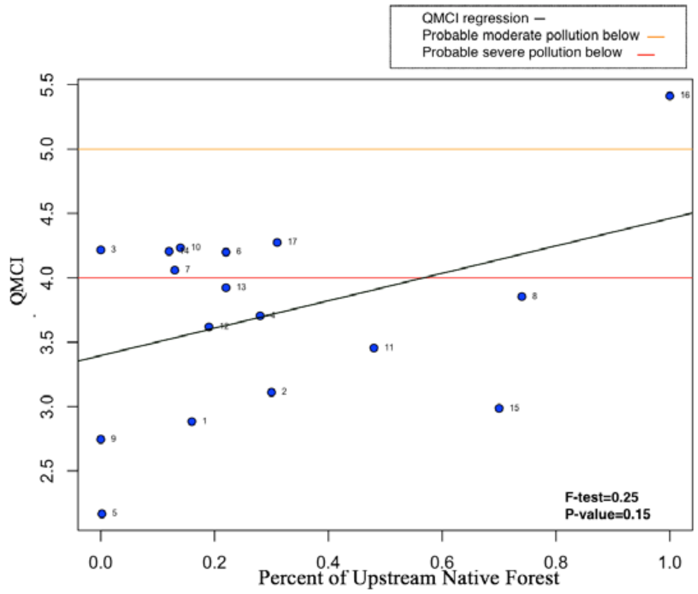

Figure 4. QMCI did not respond to the percent of upstream native forest for invertebrate samples collected in 17 Kaipara streams in December 2016.

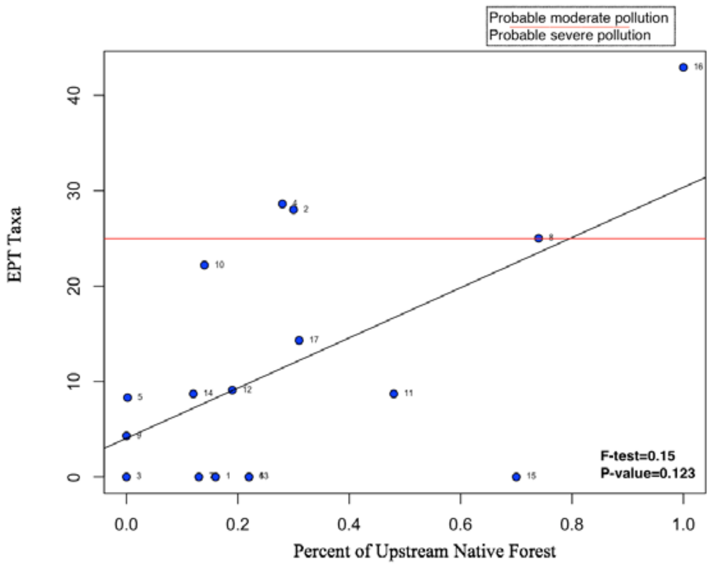

Figure 5. EPT taxa did not respond to the percent of native forest upstream in the invertebrate samples collected in 17 Kaipara streams in December 2016.

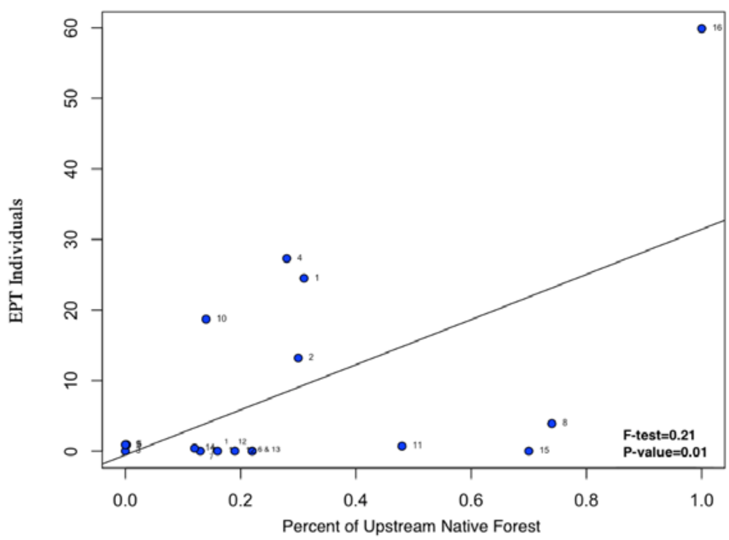

Figure 6. The number of EPT individuals was positively correlation to the percent of native forest upstream in the invertebrate samples collected in 17 Kaipara streams in December 2016.

Discussion

This study investigated the influence of land use on the macroinvertebrates of small streams in the Southern Kaipara Region. Invertebrate communities at every site (with the exception of site 16) had low species richness and reduced numbers of pollution sensitive taxa. Communities were dominated by Amphipoda, Oligochaeta, Ostracoda, P. *antipodarum* and *Chironomidae*. These changes in community structure have been extensively linked to eutrophication of waterways and agricultural land use in previous studies (Winterbourn & Fegley, 1989; Death & Joy, 2004; Ramezani *et al.*, 2016; Piggott *et al.*, 2015; Piggott, Townsend & Matthaei, 2015). While the water chemistry tests (total oxidized nitrogen, nitrate, nitrite, ammonia and dissolved phosphorus) did not indicate high nutrient levels on the sampling date, this was a single measure that did not reflect average conditions. Clearly the invertebrate communities reflect degraded water quality.

Of the 17 streams sampled, 5 lacked any riparian and/or catchment forest. Periphyton cover in the study reaches was, on average, low (19%) but sites had high levels of sediment. Fifty percent of the sites were soft-bottomed streams with sand, silt, or clay as the primary substrate. Furthermore, all the hard-bottomed streams (except site 16) were covered in fine sediment. Fine sediment results in less EPT taxa (Quinn *et al.*, 1992), high levels of bacteria and nutrients (Biggs, 2000), homogenised habitat (Davies-Colley *et al.*, 1992), and prevents vertical migration of macroinvertebrates (Descloux, Datry & Marmonier, 2013; Ramezani *et al.*, 2014). Ramezani *et al.* (2014) found sediment decreased species richness and abundance, with EPT taxa most heavily affected. Descloux, Datry and Marmonier (2013) documented a three-fold decrease in species richness associated with fine sediment input. In the Kaipara sites, there was a mean species richness of 17 across all the sites sampled in December, and no sensitive EPT taxa occurred at 11 sites.

Three types of stream were identified from the streams sampled (Fig. 7). Group one sites were characterised by soft-bottom, loose gravely, reaches entirely composed of runs. There was little to no riparian cover, minimal periphyton (<10% cover), stock accessing three of the four streams, and the lowest species richness scores (averaging 10/site). EPT taxa were absent at all but site 17, where *Zephlebia* was the dominant species. Many streams drained lifestyle blocks, livestock farming (including dairy), or rural neighborhoods. Sites in Group two had the highest number of EPT taxa (average 25), greatest species richness (average 23) and least degraded habitats. This group included the two sites (8 & 16) with the highest percentage of riparian and upstream catchment cover, were predominantly large cobbled, hard-bottomed substrates (83%), riffles high velocity, and lower temperature.

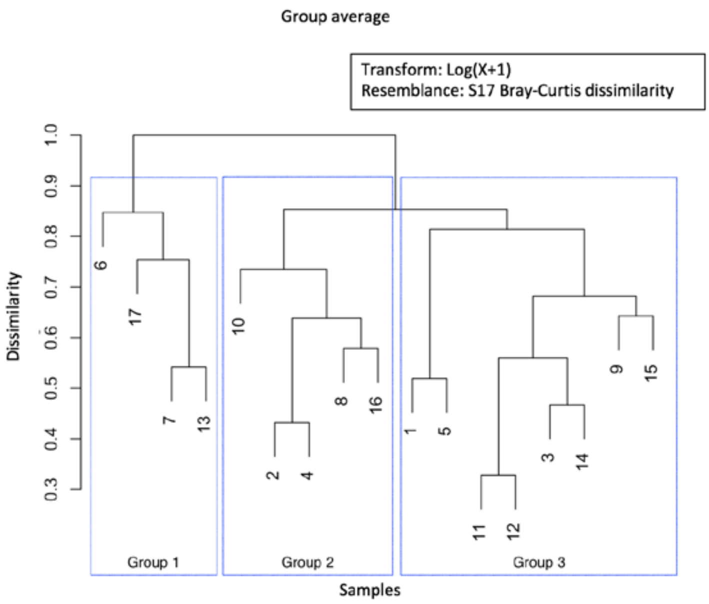

Figure 7. Dendrogram for invertebrate samples collected in 17 Kaipara streams in December 2016 showing three distinct groups.

Native fauna are usually well adapted to seasonal fluctuations in flow but are less able to adapt to anthropogenic alterations (Bunn & Arthington, 2002). However, increased flow variability caused by a shift to pastoral land use is characterised by low species diversity and chironomid dominated communities (Death, 1995; Jalon *et al.*, 1994; Munn & Brusven, 1991). Sites in group three reflected these findings with communities composed of Chironomus, Austrosimulium, and the pollution tolerant caddisfly, *O. albiceps* dominant. Periphyton was minimal at these sites with an average cover of 20%, riparian cover was minimal if present, and runs composed much of the reach length (66%). The sites were equally divided by substrate type (50% each hard- and soft-bottomed) and all had a moderate velocity.

While no single parameter examined was a universal driver of the structure of the invertebrate communities in small streams in South Kaipara, there was a clear effect of land use intensification on community assemblages. Increasing riparian and catchment cover to remediate runoff and sediment influx, strengthen bank architecture, and moderate flow changes in the streams may assist in re-establishing sensitive taxa and increasing the low levels of biodiversity present. Remediation or mitigation plans for these streams will be extremely challenging as multiple drivers (sediment, deforestation, flow mediation, etc) must be addressed. Further studies expanding the number of streams sampled and sampling over an extended time-period may manifest the specific drivers present in the Kaipara Region. It would also be of interest to test the sites for bacterial pathogens as their transport into streams is often correlated with high sediment input and increased run off which was noted in at these sites.

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Appendix 1

Methodology used by Central Environmental Laboratories to calculate chemical concentrations from water samples collected in 17 Kaipara streams in December 2016.

Test	Methodology	Detection Limit
Total oxidised nitrogen	Calculation: Nitrate + Nitrite	0.005 g/m3 NO3-N
Ammonia	APHA 22nd Ed. 4500 NH3-F (Modified)	0.005 g/m3 NH3-N
Nitrite	APHA 22nd Ed. 4110 B	0.005 g/m3 NO2-N
Nitrate	APHA 22nd Ed. 4110 B	0.005 g/m3 NO3-N
Dissolved Reactive Phosphorus	APHA 22nd Ed. 4500-P E	0.005 g/m3 PO4-P