Environment Waikato Technical Report 2006/38

Aquatic Invertebrate Biodiversity and Spatial Characterisation of Non-Perennial Streams in Native Forest in the Waikato Region

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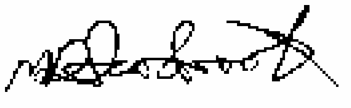

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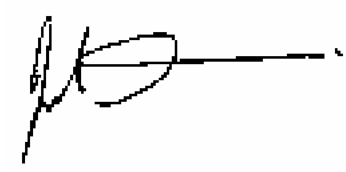

Dr John Quinn

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Executive Summary

Currently, Environment Waikato (EW) has no basis for evaluating the significance of non-perennial habitats or zero-order stream channels in terms of their indigenous biodiversity. EW have asked NIWA to investigate whether these small streams have biological values that add additional biodiversity to perennial native forest streams and to describe the character of these relatively unstudied stream types that dry up for part of the year. This initial focus was on native forest streams to document baseline values of non-perennial habitats in the absence of human perturbation.

We used channel form (morphological) and surface water (hydrological) characteristics to define the extent and describe the type of non-perennial streams in the Waikato Region. The difference between the summer dry season and winter wet season was a general increase in overall stream length in winter. In summer, the character of these headwater streams often followed a pattern of dry channel, mud, isolated pools interspersed by dry or mud habitat, standing water, then flowing water. In winter, the length of flowing or standing water habitat increased in all sites. The average amount of flowing water habitat upstream from the junction with a perennial stream increased from 30 m per stream in summer to 150 m in winter, equivalent to a 5-fold increase on average in the length of stream habitat.

We sampled aquatic invertebrate communities in mud, isolated pools, and flowing water habitats within the non-perennial stream (if that habitat type was present) and in an adjoining perennial stream (if available within native forest). Aquatic macroinvertebrate taxa found in non-perennial headwater habitats differed from those in nearby perennial streams in forested Waikato stream systems in both summer and winter. The communities were particularly different at the top of catchments where streams became isolated pools or mud. Surprisingly, taxa richness was fairly high in the mud samples (on average 15 in summer and 25 in winter) and communities were characterised by the snail *Potamopyrgus antipodarum*, the tipulid *Zelandotipula*, and the cased caddisfly *Oeconesus maori*. In summer, the amount of flowing stream habitat in non-perennial headwaters was reduced and this appeared to be a significant stress resulting in a different configuration of taxa in summer than winter. Total taxa richness was also lower in summer than winter.

Inclusion of non-perennial stream sampling could increase the overall estimate of biodiversity within stream systems as a substantial number of taxa not recorded in the perennial streams occurred in the non-perennial streams (average of 18 and 25 additional taxa in summer and winter, respectively). Therefore, non-perennial streams may harbour elements of indigenous biodiversity not found in perennial habitats and warrant consideration in catchment management and policy development, where biodiversity objectives are of interest.

1. Introduction

Streams and rivers in Waikato hill country have at their tips a myriad of small streams, seepages and wetlands. These endpoints of the stream network are usually too small to appear on topographic maps, and are usually overlooked in ecological assessment. Streams less than 500 m long are not mapped as a rule (National Topographic/ Hydrographic Authority 2003). They are highly vulnerable to human modification of the landscape and overseas studies have shown them to be hot spots of biodiversity (Dieterich & Anderson 2000, Meyer et al. 2003).

These small headwater streams are the interface between land and water and may experience periods of drying and wetting, and contraction and expansion of stream length. These conditions lead to variable habitat conditions and adaptations among biota to exploit these non-perennial habitats.

Currently, Environment Waikato (EW) has no basis for evaluating the ecological significance of non-perennial habitats. EW have asked NIWA to investigate whether these small streams have biological values that add additional biodiversity to perennial native forest stream catchments, and to describe the character of these relatively unstudied stream types that dry up for part of the year. Over 75% of mapped wadeable stream length in the Waikato is represented by four main stream types combining climate, source of flow and geology (CW/H/VA, WW/L/HS, WW/L/SS, WW/L/VA, where CW = cold wet, WW = warm wet, H = highland, L = lowland, HS = hard sedimentary, SS = soft sedimentary, VA = volcanic acidic; River Environment Classification (REC), Snelder & Biggs 2002). These types form the basis of the REMS (Regional Ecological Monitoring of Streams) sampling design used by EW for SOE monitoring. We used this framework to select sampling sites of non-perennial streams that drain into these perennial stream types. We collected samples from native forest sites because we wanted to assess biodiversity values in unmodified (baseline) conditions.

1.1 Definitions

There is considerable inconsistency in the terminology used for streams that only flow for part of the year. Temporary, intermittent, and ephemeral are all terms used to describe streams and ponds with non-permanent flow. The strict definition of 'ephemeral' is waterways that have surface water for a few days in response to rainfall, whereas we have surveyed small headwater streams that are not marked as blue lines on topographic maps that may have a range of water states from slow flowing, standing water, isolated pools and muddy or dry channels. Therefore, our streams cannot be classified as strictly ephemeral and we have called them non-perennial throughout this document.

2. Methods

2.1 Site locations

Our study represents a small sample of sites across parts of the Waikato region. We investigated 11 potential sites in each of the REC/Environment Waikato REMS classes, but chose 8 sites for biological sampling. Table 2.1 details the sites visited and their locations. Table 2.2 gives the GPS coordinates at the top and bottom of each reach and location of tributaries, when we were able to get a satellite signal, of the sites chosen for spatial extent and biological sampling. Figures 2.1 – 2.4 show the Topomap locations of the sites chosen.

Our focus was on small headwater streams in native forest catchments that would dry up for part of the year. It appeared from the initial site survey that the character of the headwater streams in each of the main REC classes was different, although the number of sites visited was small.

We focussed on Mt Pirongia and Mt Maungatautari for streams in the "CW/H/VA" REC class and these seemed mostly to be spring fed or to originate from seeps. Hence, we located only one site (MT1) for this class that did not appear to originate from a spring.

In the "WW/L/VA" REC class, the streams had the interesting characteristic of disappearing beneath the ground in places, and one site (MK1) appeared to be dry at both the top and bottom of the reach in summer and the stream emerged again down hill in pasture. For the size of the stream, these headwaters seemed to have a greater network of feeder tributaries that tended to be longer than streams in the other REC classes.

The "WW/L/SS" REC class sites were found in the Coromandel and the headwater site KB2 showed a classic drying pattern with isolated pools containing crayfish and banded kokopu slowly contracting with dry stretches between. The base sediments were worn smooth in places suggesting frequent storm flows.

The "WW/L/HS" REC class sites were hard sedimentary rock streams with steep "step-pool" sections. Note that site WP1 was in a native forest remnant with pasture upstream (only flowing through pasture in winter), although the pastoral stream section was not sampled for aquatic invertebrates.

Table 2.1: Site codes, locations, sampling notes and descriptions of the sites visited.

Site name	EW code	Catchment size classification	Location	Sample notes and descriptions
WP1	WW/L/HS	Large	Waipuna Rd, north of Te Hoe	Native forest remnant with pasture above (dry in pasture in summer, but flowing up to farm dam in winter)
H1	WW/L/HS	Small	Ohinewai Rd	Road crosses Hapuakohe Range
MK1	WW/L/VA	Small	Piakonui Rd	Base of stream at start of Mt Maungakawa walking track; top section crosses track
MK2	WW/L/VA	Large	Piakonui Rd	Non-perennial channel first tributary on the true left on the stream monitored by EW
P1	CW/H/VA		Pirongia Forest	Characterised by seeps rather than non-perennial channels; sampled mud side channel in summer only
MT1	CW/H/VA	Small	Maungatautari Forest	Small tributary sampled above a constructed pond
MT2	CW/H/VA		Maungatautari Forest	Storm channel; dry for 240 m; not sampled
MT3	CW/H/VA		Maungatautari Forest	Spring at top of reach; mud incline and obvious flow below spring; not sampled
KB1	WW/L/SS	Large	Tuateawa Rd	Unusual lower section; quite deep but very short; sampled in summer; thought it may extend in winter, but appeared to be a drainage channel at base of wetland rather than non-perennial channel; not resampled
KB2	WW/L/SS	Small	Tuateawa Rd	TL trib at top of road crossing to Tuateawa
KB3	WW/L/SS	Small	Tuateawa Rd	resurveyed a different tributary of KB2 in winter by accident.

Table 2.2: GPS location of the top and bottom of the surveyed reach and location of tributaries (labelled as "a" and "b") surveyed in the dry season (March) with Garmin Etrex GPS (except where taken from NZMS 260 map). Please note: GPS locations may be variable and were not able to be measured in some places due to the difficulty of receiving a signal beneath forest cover.

Site name	Tributary	EW code	GPS top	GPS bottom
WP1		WW/L/HS	E2719222/N6422788	E2719108/N6422637
WP1	a	WW/L/HS		E2719113/N6422617
WP1	b	WW/L/HS	E2719187/N6422682	
H1		WW/L/HS	E2721556/N6419778	E2721693/N6419829
MK1		WW/L/VA		E2742032/N6372980
MK2*	a	WW/L/VA	E2741945/N6373251*	E2742070/N6373500 (NZMS 260)
KB2		WW/L/SS	E2738882/N6502203	E2738901/N6502356
KB1		WW/L/SS	E2738597/N6502403	E2738586/N6502411
MT1		CW/H/VA	E2735312/N6347365	E2735282/N6346880

*GPS reading at this site could only be read part way along one side tributary.

Table 2.3: GPS location of the top and bottom of the surveyed reach and location of tributaries surveyed in the wet season (August) with Garmin Etrex GPS. Please note: GPS locations may be variable and were not able to be measured in some places due to the difficulty of receiving a signal beneath forest cover.

Site name	Tributary	EW code	GPS top	GPS bottom
WP1		WW/L/HS	E2719263/N6422790	E2719100/N6422633
WP1	b	WW/L/HS	E2719186/N6422675	
H1		WW/L/HS	E2721506/N6419794	E2721702/N6419828
MK1		WW/L/VA	E2742078/N6372927	E2742079/N6372999
MK1	a	WW/L/VA	E2741883/N6372927	
MK2		WW/L/VA		
KB3*		WW/L/SS	E2739170/N6502228	E2739174/N6502332
MT1		CW/H/VA		

*GPS used here was Garmin GPS12.

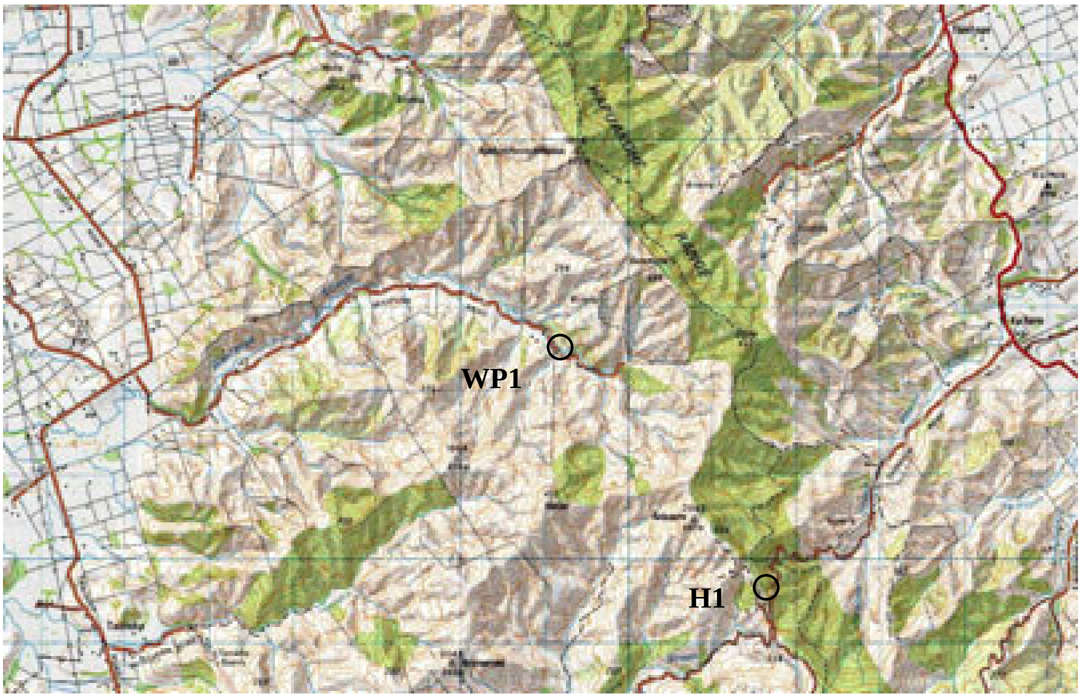


Figure 2.1: Location of “WW/L/HS” sites WP1 and H1.

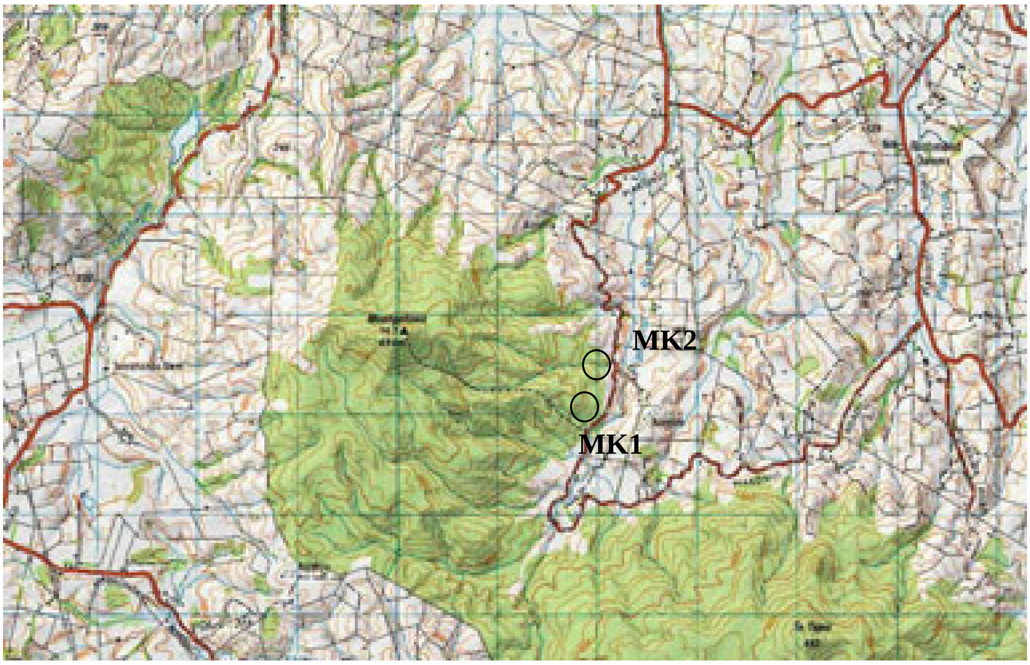


Figure 2.2: Location of “WW/L/VA” sites MK1 and MK2.

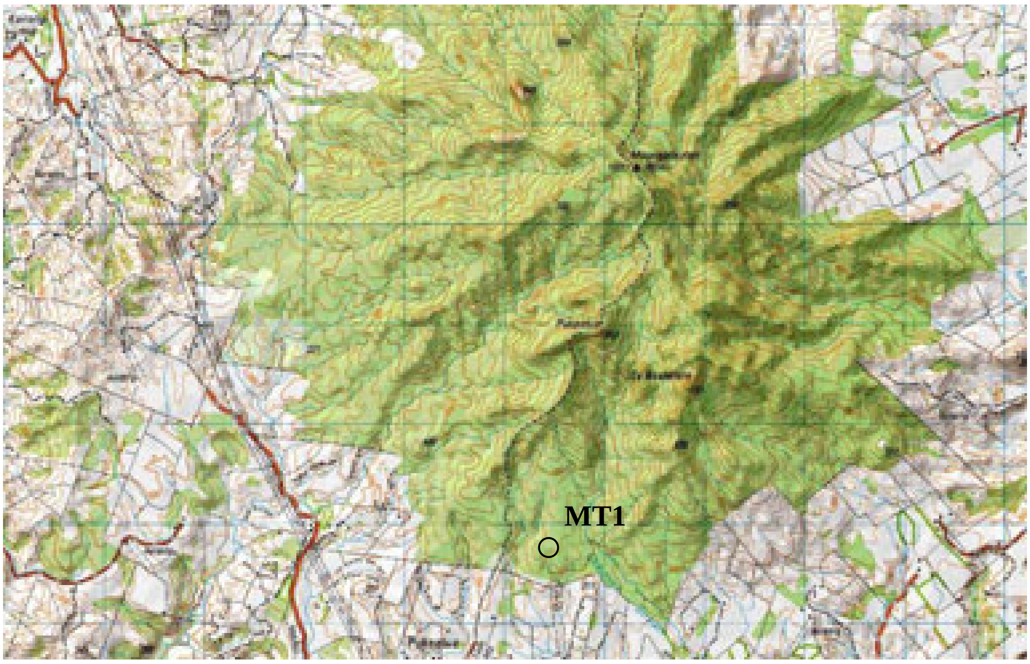


Figure 2.3: Location of “CW/H/VA” site MT1.

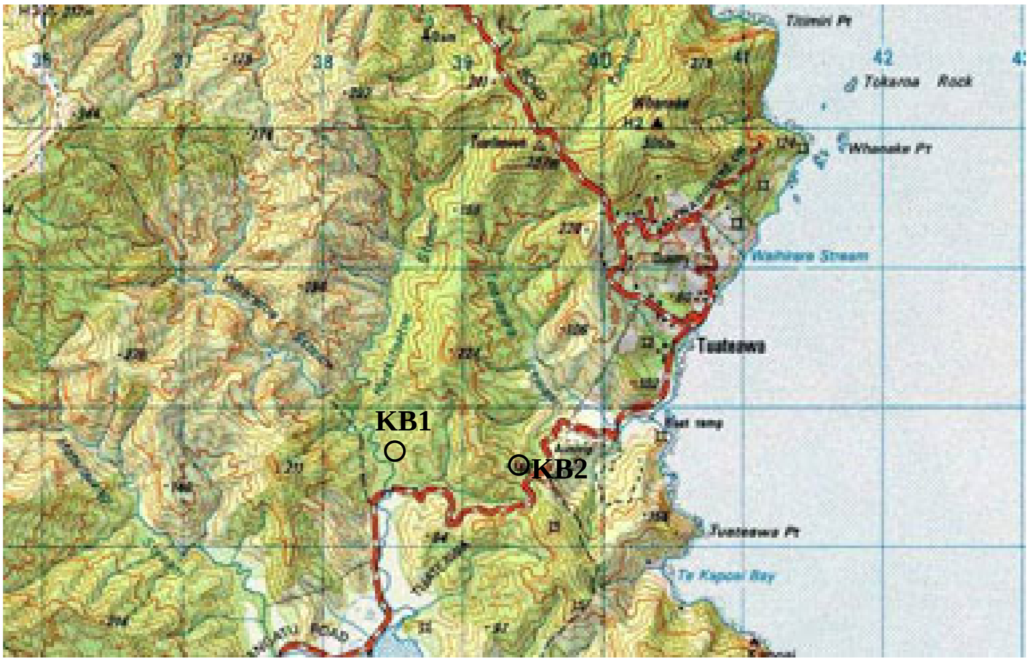


Figure 2.4: Location of “WW/L/SS” sites KB1 (surveyed in summer only) and KB2 (surveyed in summer, winter site was in same location but a different tributary and labelled KB3).

2.2 Spatial extent

We used channel form (morphological) and surface water (hydrological) characteristics to define the extent and describe the character of non-perennial streams from a sample of streams in the Waikato region. We described channel form using four categories that largely represent the increasing size and power of a stream to form a channel and can be used as an indication of the permanence or regularity of flow (Table 2.1). At the point where streams first begin, the stream does not have the power to erode a defined channel or scour plant growth (Code C – no banks, bed vegetated), but with increasing frequency and magnitude of flow, substrates are scoured to leave a stream bed and are unsuitable for plant growth (Code B – stream bed substrate, no banks, no terrestrial vegetation). As stream power increases, the channel generally becomes incised, forming stream banks (Code A – channel incised, no terrestrial vegetation). Wetlands are a unique channel form, defined by the presence of wetland vegetation (e.g., sedge, reeds, raupo), and designated as Code D.

We described the amount of surface water present using five categories (Table 2.1). The category "isolated pools" described part of the reach where pools were separated by stretches of dry or muddy channel. If a pool was greater than 10 m long it was classed as "slow flow or standing". Mud was distinguished from open-water by a depth of water less than 10 mm. Mud was distinguished from dry substrate using the 'gumboot test' where mud/water oozes out under foot in mud but does not in dry or moist soil.

Table 2.1: Coding system used to describe channel form (rows) and amount of surface water (columns). Each section of stream sampled was described using this system.

		Water				
		1. Obvious flow	**2. Slow flow or standing**	**3. Isolated pools**	**4. No open water, muddy**	**5. Dry**
Channel	**A. Channel incised, no terrestrial vegetation**	1A	2A	3A	4A	5A
	B. Stream bed substrate, no banks, no terrestrial vegetation	1B	2B	3B	4B	5B
	C. No banks, bed vegetated	1C	2C	3C	4C	5C
	D. Wetland	1D	2D	3D	4D	5D

A change in either channel-form or surface water codes (Table 2.1) delineated the start of the next stream segment. We surveyed the stream starting at the base of the reach, usually where it joined a perennial stream section if one was available in the same land use, and measured the distance of each coded segment using a cotton reel meter counter. We considered the uppermost extent of the non-perennial stream channel to be at the point where the stream was dry and had no defined streambed or banks (code 5C). We used handheld GPS (Etrex Garmin) to note locations at the base and top of the reach, where possible. Tributaries were mapped in the same way as the main stem to provide total stream network length.

Sites were surveyed twice to document the change between wet and dry seasons. The first survey was in March, representing a dry season, and the wet season survey was in August.

2.3 Biological surveys

We sampled aquatic invertebrate communities in mud, isolated pools, and flowing water habitats within the non-perennial stream (if that habitat type was present) and in an adjoining perennial stream (if available within native forest), at the same time as the winter and summer spatial extent surveys. The perennial streams ranged from 2^{nd} to 3^{rd} order.

For perennial, flowing water, and isolated pools habitats, we took composite kick net samples (500µm mesh net) from 4 – 5 points within each habitat type totalling approximately $1m^2$ (area of each sample estimated and noted to express abundance on an areal basis). We also measured dissolved oxygen and temperature (YSI 55) at several points within each of the habitat types. We sampled mud in 4 – 5 places by placing a small bucket upside down into the mud to leave an impression and then scraped the soft surface layers and associated leaf litter into the bucket. The radius of the circle was 7.5 cm giving an area of 0.017 m^2 per sample from which a composite area was calculated.

We preserved the samples with isopropyl alcohol in the field and sorted the invertebrates from the organic matter back in the laboratory. We identified the invertebrates to species where possible or the lowest practical taxonomic level using the keys of Winterbourn & Gregson (1989), Winterbourn (1973), Towns & Peters (1996), and Smith & Ward (unpubl.).

3. Results and discussion

3.1 Spatial extent of headwater habitat in wet and dry seasons

The difference between the summer dry season and winter wet season was a general increase in overall stream length (including dry channels and tributaries) in winter for the non-perennial headwater streams by an average of 18% but a range from 2 – 37% increase from summer lengths (Table 3.1). The smallest increase in stream length was at site MT1 on Mt Maungatautari and this may reflect a greater influence of groundwater rather than surface runoff, as we found headwater streams in these volcanic regions were often formed by springs and seeps. The length of increase ranged from 10 – 116 m, with the greatest length increase at site WP1, where it was found that an upstream dam existed that may have decreased stream flows in summer. Site KB1 was not resurveyed as it was found to be a drainage channel rather than a natural non-perennial stream, and site KB2 was not resurveyed due to difficulty of locating sites in heavy bush cover using GPS.

Table 3.1: Total stream length (including dry channels and tributaries) measured in summer (March) and winter (August) in non-perennial streams.

Site	Class	Summer length (m)	Winter length (m)	% change from summer
WP1	WW/L/HS	315.6	431.7	37
H1	WW/L/HS	107.6	117.5	9
MK1	WW/L/VA	194.1	264	36
MK2	WW/L/VA	511.4	544.2	6
MT1	CW/H/VA	68.3	69.5	2
KB1	WW/L/SS	76.7	-	
KB2	WW/L/SS	234	-	
KB3	WW/L/SS	-	83.6	
Mean		215.4	251.8	18

In summer, the character of these headwater streams often follows a pattern of dry channel, mud, isolated pools interspersed by dry or mud habitat, standing water, then flowing water (e.g., WP1, Fig. 3.1; MK2, Fig. 3.2; KB2 Fig. 3.4). In winter, the most obvious change was the increase in the length of flowing or standing water habitat (Fig. 3.1 – 3.5). The average amount of flowing water habitat increased from 30 m per stream in summer to 150 m in winter (Fig. 3.5). Stream MK1 on Mt Maungakawa was different to the other streams in that it disappeared underground in summer at the base of the reach, but in winter the whole stream length was wetted, apart from a few areas of mud through the middle (Fig. 3.2).

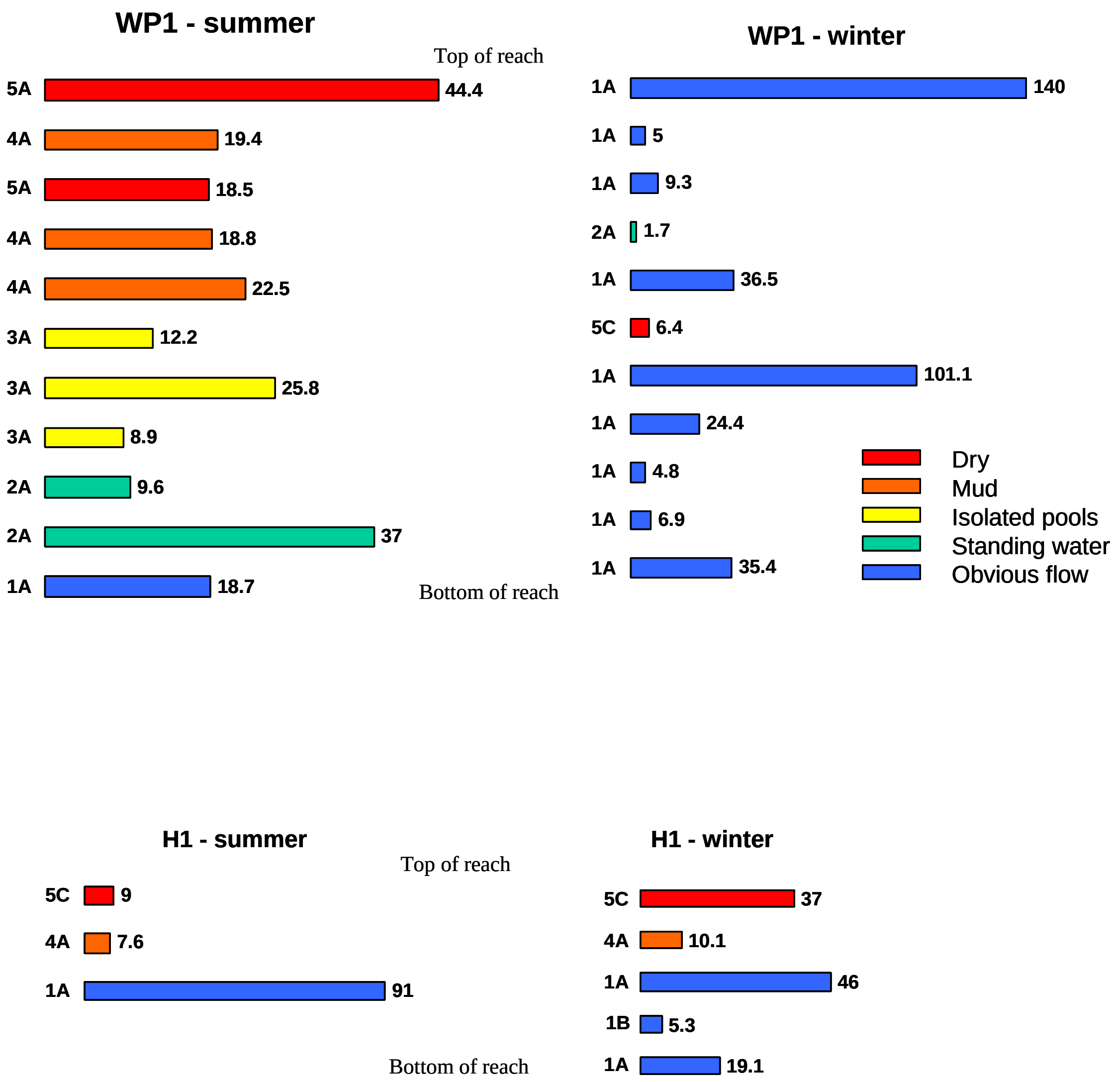
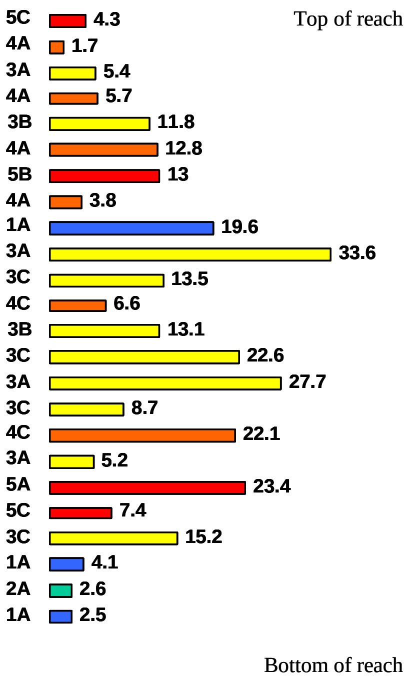


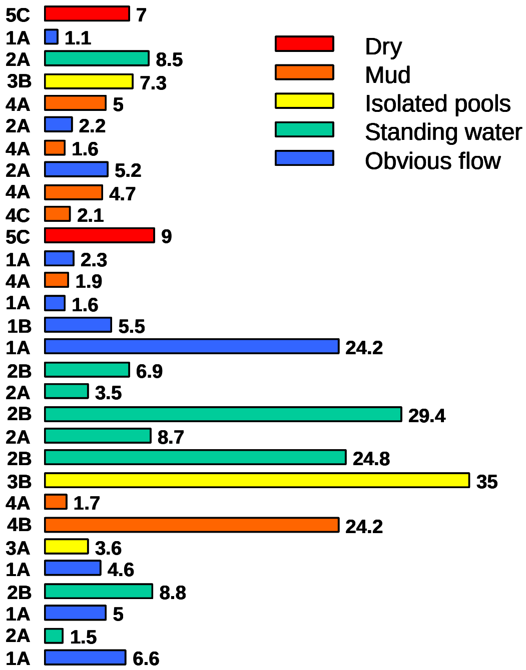
Figure 3.1: Spatial representation of the channel habitat types ("WW/L/HS" REC class) surveyed from the base of the reach (bottom of graph) to the top (top of graph). Codes on the y-axis represent the hydrological and morphological categories used to characterise the reach (see Methods) and the length of the bar and number indicate the length (m) of each code before the physical substrate changed character or the classification changed. Colours indicate the main classification according to hydrological properties.

Figure 3.2: *Next page*. Spatial representation of the channel habitat types ("WW/L/VA" REC class) surveyed from the base of the reach (bottom of graph) to the top (top of graph). Codes on the y-axis represent the hydrological and morphological categories used to characterise the reach (see Methods) and the length of the bar and number indicate the length (m) of each code before the physical substrate changed character or the classification changed. Colours indicate the main classification according to hydrological properties.

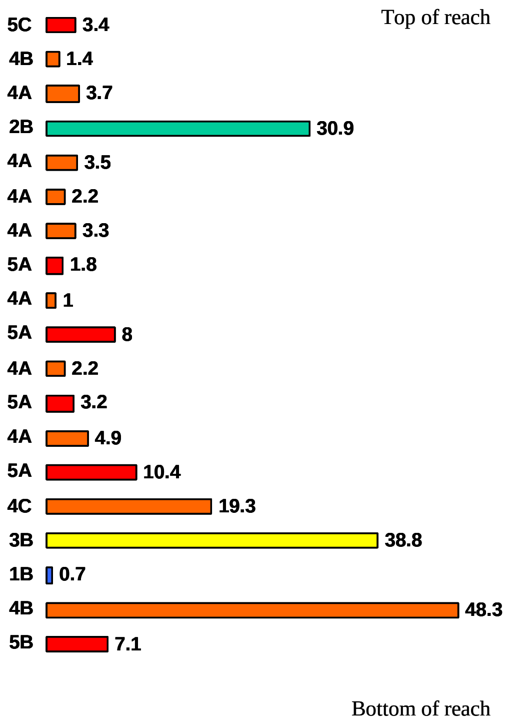
MK2 - summer



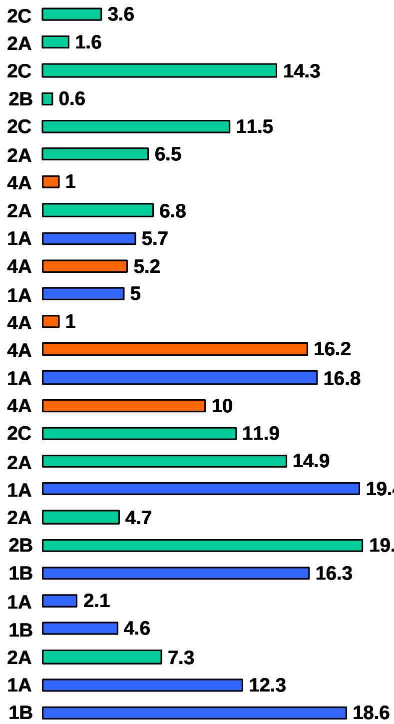
MK2 – winter



MK1 - summer



MK1 - winter



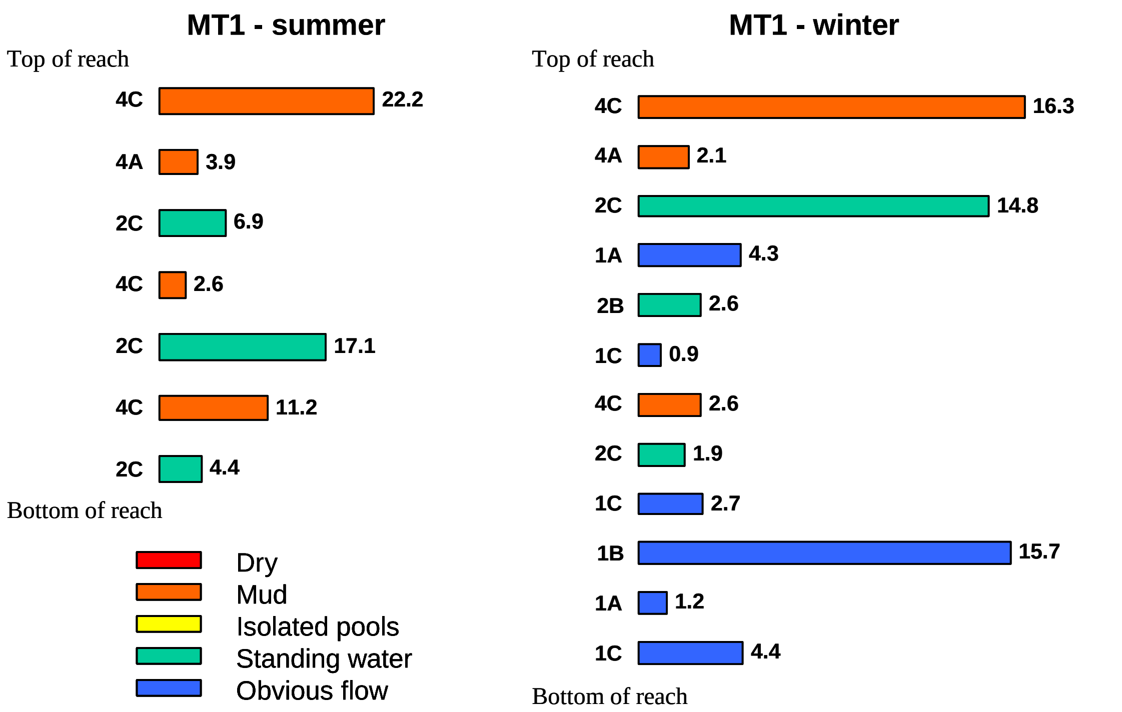


Figure 3.3: Spatial representation of the channel habitat types ("CW/H/VA" REC class) surveyed from the base of the reach (bottom of graph) to the top (top of graph). Codes on the y-axis represent the hydrological and morphological categories used to characterise the reach (see Methods) and the length of the bar and number indicate the length (m) of each code before the physical substrate changed character or the classification changed. Colours indicate the main classification according to hydrological properties.

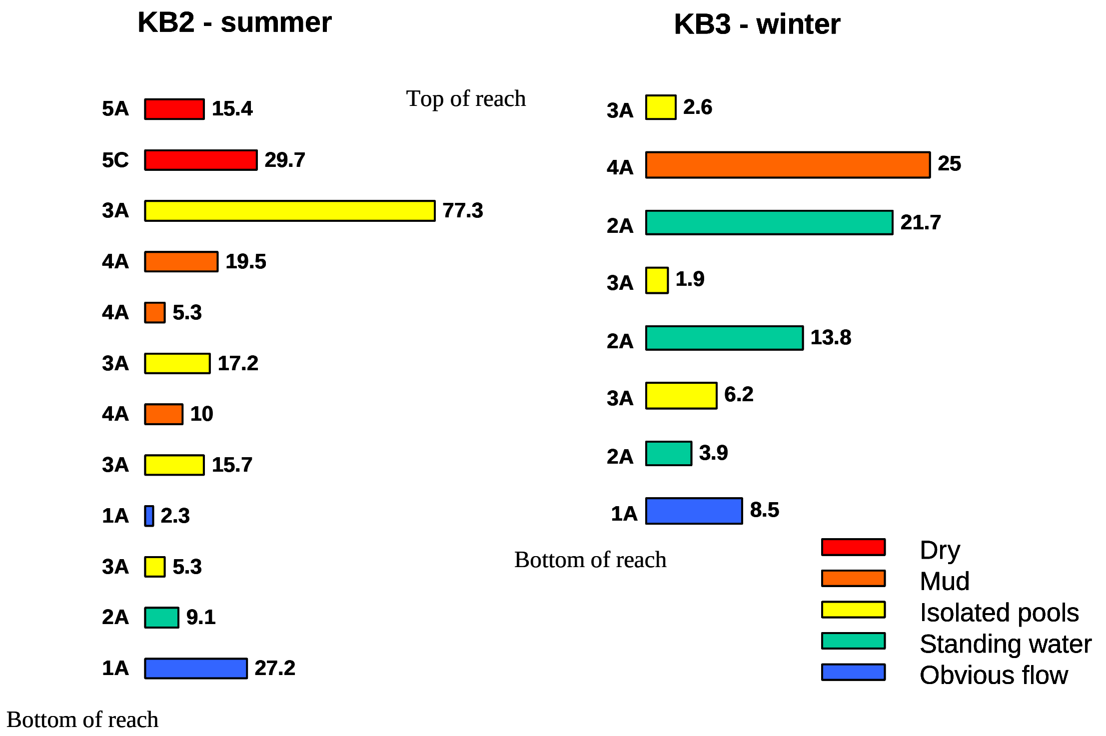


Figure 3.4: Spatial representation of the channel habitat types ("WW/L/SS" REC class) surveyed from the base of the reach (bottom of graph) to the top (top of graph). Codes on the y-axis represent the hydrological and morphological categories used to characterise the reach (see Methods) and the length of the bar and number indicate the length (m) of each code before the physical substrate changed character or the classification changed. Colours indicate the main classification according to hydrological properties.

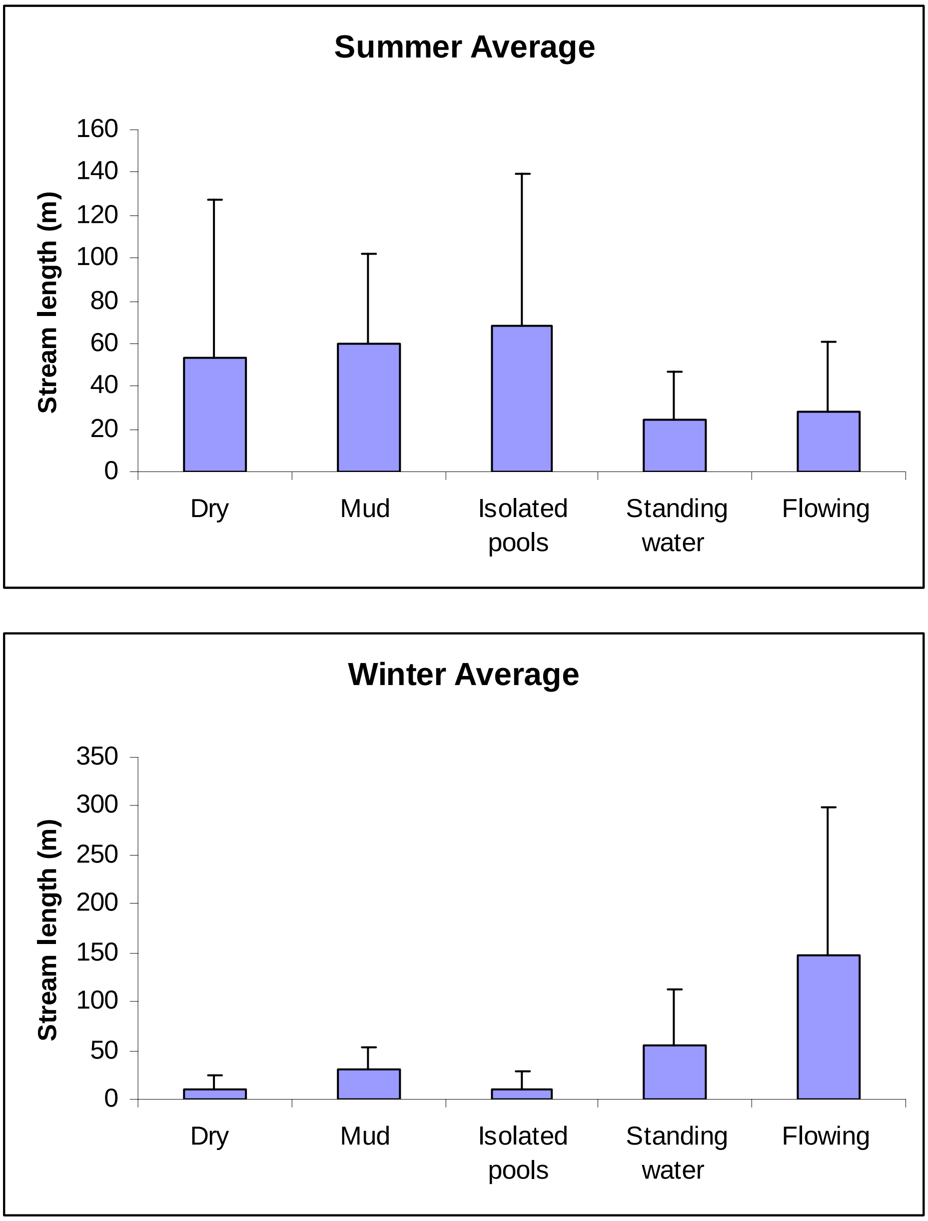
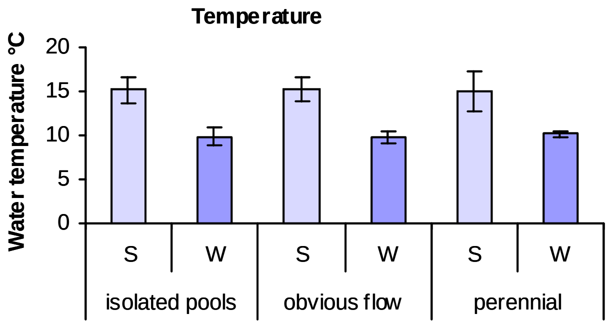


Figure 3.5: Mean length (+ 1SD) of hydrological habitat classes across all non-perennial streams measured from the point where they join a perennial stream and including tributaries in summer (top) and winter (bottom).

a)



b)

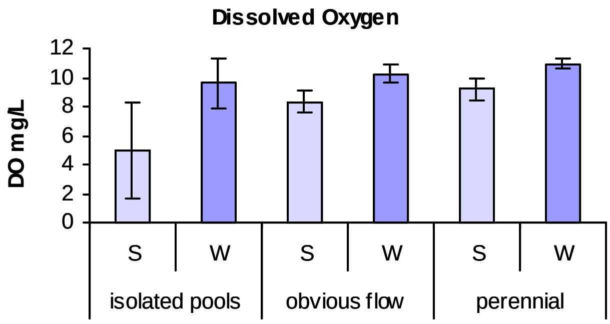


Figure 3.6: Mean (± 1SD) water temperature (a) and dissolved oxygen concentration (b) from spot measurements taken in summer (S) and winter (W) in the different habitat types of headwater streams.

The water temperature (Fig. 3.6a) in the non-perennial stream habitats (isolated pools and obvious flow) and in the perennial streams differed in summer (15ºC) and winter (10ºC) as you would expect, but remained largely the same across the habitat types reflecting the overriding influence of native forest canopy.

Dissolved oxygen was lower in summer, especially in the isolated pools and there was high variation in the DO of the pools at this time (Fig. 3.6b). In some cases, pool habitats were becoming considerably shallower and smaller in summer and crowded with remaining biota (e.g., KB2 where crayfish were seen near the surface of the water creating current with their chelae to pass water over their gills, and where 3 banded kokopu and 5 large crayfish were caught in one kick net scoop of a small pool (0.15 m deep) with DO of 1.8 mg/L).

3.2 Taxa richness

In summer, the trend in these native forest headwater streams was for declining taxa richness in the non-perennial habitats (highest in flowing and lowest in mud habitats) compared to the perennial streams (Fig. 3.7a). However, because the amount of habitat sampled in mud environments was much less (0.09m^2) than the other habitat types (1m^2), care must be taken when comparing the habitat types. Nevertheless, taxa richness was still fairly high in the mud samples (on average 15 in summer and 25 in winter), and the counts of invertebrates were high (see below). Species of sensitive taxa such as Ephemeroptera, Plecoptera, and Trichoptera (EPT, excluding Hydroptilidae (none present)) showed a similar decline from highest numbers of taxa in perennial and least in mud samples in both seasons (Fig. 3.7b). On average, two or three species of EPT taxa were found in mud habitats in summer and winter, and it is thought that the abundance of leaf litter and the shaded environment in native forest affords a moist environment with sufficient oxygen to support these species. The EPT taxa in mud habitats were primarily caddisflies (Trichoptera) such as *Oeconesus maori* and *Pseudoeconesus* sp., but the stoneflies (Plecoptera) *Spaniozerca zelandica* and *Austroperla cyrene*, and mayflies (Ephemeroptera) *Neozephlebia scita* and *Zephlebia nebulosa* were also found.

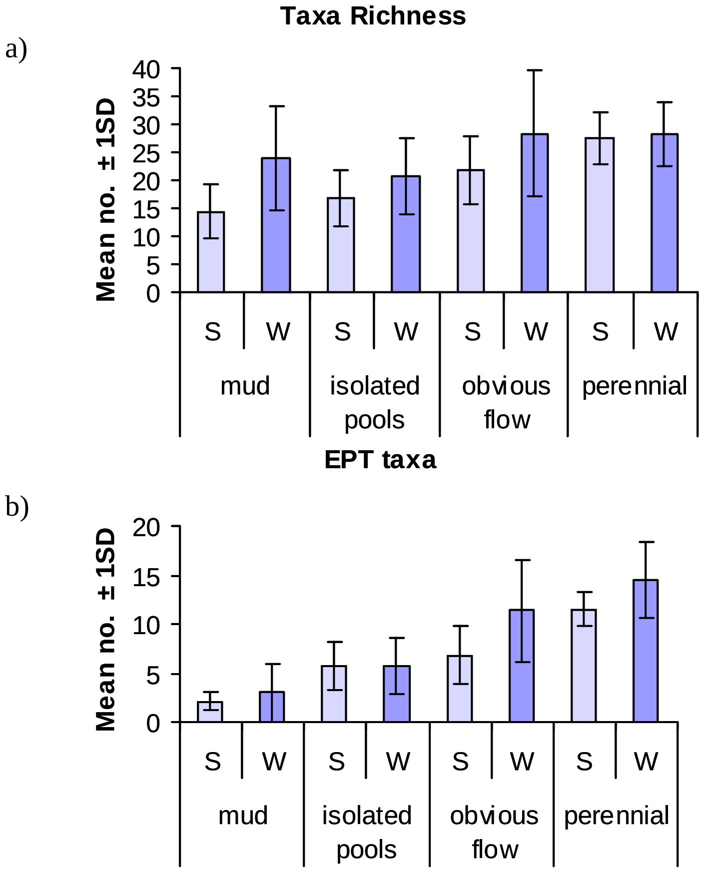


Figure 3.7: Mean taxa richness and EPT taxa richness (± 1SD) of macroinvertebrates recorded from c. 1 m^2 samples of isolated pools, obvious flow, and perennial habitats and from 0.09m^2 samples of mud habitat across the REC classes in summer (S) and winter (W).

3.3 Abundance and composition

Densities of invertebrates were fairly similar across the habitat types (Fig. 3.8), although numbers were extremely high in some mud samples when extrapolated to m^2, presumably as individuals become concentrated into smaller and smaller areas, and because the typical size of the dominant invertebrates is smaller (chironomids, amphipods etc.).

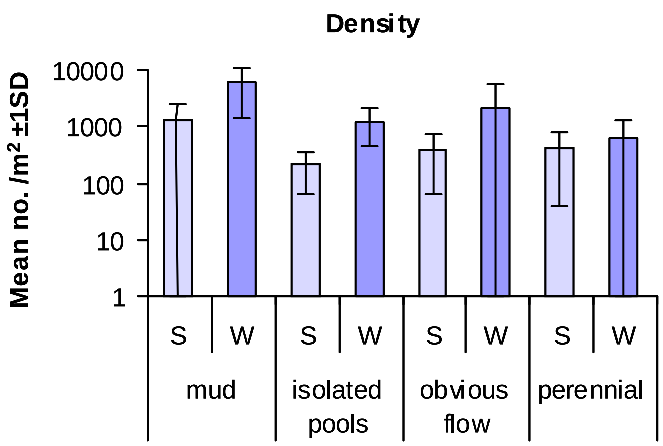


Figure 3.8: Mean density (± 1SD) of macroinvertebrates per m^2 in samples taken in mud, isolated pools, obvious flow, and perennial habitats across the REC classes. Note log scale on y-axis.

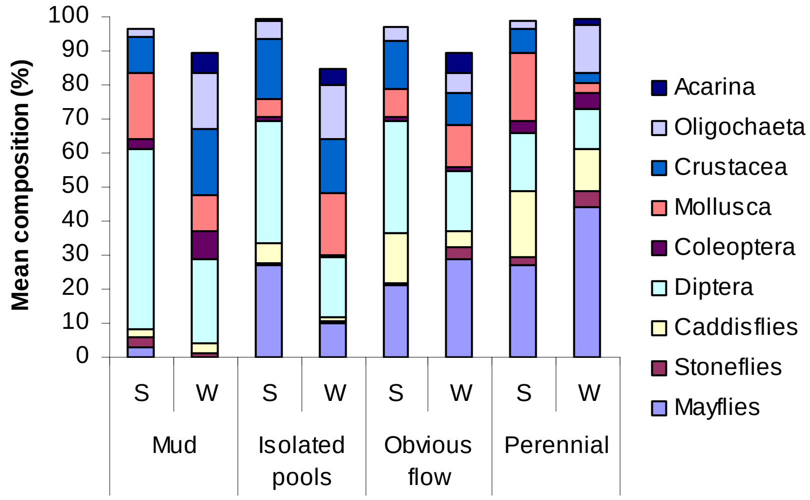


Figure 3.9: Mean relative abundance of the main taxa groups in each of the habitat types in summer (S) and winter (W).

The average relative abundance of the main taxa groups (Fig. 3.9) showed that mud habitats are distinctive from the other habitat types by having fewer mayflies and more dipterans including chironomids. A greater proportion of Crustacea, particularly amphipods, were found in the non-perennial habitats than the perennial habitats. In winter, there was an increase in the relative abundance of mites (Acarina) and worms (Oligochaeta). Mites were virtually absent in summer, but made up 5% of the fauna during winter.

3.4 Contribution of non-perennial habitats to overall biodiversity

The comparison of the total number of species found in each of the habitat types showed that non-perennial headwater streams may have fewer taxa, particularly those considered sensitive to pollution, than perennial streams. However, it is also important to consider the total biodiversity of the stream system. Assessments of these small headwater tributaries have added taxa that were not found in the perennial streams to the total number of species (Table 3.2). In summer, across sites KB2, MK2, MK1, and MT1 there were 7 – 26 additional taxa (average of 18 taxa) recorded in non-perennial but not in perennial habitats, increasing the biodiversity of the system by 74% on average (range 39 – 48 total taxa across sites). In winter the range of additional taxa was even greater (12 – 40, average 25, average 86% more than perennial taxa). For example, the MK2 stream system more than doubled from 32 to 72 total taxa. An average of 5 (28%, summer) and 7 (31%, winter) EPT taxa were added to the overall biodiversity of the stream systems when non-perennial headwater streams were surveyed (Table 3.3). However, it is important to note that the area sampled in perennial habitat ($1m^2$) was less than that sampled in all the non-perennial habitat types when amalgamated ($2.1m^2$) as was done in this comparison. Interrogation of REMS data for perennial native forest sites near where these samples were taken may provide interesting data to compare with the records for these non-perennial streams.

Table 3.2: The total biodiversity of each site from the perennial stream and including the non-perennial stream habitats sampled. Additional taxa are the number of taxa that add to the total biodiversity of a catchment when the non-perennial stream network is included for these sites in the Waikato region. Sites without appropriate nearby perennial streams were not included in this analysis.

Season	Site code	Perennial stream taxa richness	Total taxa	Additional taxa
Summer	KB2	22	48	26
	MK2	25	44	19
	MK1*	25	45	20
	MT1	32	39	7
Mean				**18**
Winter	KB3	34	46	12
	WP1§	22	50	28
	MK2	32	72	40
	MK1*	47	64	17
	MT1	25	52	27
Mean				**25**

* Perennial stream used was MK2. § Upstream catchment of perennial stream largely in pasture.

Table 3.3: The EPT taxa of each site from perennial streams and including the non-perennial stream habitats sampled. EPT taxa are generally considered sensitive taxa and the additional EPT taxa shows the number of these taxa that would be added to the total biodiversity of a catchment when the non-perennial stream network is included for these sites in the Waikato region. Sites without appropriate nearby perennial streams were not included in this analysis.

Season	Site code	Perennial stream EPT taxa	Total EPT taxa	Additional EPT taxa
Summer	KB2	14	9	5
	MK2	19	13	6
	MK1	18	13	5
	MT1	15	12	3
Mean				**5**
Winter	KB3	18	15	3
	WP1	26	17	9
	MK2	26	17	9
	MK1	25	17	8
	MT1	15	9	6
Mean				**7**

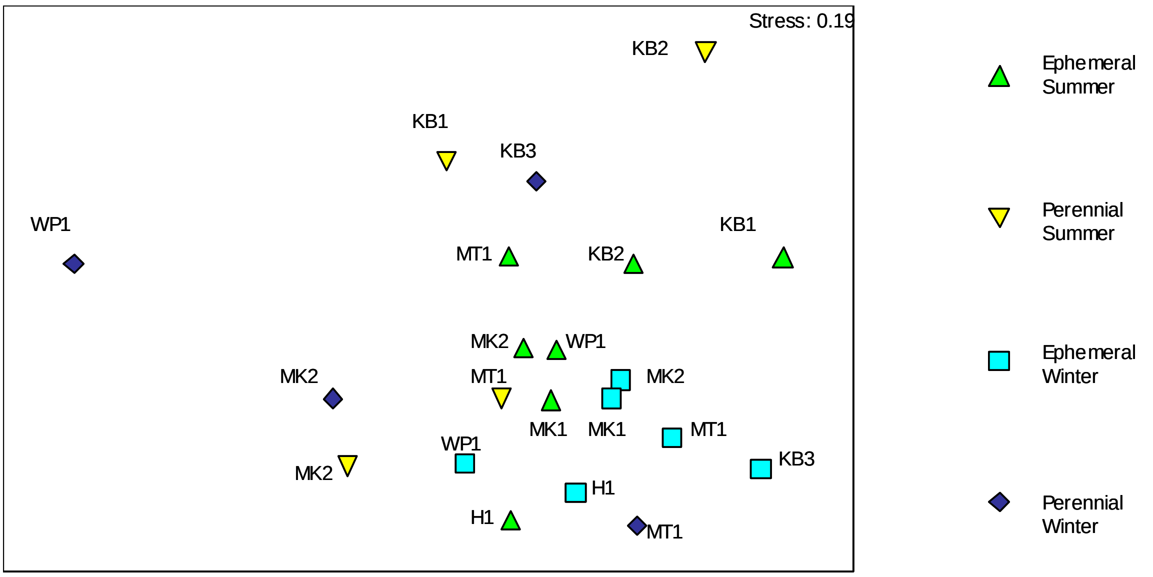


Figure 3.10: Ordination based on macroinvertebrate community species presence or absence in the non-perennial (mud, pools, flowing) and perennial habitats in summer and winter.

A comparison of perennial sites with all non-perennial habitats combined in summer and winter from an ordination (PRIMER version 5) based on the presence and absence of taxa using Bray-Curtis distance measures (Multi-dimensional scaling (MDS) plot, Fig. 3.10) shows that in two-dimensional space, the non-perennial sites are loosely grouped together, although the stress is high (0.19). ANOSIM analysis found that taxa in non-perennial habitats were significantly different from those in perennial streams ($p < 0.01$) and the taxa occurring in summer and winter were different ($p < 0.01$). WP1 (perennial) appears as an outlier as this site drained a largely pastoral catchment and was only sampled once (in winter).

SIMPER analysis was performed on the presence and absence data (PRIMER version 5). Some of the species that occurred more often in the non-perennial headwater habitats than the perennial sites included *Oeconesus maori*, Sphaeridae, *Zelandotipula*, *Zephlebia nebulosa*, *Zephlebia borealis* and crayfish (*P. planifrons*), while species such as *Deleatidium*, *Coloburiscus humeralis*, and *Triplectides dolichos* occurred more frequently in perennial habitats. Overall differences between the summer and winter samples were characterised by increased occurrence of *Coloburiscus humeralis*, *Zephlebia* spp., Acarina, and Ostracoda in winter. Crayfish were more common in summer possibly due to a concentration effect or because they were more active during warmer weather.

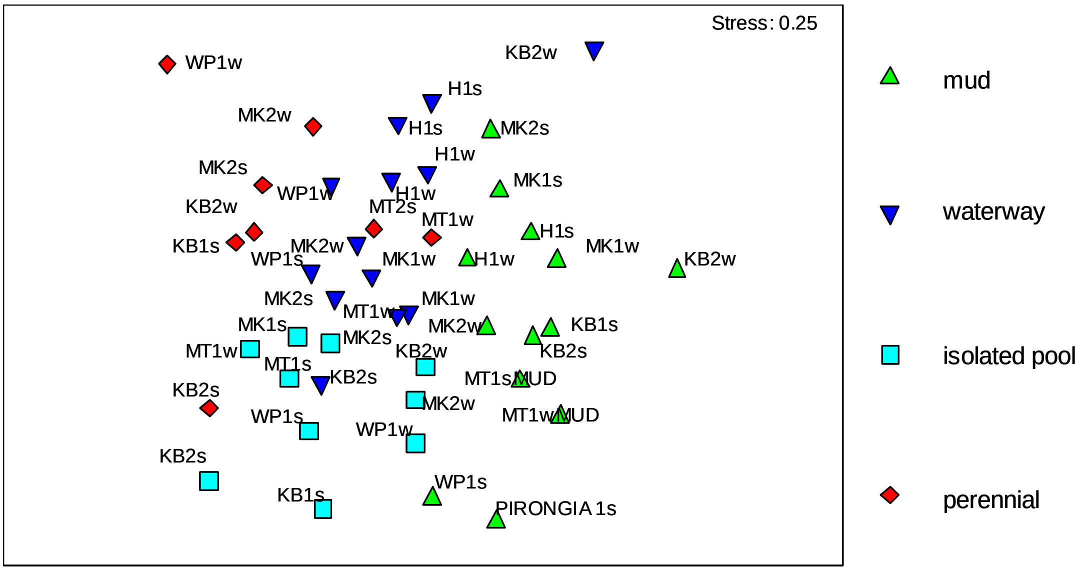


Figure 3.11: Ordination of presence and absence data of macroinvertebrate species recorded in non-perennial (mud, waterway, isolated pool) samples and perennial samples. Waterway describes flowing non-perennial habitat.

The relationship of the different taxa of communities found in non-perennial habitat to perennial habitat (presence and absence data, PRIMER version 5) shows that the sites were grouped by different habitat types (stress 0.25, Fig. 3.11), although the stress is high in two dimensional space. ANOSIM analysis found significant differences between the habitat types overall ($P = 0.001$) and pairwise tests showed that the only non-significant difference was between the perennial and the non-perennial flowing habitat ($P = 0.118$).

Species that characterised the mud group included, *P. antipodarum*, *Polypedilum* spp., *Molophilus* sp., and *Zelandotipula*. Pools were characterised particularly by the chironomid species (*Paucispinigera*, *Polypedilum*, *Tanypodinae*) and tubificid worms, crayfish, and *Polyplectropus* sp. Flowing non-perennial waterways were distinctive from the other types due to the presence of *Zephlebia nebulosa* and *dentata*, and *Orthopsyche fimbriata*. Perennial habitats were characterised by a high frequency of occurrence of the mayflies *Zephlebia dentata*, *Deleatidium*, and *Coloburiscus humeralis*, by the caddisfly *Triplectides dolichos* and chironomids Tanypodinae and *Stictocladius*.

4. Conclusions

Aquatic macroinvertebrate taxa found in non-perennial headwater habitats differed from those in nearby perennial streams in forested Waikato stream systems. The communities were particularly different when streams become isolated pools or mud at the top of catchments. In summer, the amount of flowing stream habitat was reduced and this appeared to result in a different configuration of taxa and fewer taxa in summer than winter. Inclusion of non-perennial stream sampling could more than double the overall estimate of biodiversity within headwater stream systems, as a substantial number of taxa not recorded in the perennial streams occurred in non-perennial habitats (average of 18 and 25 additional taxa in summer and winter, respectively). This information provides a clear imperative for considering non-perennial habitats in biodiversity policies and assessments of environmental effects.

5. References

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6. Appendix 1: Total taxa list.

Order	Species
Megaloptera	*Archichauliodes diversus*
Ephemeroptera	*Acanthophlebia cruentata*
	Arachnolocolus phillipsi
	?Austroclima
	Austroclima sepia
	?Austronella planulata
	Deleatidium spp.
	Coloburiscus humeralis
	Ichthybotus hudsoni
	Isothraulus abditus
	Mauiulus luma
	?Mauiulus sp.
	Neozephlebia scita
	Nesameletus sp.
	Tepakia caligata
	Zephlebia borealis
	Zephlebia turberculata
	Zephlebia nebulosa
	Zephlebia spp.
	Zephlebia versicolor
	Zephlebia dentata
Plecoptera	*Austroperla cyrene*
	Acroperla trivacuata
	Megaleptoperla diminuta
	Megaleptoperla sp.
	Plecoptera indet.
	Spaniocerca zelandica
	Stenoperla prasina
	Zelandobius confusus grp
	Zelandoperla decorata
Trichoptera	*Edpercivalia* sp.
	Helicopsyche spp.
	Hydrobiosidae
	Hydrobiosis umbripennis grp
	Hydrobiosella mixta
	Hydrochorema crassicaudatum
	Oecetis unicolor
	Oeconesus maori
	Olinga feredayi
	Orthopsyche fimbriata
	Orthopsyche thomasi
	Philorheithrus sp.
	Plectrocnemia maclachlani
	Polyplectropus sp.

Order	Species
Trichoptera	*Pseudoeconesus* sp.
	Psilochorema sp.
	Psilochorema donaldsoni
	Psilochorema mimicum
	Pycnocentria sp.
	Pycnocentrodes sp.
	Tiphobiosis sp.
	Triplectides obsoletus/dolichos
	Triplectidina
	Zelandoptila moselyi
Diptera	*Aphrophila* sp.
	Austrosimulium sp.
	Chironomus sp.
	Chironomini sp.
	Ceratopogonidae (Ceratopoginae)
	Ceratopogonidae (Forcipyimiinae)
	Corynoneura sp.
	Cricotopus sp.
	Culex sp.
	Diptera indet.
	Empididae
	?Ephydridae
	Eriopterini group
	Eukiefferiella sp.
	Harrisius pallidus
	Hexatomini
	?Kaniwhaniwhanus sp.
	Limoniinae
	Limonia nigrescens
	Macropelopiini sp.
	Molophilus sp.
	Muscidae
	Naonella forsythi
	Nothodixa sp.
	Orthocladiinae
	Paradixa sp.
	Paralimnophila spp.
	Paralimnophila skusei
	Paucispinigera sp.
	Polypedilum spp.
	Pirara sp.
	Psychodidae spp.
	Sciomyzidae
	Stempellina sp.
	Stictocladius nr SO4.
	Stratiomyidae

Order	Species
Diptera	Tabanidae
	Tanypodinae
	Tanytarsus
	Tanyderidae
	Tipulidae
	Thaumaleidae
	Zelandotipula sp.
Hemiptera	*Microvelia* sp.
Odonata	*Antipodochlora braueri*
	Anisoptera sp.
	Xanthocnemis zealandica
	Austrolestes colensonis
Coleoptera	?Curculionidae larva
	Elmidae
	Hydraenidae (adult)
	Hydrophilidae
	Ptilodactylidae
	Scirtidae
Mollusca	*Ferrissia*
	Potamopyrgus antipodarum
	Sphaeriidae
Oligochaeta	Lumbriculidae
	Enchytraeidae
	Eiseniella sp.
	Naididae
	?Phreodrilidae
	Tubificidae
Other	*Paratya*
	Ostracoda
	Amphipoda
	Paracalliope fluviatilis
	Taltridae
	Acarina
	Flatworm
	Paranephrops planifrons
	Hirudinea
	Kempynus
	Collembola
	Ostracoda
	Copepoda
	Nematoda
	Nemertea