The littoral macroinvertebrate fauna of 17 dune lakes on the Aupouri Peninsula, Northland

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Cover photo: Te Paki Dune Lake, Aupouri Peninsula (*photo by Olivier Ball, NorthTec*).

The littoral macroinvertebrate fauna of 17 dune lakes on the Aupouri Peninsula, Northland

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Contents

1. Executive summary

1. The Northland Regional Council has sought advice from NorthTec Environmental Sciences Department on the nature of the littoral invertebrate fauna from a range of Aupouri Peninsula dune lakes and whether such information can be used to indicate the health of these lakes. This report, funded by FRST Medium Envirolink Grant 681-NLRC-96, outlines the findings of our study.

2. The macroinvertebrate fauna in the littoral zones of 17 lakes on the Aupouri Peninsula was surveyed in November 2008. Sampling was undertaken at four sites on each lake by sweep-netting in a standardised manner. Water samples for nutrient and other chemical analyses were collected simultaneously at most of the lakes by Northland Regional Council personnel. The principal land-use/vegetation cover of the lake catchments was sand dune-scrub (3 lakes), plantation forest (4), pasture (8) and a combination of exotic forest and pasture (2). The lakes varied in trophic status from oligotrophic to supertrophic.

3. In total, 69 invertebrate species were found, 12 to 32 species per lake. Insects and molluscs (snails and bivalves) were the numerically dominant groups. Diptera (especially chironomid midges), Hemiptera (water boatmen and backswimmers), and Odonata (dragonflies and damselflies) were the dominant insect orders. Coleoptera (beetles), Trichoptera (caddisflies) and Lepidoptera (moths) were also well represented. Other non-insect groups present were leeches, flatworms, segmented worms, sponges and mites. Crustaceans were poorly represented in samples.

4. Some of the more abundant species were widespread with 3 species (a dragonfly *Hemicordulia australiae*, a damselfly *Xanthocnemis zealandica*, and the midge *Chironomus* sp.) being found in all 17 lakes. Waterboatmen (*Diaprepocoris zeaalandiae* and *Sigara* spp.) were found in 16 of the lakes while a further four species occurred in 15 lakes. Fourteen species were found in only one lake.

5. A previously unrecorded species of isopod (Crustacea: Sphaeromatoidea) was found in Lake Ngakeketa South and larvae of an introduced spongillafly (Neuroptera: Sisyridae), first recorded in New Zealand near Kerikeri in 1998, were taken in two lakes. Larvae of a poorly known endemic mosquito (*Coquillettidia*) were also found in two lakes but could not be identified to species as larvae of the two known species have not been described. However, they were likely the larvae of *C. iracunda*, which is known from Northland.

6. A feature of the lake faunas was the commonness of recent arrivals. These were of two broad types; self-introduced insects (mainly dragonflies) and species accidentally or intentionally introduced by human activities (mainly snails). All five dragonfly species found are strong-flying species and at least four of them are believed to have arrived in New Zealand within the last 100 years. One species, *Tramea loewii*, is known only from the Aupouri Peninsula where it was first seen in 2005. The Australian damselfly *Ischnura aurora* was found in two lakes. The whirligig beetle *Gyrinus convexiusculus* may also be self-introduced from Australia. Three introduced and three endemic gastropod species (snails) were found, two of the introduced species (*Physa acuta* and *Pseudosuccinea columella*) being most widespread. The third introduced snail *Planorbella* sp. appears to be a very recent introduction and was found in three of the Sweetwater lakes.

7. Analyses of invertebrate community composition indicated considerable variation among lakes in both species composition and relative abundance of species. Relationships between community structure and surrounding land-use/vegetation cover, lake trophic status and measured physico-chemical parameters were either weak or absent. The most distinctive lake fauna was that of Te Kahika, which was species-poor, lacked molluscs and included few hemipterans or beetles. Its distinctiveness can almost certainly be attributed to its low pH (<4) and associated chemical factors.

8. The littoral faunas of the most eutrophic lakes (Bulrush, Waiparera and West Coast Rd) were dominated numerically by Chironomini (as was “oligotrophic” Te Kahika) and had small populations of molluscs. In contrast, snails (*Potamopyrgus antipodarum*) dominated in two other eutrophic lakes (and one mesotrophic lake) while the relative abundance of chironomids was low. High relative abundance of Chironomini can be indicative of nutrient enriched conditions. Results from Lake Te Kahika show that this is not always the case. Likewise, their presence in low densities was not necessarily indicative of non-enriched conditions. Because a strongly vegetated littoral zone is a highly productive environment and a depository of much organic matter, it may be “effectively eutrophic” regardless of conditions in the open water. Hence, the littoral fauna appears to be of limited value as an indicator of trophic status for use in management. Much of the variation in faunal composition among lakes on the Aupouri Peninsula is likely to be determined by lake or site-specific habitat features that were not a focus of the present study.

2. Introduction

The littoral zone of a lake is the interface between the land and the water. This ecotone can be a highly productive part of a lake supporting extensive emergent and submergent vegetation, large quantities of decaying organic matter, a diverse invertebrate community and populations of fish, amphibians and birds. It is also where groundwater, surface runoff and nutrients pass into the lake and can have the important ecological role of intercepting nutrients and minimising their release into the open water (Rowe 2004). Where stock, notably cattle have unrestricted access to the littoral zone they can also be a significant contributor of nutrients and cause physical damage to the lake littoral and its biological communities. Fencing of lakes can ameliorate this problem as seen, for example, at Bulrush Lake on the Aupouri Peninsula. Appreciation of the nutrient absorbing function of littoral vegetation (Wetzel 1993) has led to the development of artificial wetlands to protect water quality and the integrity of lake ecosystems (e.g., Hammer 1989, Sukias & Tanner 2004).

Littoral and benthic invertebrates have significant roles in the food webs of lakes. They feed on living and decaying plants, algae, fine detritus and each other, and are eaten in turn by fish and birds. The winged adult stages of various insects with aquatic larvae also contribute to the food webs of terrestrial ecosystems as do those living in streams and rivers. Invertebrates also have the potential to be indicators of water quality and "lake health" and therefore as environmental monitoring agents as in running waters. However, they appear to have rarely been used for this purpose, especially in New Zealand.

Ecological research on the littoral zone of New Zealand lakes has focussed primarily on the composition and structure of plant communities, and more recently on what influences their distribution, abundance and productivity (de Winton & Schwartz 2004). Whereas the general nature of the invertebrate fauna of lakes is moderately well known in New Zealand (Winterbourn & Lewis 1975, Kelly & McDowall 2004) few studies have documented the composition and abundance of the littoral or weed bed-associated fauna of individual lakes in a systematic manner. The main exceptions are three moderately large lakes in the South Island: Wanaka, Coleridge and Alexandrina. The Alexandrina and Wanaka studies targeted the invertebrate communities of weed beds (Talbot & Ward 1987, Kelly & Hawes 2005), whereas the Coleridge study considered a stony shore (James *et al*. 1998, 2000). Recent studies in large assemblages of Canterbury lakes have investigated the composition of the littoral invertebrate fauna in relation to the presence and absence of trout (Wissinger *et al*. 2006) and how permanence of water affects invertebrate communities (Wissinger *et al*. 2009). Weatherhead & James (2001) also investigated the distribution of invertebrates in the littoral zone of nine large New Zealand lakes, only three of which were in the North Island and none north of Taupo.

The composition of aquatic macrophyte communities in Northland lakes is well known as a result of two extensive surveys by NIWA scientists in the last decade (Champion *et al*. 2002, Wells *et al*. 2007). In contrast, knowledge of their invertebrate faunas is limited. A survey of western coastal dune lakes of the North Island (Cunningham *et al*. 1953) included several Northland lakes, including two (Waiparera and Ngatu) on the Aupouri Peninsula. The littoral fauna was not investigated and very limited benthic sampling recovered only three taxa in very low numbers. The larger invertebrates seen in some lakes during macrophyte surveys are included in the reports of Champion *et al*. (2002) and Wells *et al*. (2007).

3. The lakes: setting, physical and biological features

The Aupouri Peninsula is a narrow strip of land about 100 km long at the northern tip of New Zealand. Most of the land is low-lying (< 100 m) although hills exceeding 300 m occur in the far north. Numerous sand dune lakes are present on the peninsula, 17 of which were investigated in the present study (Figure 1, Table 1). All were below 94 m a.s.l. and ranged in area from about 1.5 to 103 hectares. However, only two (Waiparera and Ngatu) exceed 50 ha. Maximum depth of the lakes ranges from 1.5 to 8.5 m, although this (and area) may vary a little seasonally depending on rainfall patterns. Lakes are of two types: basin lakes in hollows or between dunes, and dammed valley lakes, which tend to be long and narrow, formed where streams have been blocked by drifting sand. Most lakes are <5000 years old and some are as recent as 150 years (Collier 1996).

The principal land cover in the lake catchments is either pasture or exotic plantation forest, although sand dunes and native scrub dominate the catchments of the three northernmost lakes (Appendix 1). *Pinus radiata* was first planted in the 1970s and exotic forest now covers about 25% (3000 ha) of the peninsula (Collier 1996). Many of the lakes, especially those in plantation forest have a well-developed band of riparian native scrub-forest that includes manuka and kanuka. The littoral zone of most lakes is dominated visually by often extensive beds of reeds and rushes with *Eleocharis* and *Baumea* species abundant.

The lakes are characterised by soft waters, moderately high sodium chloride levels reflecting their proximity to the sea, and warm temperatures that can exceed 25^{o}C. Lake trophic condition was assessed using data collected from 2005 to 2007 (NRC 2008) by calculating the trophic level index (TLI) of Burns *et al*. (2000). Measurements of secchi disk depth, total nitrogen, total phosphorus and chlorophyll concentrations of lake water are combined with the resultant index value indicating trophic state. Of the 17 lakes, one (Te Kahika) was considered to be oligotrophic, seven mesotrophic, seven eutrophic, and two supertrophic. However, recalculation of the TLI using NRC data for September and November 2008 and March 2009 (the months surrounding our survey) indicated differences in trophic status of some lakes (Table 1). It should also be noted that Te Kahika is an unusually clear lake with a pH as low as 3.6 and high concentrations of aluminium and sulphate possibly originating from mineral springs (NRC 2005, NRC unpublished survey data). Its clarity and perceived oligotrophic status is undoubtedly associated with its acidic nature.

Aquatic weeds are a major threat to Northland's lakes and their spread and occurrence on the Aupouri Peninsula in the last decade have been documented by extensive surveys (Champion *et al*. 2002, Wells *et al*. 2007). *Ceratophyllum demersum* (hornwort) and the oxygen weeds *Egeria densa* and *Lagarosiphon major* are notable pest species and the aggressive bladderwort *Utricularia gibba* has spread to many lakes (10 of those we surveyed) since 2004 (NRC 2008). Eight species of introduced fish have been reported from Northland lakes of which the mosquito fish *Gambusia affinis* is most widespread. It inhabits the littoral zone of dune lakes, sometimes in great abundance and is a potential competitor of the native common bully *Gobiomorphus cotidianus*.

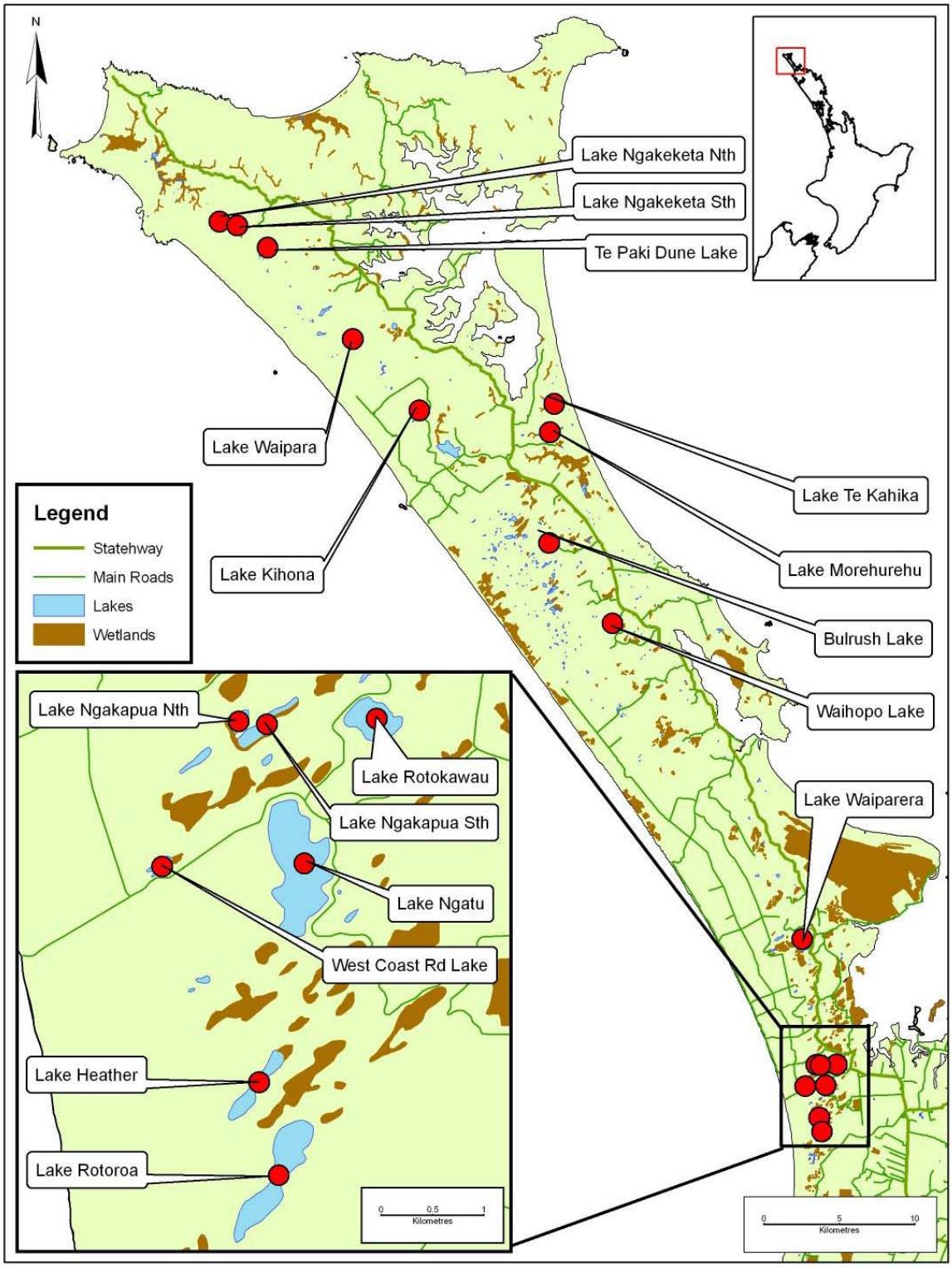

Figure 1. Map of the Aupouri Peninsula showing locations of the 17 lakes surveyed.

Table 1. Physical, chemical, catchment and trophic characteristics of the 17 Aupouri Peninsula lakes studied. Lake depth and area fluctuate depending on rainfall and are rounded to the nearest 0.5 m and ha, respectively. Conductivity (Cond.) and pH are average values using combinations of data from September 2008, November 2008, and March 2009 (NRC unpublished data). Trophic state is based on the Trophic Level Index of Burns *et al*. (2000), as reported by NRC (2008 and unpublished data), and for September 2008–March 2009 (in parentheses) (NRC unpublished data). Sources of other data are Wells *et al*. (2007) and our own observations. - = no data.

Lake	NRC Site#	Depth(m)	Area(ha)	Land-use	pH*	Cond. (µS cm^{-1})*	Trophic state**
Ngakeketa North	108620	7	13	Scrub	7.1 (n=2)	222 (n=2)	E (E)
Ngakeketa South	100996	8.5	12.5	Scrub	7.2 (n=1)	250 (n=1)	E (E)
Te Paki Dune	108230	2.5	2	Scrub	6.7 (n=2)	156 (n=2)	M (M)
Waipara	108240	5	1.5	Pine	5.9 (n=3)	150 (n=3)	M (E)
Te Kahika	101909	11	18	Pine	3.8 (n=3)	691 (n=3)	O (O)
Kihona	101907	8.5	8	Pine	-	-	E (M)
Morehurehu	101908	14	36	Pine	6.1 (n=3)	310 (n=3)	M (M)
Bulrush	101910	2	5	Pasture	-	-	S (H)
Waihopo	108232	3	3.5	Pasture	6.5 (n=3)	219 (n=3)	E (E)
Waiparera	101033	6	103	Pasture	7.2 (n=3)	250 (n=3)	E (S)
Rotokawau	106734	3	14	Pasture	6.5 (n=2)	136 (n=2)	E (M)
Ngakapua North	108242	8	2	Pine/Pasture	6.3 (n=3)	153 (n=3)	M (E)
Ngakapua South	101913	5	6.5	Pasture	6.2 (n=3)	158 (n=3)	E (E)
Ngatu	101032	6.5	50	Scrub/Pasture	6.5 (n=2)	173 (n=2)	M (E)
West Coast Road	108707	1.5	1.5	Pine/Pasture	-	-	S (S)
Heather	101031	5.5	8	Pasture	6.6 (n=2)	176 (n=2)	M (E)
Rotoroa	100425	8	26.5	Pasture	6.2 (n=2)	258 (n=2)	M (E)

*n = number of data points used to obtain the mean

**O = oligotrophic, M = mesotrophic, E = eutrophic, S = supertrophic, H = hypertrophic

4. Methods

Fieldwork was carried out between 16 and 22 November 2008. At each lake, samples were obtained at four sites approximately equidistant from each other on the lake perimeter. Access to a majority of sites was by kayak. Invertebrates were collected by sweeping submerged vegetation and the sediment beneath it with a hand net (mesh size 0.5 mm). Area sampled at each site was as close to 3 m^2 as possible. Samples were transferred to zip-lock bags in the field and preserved with alcohol to give a final concentration of approximately 70%.

Invertebrates were sorted from samples in the laboratory, and transferred to a Bogorov tray for identification and counting at 10X magnification. In a few instances sub-samples representing a known proportion of the total sample of very abundant chironomid larvae and the snail *Potamopyrgus* were counted. Insects were identified using Winterbourn *et al*. (2006), Rowe (1987) (Odonata), and Young (1962) and Buckley & Young (2008) (Corixidae and Notonectidae). Molluscs were identified with Winterbourn (1973) and NIWA (2007), and crustaceans and oligochaetes using Chapman & Lewis (1976) and Brinkhurst (1971), respectively.

Water samples for chemical analysis and measurement of chlorophyll concentration were obtained concurrently by Emma Simpson (NRC) as part of council's quarterly lake sampling program. A photographic record of all sites was made.

Invertebrate data for each of the 4 sites on a lake were pooled to give a single data set representing a total area of ~12 m^2 for each lake. Total abundance, species richness, abundance of individual taxa and their relative abundances (%) were calculated for each lake. Similarities among lake faunas and their relationship to physico-chemical factors and land-use were explored with cluster analysis (average linkage) and Bray-Curtis ordination using PC-ORD software (McCune & Mefford 1999). Sorensen (Bray-Curtis) distance (D) was used as a measure of similarity ($D = 2W/A + B$), where A and B are the sums of abundances (or numbers of taxa) in the samples being compared, and W is the sum of shared abundances (or numbers of taxa). For cluster analyses based on presence-absence data, all species were used, but some groups were combined for relative abundance ordination as not all individuals could be identified to species level. Thus, *Ischnura* was combined with *Xanthocnemis*, *Sigara* and Tubificidae were considered to be single taxa, and chironomids were grouped at the subfamily (Tanypodinae, Orthocladiinae) or tribal (Chironomini, Tanytarsini) levels.

To explore relationships between lake community composition and environmental factors, Spearman rank correlation was used to test the order of lakes on axes 1 and 2 of the relative abundance ordination with land-use and other physico-chemical factors.

5. Results and discussion

5.1 Richness and abundance of littoral invertebrate fauna

A diverse invertebrate fauna was found in the 17 lakes surveyed on the Aupouri Peninsula. Sixty nine species were identified in total with numbers of species per lake ranging from 12 (Te Kahika) to 32 (Ngakapua North) (Figure 2). Overall abundance of invertebrates also varied widely from 195 to 4622 per standard collection. Greatest abundance was found in Rotoroa and lowest in Morehurehu (Figure 3).

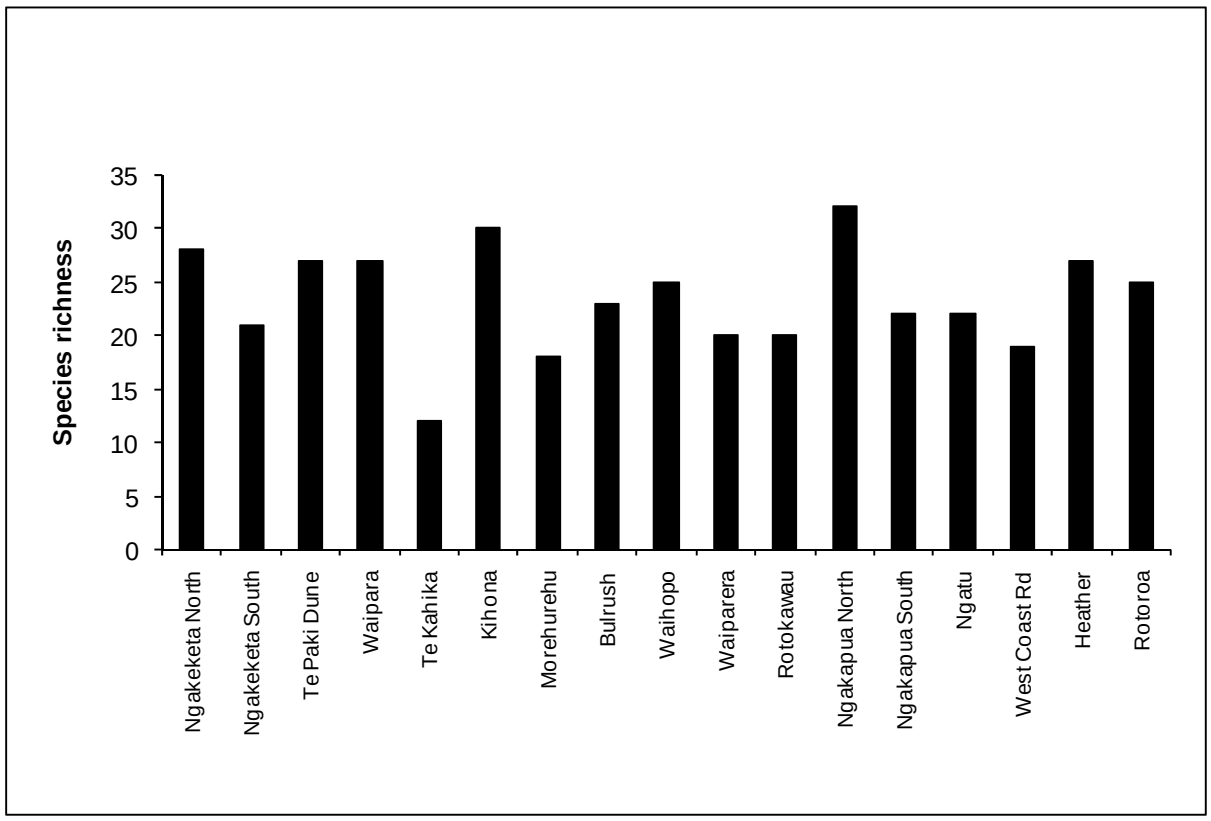

Figure 2. Numbers of macroinvertebrate species found in the 17 lakes. Lakes are arranged in order from north to south.

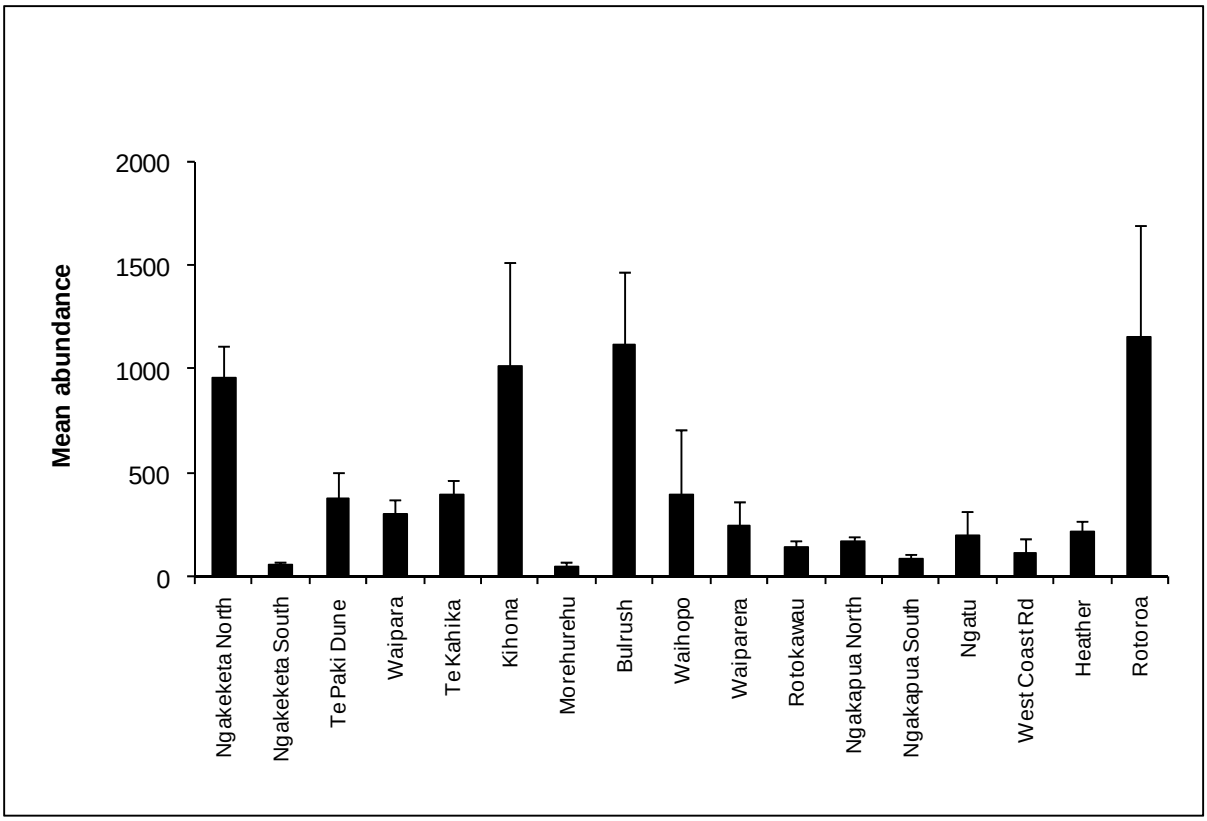

Figure 3. Abundance of macroinvertebrates in ~12m^2 samples per lake (mean +1SE, n = 4). Lakes are arranged in order from north to south.

A full list of species found and their distributions are given in Appendix 2. The most diverse groups were insects and molluscs with 46 and seven species, respectively. The most diverse insect groups were the Diptera (true flies) (15 species), Coleoptera (beetles) (13 species) and Odonata (dragonflies and damselflies) (8 species). Of the seven species of mollusc, six were gastropods (snails) and one was a bivalve. Other insect orders represented were the Hemiptera (bugs), Trichoptera (caddisflies), Lepidoptera (moths) and Neuroptera (spongillaflies). Non-insect groups other than molluscs were leeches, flatworms, segmented worms, sponges and mites. Crustaceans were poorly represented in littoral samples.

5.2 Taxonomic account

With two exceptions (*Paroxyethira* and *Sigara*), all identified species belonged to separate genera. Therefore, to simplify reading, their full names are given on first mention and thereafter only generic names are used.

Odonata (dragonflies and damselflies)

Species of Odonata were prominent members of the fauna in all lakes and included the largest invertebrates found. Nymphs of all species are predators on other aquatic invertebrates and possibly tadpoles and small fish. Of the 8 taxa recorded, 5 were dragonflies (Anisoptera) and 3 were damselflies (Zygoptera). *Hemicordulia australiae* was the most abundant dragonfly and was found in all 17 lakes. The other four dragonflies *Aeshna brevistyla*, *Tramea loewii, Diplacodes bipunctata* and *Hemianax papuensis* were found in 15, 8, 7 and 3 lakes, respectively.

The most abundant damselfly *Xanthocnemis zealandica* occurred in all lakes. Despite being common and widely distributed in much of New Zealand (Rowe 1987) *Austrolestes colensonis* was only seen in Lake Kihona where two nymphs were taken. *Ischnura aurora* was positively identified in two lakes, in one of which adults were flying (Waiparera). Because the nymphs of *Ischnura* are very similar to those of *Xanthocnemis* (and many lacked caudal lamellae used for identification) it may have been present in some other lakes but remained unrecognised.

Apart from *Xanthocnemis* and *Austrolestes* the odonate fauna comprised vagrant species that appear to have self-colonised New Zealand and become established in the last century (Rowe 1987). The species of *Tramea* was first seen in this country (at Lake Rotokawau) in 2005 (Pohe *et al*. 2007).

Coleoptera (beetles)

Aquatic beetles belonging to 5 families (Gyrinidae, Dytiscidae, Hydrophilidae, Scirtidae and Hydraenidae) were found in the lakes but were never abundant. Except for the detritivorous scirtid larvae, the adults and larvae of all species found are predators. Beetles included both the larvae and adults of three species, adults only of seven species, and larvae only of a further three. Notable finds were New Zealand's largest dytiscid beetle *Onychohydrus hookeri*, which was seen in six lakes and the whirligig beetle *Gyrinus convexiusculus* that was taken from four. The latter is an Australian species that is only known from the Waikato and Northland (Wise 1989).

Hemiptera (bugs)

The order Hemiptera was represented by three families, Corixidae, Notonectidae and Veliidae. Members of all three families feed by piercing and sucking using needle like stylets that form a feeding tube, but have contrasting sources of food. Thus, corixids are primarily herbivorous, notonectids are carnivorous and the surface-dwelling veliids feed on the bodies of dead insects.

Corixids (waterboatmen) were present in all lakes except Te Kahika, and in most lakes both New Zealand genera *Diaprepocoris* and *Sigara* were found. The only species of *Diaprepocoris* in New Zealand is *D. zealandiae*, whereas at least three species of *Sigara* occurred in the lakes. They were *S. arguta* (the most common species in New Zealand), *S. infrequens* and *S. potamius*. However, only adult male *Sigara* can be identified to species with certainty (Young 1962) and adults were not present in samples from six lakes inhabited by corixids. *D. zealandiae* was most abundant in Lakes Ngakeketa North and Rotoroa, and *Sigara* was very abundant in Bulrush Lake.

The backswimmer *Anisops assimilis* was found in 15 lakes but varied considerably in abundance. It was most common in Lakes Bulrush, Te Paki and Waipara, and was the only hemipteran taken from Te Kahika. The abundance of *Anisops* was generally low in the Sweetwater lakes where present.

Few specimens of the small water skater *Microvelia macgregori* were present in our samples.

Trichoptera (caddisflies)

The caddisflies were represented by four species in two families, Hydroptilidae and Leptoceridae. Larvae of New Zealand hydroptilids (micro-caddisflies) are thought to be predominantly algal feeders, whereas the leptocerids found in the Northland lakes are both detritivores. The most abundant species was the hydroptilid *Paroxyethira hendersoni*, which was found in 15 lakes. A second, unidentified species of *Paroxyethira* (possibly *P. eatoni*) co-occurred with *P. hendersoni* in eight lakes. The two species differ in the form of their cases: those of *P. hendersoni* have pairs of horizontally oriented spines at each end, whereas cases of the second species lack spines.

Triplectides cephalotes and *Oecetis unicolor* were the two species of Leptoceridae found. Both are common members of lake faunas throughout New Zealand. *Triplectides* was collected from 12 lakes and *Oecetis* from six. Both were most abundant in samples from Bulrush Lake.

Lepidoptera (moths)

Caterpillars of New Zealand's only native aquatic moth *Hygraula nitens* were found in six lakes and were most abundant in two of the most northern ones, Te Paki Dune and Ngakeketa North. They occur in ponds and lakes throughout New Zealand and feed on living stems and leaves of submerged macrophytes. *Hygraula* builds a portable case from plant fragments, and can be very like that of the caddisfly *Triplectides*.

Neuroptera (spongillaflies)

Two larval Sisyridae (spongillaflies) were found in samples from Lake Kihona and one larva was found at Ngakeketa North. There are no endemic sysirids in New Zealand and the family was first recorded here in 1998 by Wise (1998) who reported the finding of two adults of the Australian species *Sisyra rufistigma* on foliage overhanging the banks of a weir pond on the Kerikeri River, Northland. Subsequently, specimens were found at Opononi on the Hokianga Harbour and at Bethels Beach north-west of Auckland. In 2006 *Sisyra* larvae were identified by Stephen Moore (Landcare Research; pers.comm.) in collections from streams in the Oratia/Opanuku catchment, Waitakere and in Hawkes Bay. Larvae from Lake Kihona resemble those he found and are assumed to be *S. rufistigma*. The common name spongillafly refers to the sponge-feeding habit of the larvae. Sponges (Spongillidae) occur in several Aupouri lakes (Wells et. al. 2007) and were present in some of our samples including those from Ngakeketa North.

Diptera (true flies)

At least 15 species of Diptera belonging to 8 families were found in the lakes. The most abundant and diverse family was the Chironomidae with eight species in three subfamilies. The Ephydridae (shore flies) was represented by two unidentified species and all other families by single species.

The most abundant group of chironomids was the tribe Chironomini, subfamily Chironominae. The tribe included three genera *Chironomus*, *Polypedilum* and *Parachironomus*, each apparently represented by a single species. Pupae of *Parachironomus* conformed to the description by Forsyth (1971) of *P. cylindricus*, the only species described from New Zealand. As larvae need to be mounted on slides to identify genera they were treated at the tribal level in making counts from lake samples. Chironomini were present in all 17 lakes and were especially abundant in Bulrush Lake. They were also abundant in Lakes Waiparera, Ngatu and Te Kahika. *Chironomus* was found in all lakes, whereas *Polypedilum* and *Parachironomus* were identified in 5 and 3 lakes, respectively.

Tanytarsini (subfamily Chironominae) were present in small numbers in samples from 13 lakes. *Tanytarsus funebris* was the commonest, and possibly the only species present. However, some larvae that otherwise appeared to be identical to *funebris* showed differences in the structure of their antennae.

Subfamily Tanypodinae contained a single distinctive species in the tribe Macropelopiini. Its predominantly carnivorous larvae were found in 11 lakes and were most common in Te Paki Dune, Te Kahika and Waipara.

The third subfamily Orthocladiinae was found in 16 lakes but never in very high numbers. Their greatest abundance was in Lake Waihopo. A species of *Cricotopus* was found in 15 lakes, an apparently undescribed species of *Eukiefferiella* in two lakes, and an unidentified species in Lake Ngakapua South.

Except for the Tanypodinae, all chironomid larvae found in the lakes are non-predatory species that are likely to feed on a mixture of fine organic detritus and algae. Most of the species found, and probably others, are also likely to inhabit bottom sediments away from the littoral zone (Timms 1982) and be an important food of fish.

Of the other dipterans found in this survey the most interesting finds were larvae of the mosquito *Coquillettidia* in Lakes Kihona and Ngakapua South. Two species of *Coquillettidia* are known from New Zealand but their larval stages have not been described so the specific identities of our larvae could not be determined. However, *C. iracunda* appears to be the only species reported from Northland (Belkin 1968). Unlike most mosquito larvae, which respire at the water surface, larvae of *Coquillettidia* have a short, pointed siphon that is used to penetrate plant tissues from which oxygen is withdrawn (Figure 4).

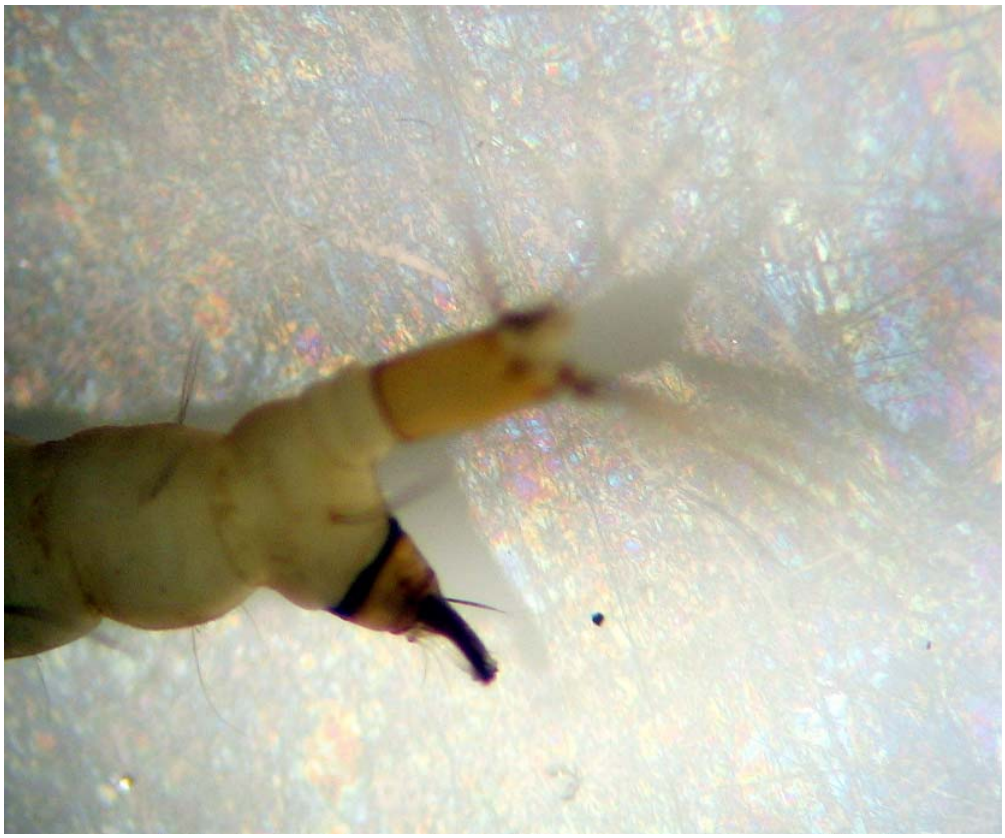

Figure 4. Plant-penetrating siphon of the larva of *Coquillettidia* sp. (mosquito)

Crustacea

Few crustaceans were found in littoral samples from any lake. Occasional cladocerans, copepods and ostracods were seen but no amphipods, freshwater crayfish, crabs or shrimps were found. Three individuals of a minute isopod resembling Chapman & Lewis's (1976) illustration of an "unidentified anthuridian isopod" from Spirits Bay were found in Lake Ngakeketa South. They resemble *Paravireia*, a genus of Sphaeromatoidea with uncertain family affinity (G. Fenwick, NIWA, pers. comm.) with two marine representatives in New Zealand. Asher *et al*. (2008) reported *Paravireia* as part of a sponge-associated community in Waimea Inlet, Nelson, suggesting it may associate with sponges in Northland lakes.

Acari (mites)

A few very small oribatid mites were present in samples taken from 8 lakes and the large red mite *Hydrachna maramauensis* was collected from three lakes. Larval stages of the latter parasitise waterboatmen and backswimmers and become free-swimming predators as adults (Stout 1953). Because their hemipteran hosts are abundant in Northland dune lakes *Hydrachna* maybe more common than our findings indicate, especially in summer.

Mollusca (snails and bivalves)

Molluscs made up a significant proportion of the littoral fauna of the Northland lakes. However, the distribution and dominance of species among lakes was highly variable and no molluscs were found in Lakes Te Kahika and Morehurehu. Six gastropod species (snails) and one bivalve were encountered in our survey.

Three of the gastropods (*Physa acuta*, *Pseudosuccinea columella* and *Planorbella* sp.) are introduced species that have become established in various parts of the country and the others are native to New Zealand. *Pseudosuccinea* was found in 12 lakes but never in high abundance, whereas *Physa* was collected from 11 lakes and was the most abundant snail in 4 of them (Waihopo, Rotokawau, West Coast Rd and Heather). *Planorbella* appears to have invaded freshwaters in the northern North Island very recently (B. Smith, NIWA pers. comm.) and was present in three of the Sweetwater lakes, Ngatu, Ngakapua North and Ngakapua South.

Of the three native gastropods, the common hydrobiid *Potamopyrgus antipodarum* was found in eight lakes and was extremely abundant in Lakes Rotoroa, Kihona and Ngakeketa North. However, only small numbers were recorded in five other lakes. The small planorbid *Gyraulus corinna* was the most abundant invertebrate in samples from Te Paki Dune lake but was only seen in two other lakes where it was rare. *Glyptophysa variabilis* occurred in Lakes Rotoroa and Ngakeketa South at either end of the Aupouri Peninsula. Shells of *Glyptophysa* were amongst the largest reported but consistent in size with those from other northern localities (Dell 1956). The distribution of this snail appears to have been reduced since the introduction of *Physa*, which is now widespread in New Zealand. The two species are rarely found together (Winterbourn 1973) but appear to co-exist in Lakes Rotoroa and Ngakeketa South where they differ substantially in size.

The pea mussel *Musculium novaezelandiae* (= *Sphaerium novaezelandiae*) was collected from 10 lakes and was the numerically dominant mollusc in lakes Waipara and Bulrush. Exceptionally large specimens were found in Lake Waipara where it was one of the three most abundant invertebrates. Pea mussels are filter-feeders that ingest fine particles and associated microorganisms derived from surrounding sediments. They live on the lake bottom and also move about within macrophyte beds. The 6 snail species also feed on fine particles but they are grazers not filter feeders and usually include algae scraped from plants and other hard surfaces in their diets.

Annelida (segmented worms and leeches)

Few oligochaete worms were found in samples from the littoral zone even of the more eutrophic lakes and Tubificidae was the only family recorded. A small species of *Aulodrilus* was the only oligochaete identified from the West Coast Rd Lake where the largest numbers of worms were found.

Leeches (Hirudinea) were represented by a single species *Alboglossiphonia multistriata*, which was found in four lakes including Waiparera where 15 individuals were taken. *Alboglossiphonia* is not a blood-sucking species and probably feeds mainly on snails. It is one of our commonest freshwater leeches.

Turbellaria (unsegmented flatworms)

Small numbers of the widely distributed flatworm *Cura pinguis* were found in six lakes. A small, pale unidentified species (possibly a rhabdocoel) was also found in Lake Ngakeketa North.

Porifera (sponges)

Freshwater sponges (Spongillidae) have been reported in a number of the Aupouri lakes during vegetation surveys (Wells *et al*. 2007) but identifications have not been made. Some sponges were found attached to pieces of dead plant matter in the present study but only in Lakes Ngakeketa North and Morehurehu.

Fish and amphibians

Although not invertebrates, we recorded the presence and numbers of fish and frog tadpoles caught as bycatch in littoral samples. Common bullies (*Gobiomorphus cotidianus*) were taken in eight lakes including five of the seven Sweetwater lakes. However, they were most abundant in collections from the two Ngakeketa lakes in the far north. The introduced mosquito fish (*Gambusia affinis*) was also found in five Sweetwater lakes and Waiparera, and carp (*Carassius* sp.) were taken in Ngakapua South. Bullies and mosquito fish both occurred in sweep-net samples from Lakes Waiparera, Ngatu, Rotoroa and Ngakapua South.

Tadpoles of an introduced *Litoria* frog species were most abundant in Te Paki Dune Lake and were also found in Waipara and Ngakapua North.

5.3 Features of the individual lake faunas

Because the lakes varied considerably in the composition of their littoral faunas and the relative abundance of species, brief summaries of their faunal characteristics are given below. Lakes are considered from north to south.

Ngakeketa North (28 species)

The littoral fauna was dominated by molluscs with *Potamopyrgus* the most abundant species. The bivalve *Musculium*, damselflies (*Xanthocnemis*), waterboatmen (*Diaprepocoris* and *Sigara*), backswimmers (*Anisops*) and the aquatic moth *Hygraula* were common. However, chironomid abundance was only moderate. The finding of a spongillafly larva (Sisyridae) in the lake is notable. Common bullies were found in the littoral zone.

Ngakeketa South (21 species)

Faunal abundance was the second lowest of the 17 lakes. The commonest taxa were *Xanthocnemis*, Orthocladiinae and *Potamopyrgus*. An unusual isopod (Sphaeromatoidea) was found here but in no other lakes. The common bully was present in the littoral zone.

Te Paki Dune Lake (27 species)

The fauna of this lake was unusual in being dominated numerically by the gastropod *Gyraulus*. Other abundant species were *Musculium*, *Anisops* and *Diaprepocoris*. Three dragonflies and the damselfly *Xanthocnemis* were common. Two notable members of the fauna were the large diving beetle *Onychohydrus* whose larvae were common, and the whirligig beetle *Gyrinus*. Tadpoles of a *Litoria* species were also prevalent.

Waipara (27 species)

The pea mussel *Musculium*, backswimmers (*Anisops*) and the waterboatman *Diaprepocoris* were abundant and a large population of the dragonfly *Hemicordulia* was present. Larvae of *Xanthocnemis*, the dytiscid beetle *Onychohydrus* and the microcaddis *Paroxyethira* were also common in this lake. Whirligig beetles were present but few chironomids were found, the most abundant being a species of predatory Tanypodinae.

Te Kahika (12 species)

Te Kahika is an unusual lake that has a very low pH (<pH 4). The low pH was reflected in the species-poor fauna and the complete absence of molluscs. Chironomini including *Parachironomus* dominated the fauna. Abundance of the damselfly *Xanthocnemis* was greater than in any other lake and numbers of *Hemicordulia* larvae were second only to Waihopo. The backswimmer (*Anisops*) was also abundant. Tanypodinae and gyrinid beetles were common. Gyrinid larvae were found in Te Kahika indicating that whirligig beetles breed and develop in the lake.

Kihona (30 species)

More invertebrate species were found in Kihona than any other lake except Ngakapua North, where 32 species were found. The littoral fauna was strongly dominated by *Potamopyrgus*. Three other molluscs, the bivalve *Musculium* and the introduced snails *Physa* and *Pseudosuccinea* were also abundant. *Xanthocnemis*, *Hemicordulia* and *Paroxyethira* were common, but chironomids, waterboatmen and backswimmers were present in low numbers. Two larvae of the spongillafly *Sisyra* were found.

Morehurehu (18 species)

Invertebrate abundance was lower in Morehurehu than in any other lake. Corixids were the most abundant group and both *Hemicordulia and Xanthocnemis* were relatively abundant. The chironomid population was small and no molluscs were found.

Bulrush (23 species)

Bulrush supported a large population of Chironomini and both *Anisops* and *Sigara* were very abundant. However, the other corixid *Diaprepocoris* was not found. *Xanthocnemis* and *Musculium* were also abundant and the caddisflies *Triplectides* and *Oecetis* were common. Snails were rare.

Waihopo (25 species)

Chironomini, the backswimmer *Anisops*, Corixidae and the dragonfly *Hemicordulia* were co-dominant in this lake. *Xanthocnemis*, Orthocladiinae and the snail *Physa* were also abundant, and micro-caddis and pea mussels were common. Four of the five dragonfly species recorded in the 17 lakes were found in Waihopo and their total abundance was greater there than in any other lake.

Waiparera (20 species)

The littoral fauna of this large lake was dominated by Chironomini. *Xanthocnemis* was also abundant and a second damselfly *Ischnura* was present. Adults of both damselfly species were flying at the time of sampling. *Anisops* was common and although *Sigara* was present *Diaprepocoris* was not seen. The two leptocerid caddisflies were present in low to moderate numbers. Molluscs were not abundant and only *Potamopyrgus* and *Physa* were found. The littoral zone of Waiparera also provided habitat for the leech *Alboglossiphonia*.

Rotokawau (20 species)

Rotokawau had a moderately low density fauna dominated by Chironomini. Corixids, *Physa* and *Hemicordulia* were also abundant. *Anisops* was not present in samples and few damselfly larvae were seen. Samples from this lake included the largest numbers of *Physa* and the second greatest abundance of *Pseudosuccinea*. Interestingly, the shells of both snail species had a more banded and etched appearance than those from other lakes for reasons that are unknown. Mosquito fish (*Gambusia*) were very abundant in the littoral zone.

Ngakapua North (32 species)

The 32 invertebrate species found was the most for any lake. Corixids were numerically dominant followed by Odonata and Chironomidae. Unlike most lakes Orthocladiinae were the main subfamily of chironomid midges present. *Xanthocnemis* was most abundant of the six odonates found, and both *Hemicordulia* and *Tramea* had large populations. Larvae of the large diving beetle *Onychohydrus* and the aquatic moth *Hygraula* were found in Ngakapua North (and Ngakapua South). All snails found were introduced species and included the largest population of *Planorbella*. Mosquito fish were not present in samples despite being found in five other Sweetwater lakes including Lake Ngakapua South.

Ngakapua South (22 species)

Invertebrate abundance was the third lowest found in our sampling program. Chironomids (mainly Chironomini), corixids and *Xanthocnemis* were most common. The only mollusc seen was a single specimen of *Planorbella*. Small numbers of carp and the common bully *Gobiomorphus* were present in littoral samples.

Ngatu (22 species)

The littoral fauna of Ngatu was dominated by Chironomini with a second group of midges, the Tanytarsini, sub-dominant. Few dragonflies and only six damselfly larvae were found although two of these were *Ischnura*. Corixids were also uncommon and the backswimmer *Anisops* was not seen. *Planorbella* was the most abundant mollusc. Two other introduced snails were found in very small numbers along with the more common pea mussel *Musculium*. Mosquito fish were common in littoral samples and two bullies were caught.

West Coast Road (19 species)

The fauna was strongly dominated by Chironomini with Tubificidae (Oligochaeta) sub-dominant. This was the only lake in which tubificid worms were common. Unusually, backswimmers were more abundant than corixids, which were all *Sigara*. *Hemicordulia* was the only moderately common dragonfly and only two damselfly larvae were found. The only molluscs collected were *Physa* and *Pseudosuccinea*, both in small numbers. Eight leeches (*Alboglossiphonia*) were found. Mosquito fish were extremely abundant.

Heather (27 species)

Odonata and Hemiptera were strongly represented in Lake Heather. Four dragonfly species were common and *Xanthocnemis* was particularly abundant. Both corixid species were abundant but backswimmers were less common. Chironomidae were moderately abundant with Orthocladiinae twice as prevalent as Chironomini. The only molluscs found were *Pseudosuccinea* and *Physa*. Lake Heather was the only Sweetwater lake in which the whirligig beetle *Gyrinus* was found. *Onychohydrus* was also present. Mosquito fish were not seen but three bullies were present in samples.

Rotoroa (25 species)

Rotoroa had the highest abundance of littoral invertebrates of any lake, over 73% being contributed by the snail *Potamopyrgus*. Apart from a single specimen found in Rotokawau this was the only Sweetwater lake containing this native freshwater snail. *Physa* and *Pseudosuccinea* were also present along with numerous very large specimens of the native pulmonate snail *Glyptophysa*. Both corixid species were abundant in Rotoroa but only four *Anisops* were found. *Xanthocnemis*, *Hemicordulia* and two caddisflies *Paroxyethira hendersoni* and *Oecetis* were also common. Mosquito fish were abundant and bullies were present.

5.4 Community analyses

The relative abundance and dominance of taxa varied considerably among lakes. Dipterans (predominantly Chironomidae) were most abundant in eight lakes, molluscs in four, hemipterans (waterboatmen and backswimmers) in four and Odonata in one lake (Figure 5). Of the 69 species found, 3 (*Hemicordulia*, *Xanthocnemis and Chironomus*) were collected from all 17 lakes. *Sigara* was found in 16 lakes and *Aeshna*, *Anisops*, *Paroxyethira hendersoni* and *Cricotopus* (Orthocladiinae) in 15 lakes. Fifteen species or taxa were collected from over half the lakes but 14 others were seen in one lake only. Although *Potamopyrgus* is commonly regarded as a dominant taxon in the weed beds of lakes (Kelly & McDowall 2004) it was seen in only eight lakes on the Aupouri Peninsula and was abundant in only three.

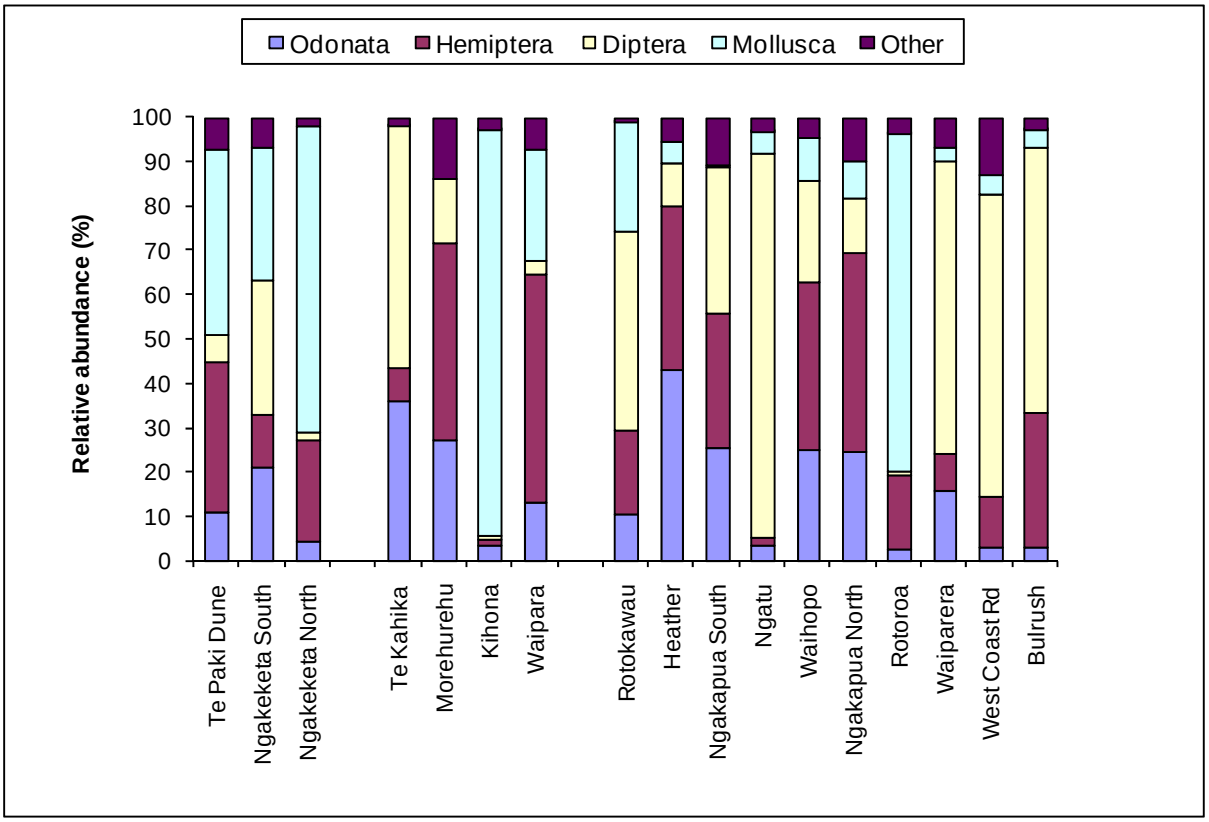

Figure 5. Relative abundance (%) of four major macroinvertebrate groups (Odonata, Hemiptera, Diptera, Mollusca) and others in the 17 lakes. Lakes are arranged in three groups based on the predominant catchment land-use/vegetation: scrub (left), plantation forest (middle), pasture (right).

A feature of the lake littoral fauna was the presence of recently introduced or self-introduced species. With one exception (the native diving beetle *Onychohydrus*) the largest invertebrates present were larvae of five dragonfly species. At least four of the five species are believed to be self-introduced and may have become established during the last century (Rowe 1987). Because they have tropical-subtropical origins they occur mainly in the north of the country and are rare or absent from the South Island. All five dragonfly species were found in Ngakapua North, and four other lakes were inhabited by four species. In contrast, of the three damselflies found, *Ischnura* is the only recently self-introduced species. It is native to Australia and was recorded in Lakes Waiparera and Ngatu.

Unlike the Odonata (dragonflies and damselflies) three of the snail species present in the Aupouri Peninsula lakes have been introduced into the country, either accidentally or deliberately. All three probably have North American origins. *Physa acuta* is a highly successful invader of freshwaters in many parts of the world and is widespread and often abundant in many parts of New Zealand. It was found in 11 of the lakes. *Pseudosuccinea columella*, which can be an intermediate host of the liver fluke, *Fasciola hepatica* (Pullan 1969) was found in 12 lakes. The third, and most recently introduced snail, *Planorbella* sp. was taken from three lakes. All three introduced snails were present in Ngatu and Ngakapua North.

The two other introduced or self-introduced species found were larvae of a spongefly (Neuroptera: Sisyridae) and a whirligig beetle *Gyrinus convexiusculus*. Both are believed to be Australian species and are known only from north of Auckland and the Waikato.

Cluster analysis of lake faunas based on presence-absence of species distinguished four broad groups (Figure 6). The community of acidic Lake Te Kahika was most distinct as it contained far fewer species than any other lake. Cluster 2 contained the two supertrophic lakes Bulrush and Waiparera, and cluster 3 the third supertrophic lake (West Coast Rd) and three further lakes with pasture-dominated catchments. The remaining cluster included a mixture of mesotrophic and eutrophic lakes in exotic forest, pasture and scrub-dominated catchments.

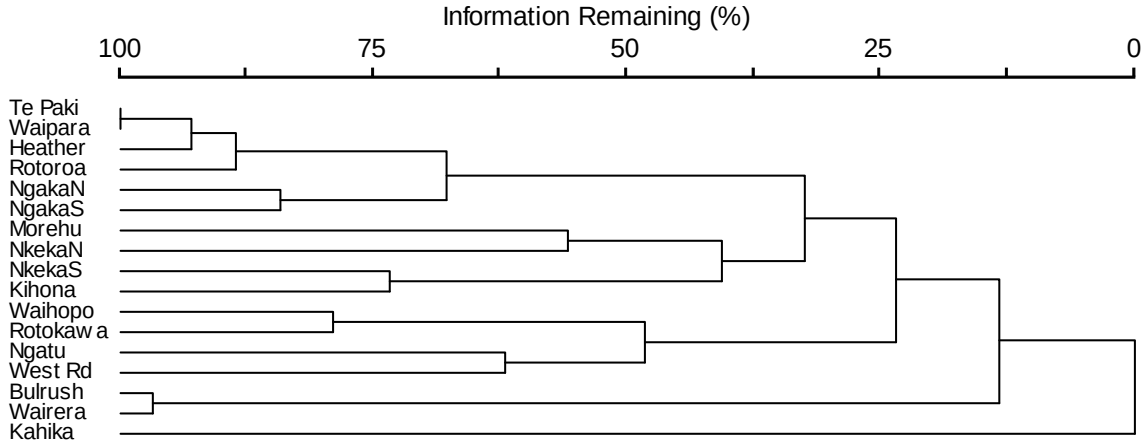

Figure 6. Result of a cluster analysis showing the similarity of the 17 lake littoral faunas based on presence/absence data. Similarity was assessed with the Sorensen coefficient and clustering by average linkage. NgakaN = Ngakapua North, NgakaS = Ngakapua South, Morehu = Morehurehu, NkekaN = Ngakeketa North, NkekaS = Ngakeketa South, Rotokawa = Rotokawau, West Road = West Coast Road, Wairera = Waiparera, Kahika = Te Kahika.

Ordination based on relative abundance of species revealed three general groupings of lakes (Figure 7). Most distinctive was the group containing Ngakeketa North, Kihona and Rotoroa, all with faunas dominated numerically by *Potamopyrgus*. A second group (in the top right hand corner of the ordination diagram) consisted of 6 lakes with Chironomini dominant, and included acidic Te Kahika. Two other Chironomini-dominated lakes were outside this cluster, however. Of the remaining lakes Te Paki was an obvious outlier. It was the only lake with a large (and dominant) population of the native snail *Gyraulus* and a high proportion of *Hygraula* (aquatic moth) larvae.

The rank order of sites on axis 1 was significantly correlated with landuse/vegetation cover (left to right: scrub, exotic, forest, pasture) ($r_s = 0.49$, $P<0.05$) but no other measured environmental factors. Axis 2 was correlated with lake area ($r_s = 0.85$, $P<0.01$) and the presence of *Gambusia* ($r_s = 0.65$, $P<0.05$), factors that were intercorrelated ($r_s = 0.54$, $P<0.05$). No chemical factors or indicators of trophic condition were correlated significantly with the ordination axes.

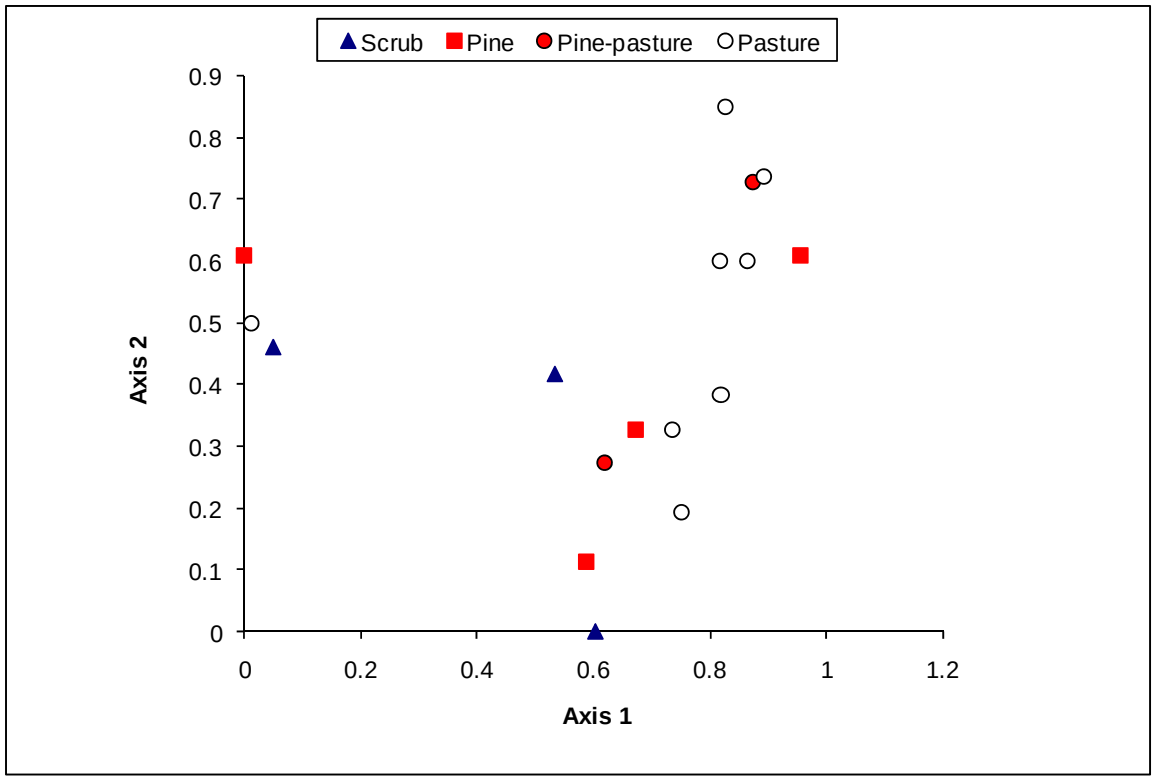

Figure 7. Result of a Bray-Curtis ordination of the 17 lake faunas based on relative abundance (%) data. Lakes symbols indicate catchment land-use/vegetation. Lakes with more similar faunas are closer together.

In the 17 lakes, total faunal abundance was not correlated with any measure of trophic enrichment tested (total nitrogen, total inorganic nitrogen, total phosphorus, dissolved reactive phosphorus, chlorophyll a; NRC unpublished data September 2008–March 2009), but abundance of Chironomini was positively correlated with concentration of total inorganic nitrogen in lake water (r_s = 0.59, P<0.05) and almost significantly correlated with dissolved reactive phosphorus concentration (r_s = 0.41). Although abundance of molluscs was not correlated significantly with these enrichment measures, a very strong relationship was found between the percentages of Mollusca and Chironomini in littoral communities (r_s = 0.76, P<0.01; Figure 8). This relationship indicates that many of the lakes are dominated by one or other of these faunal groups but not both together.

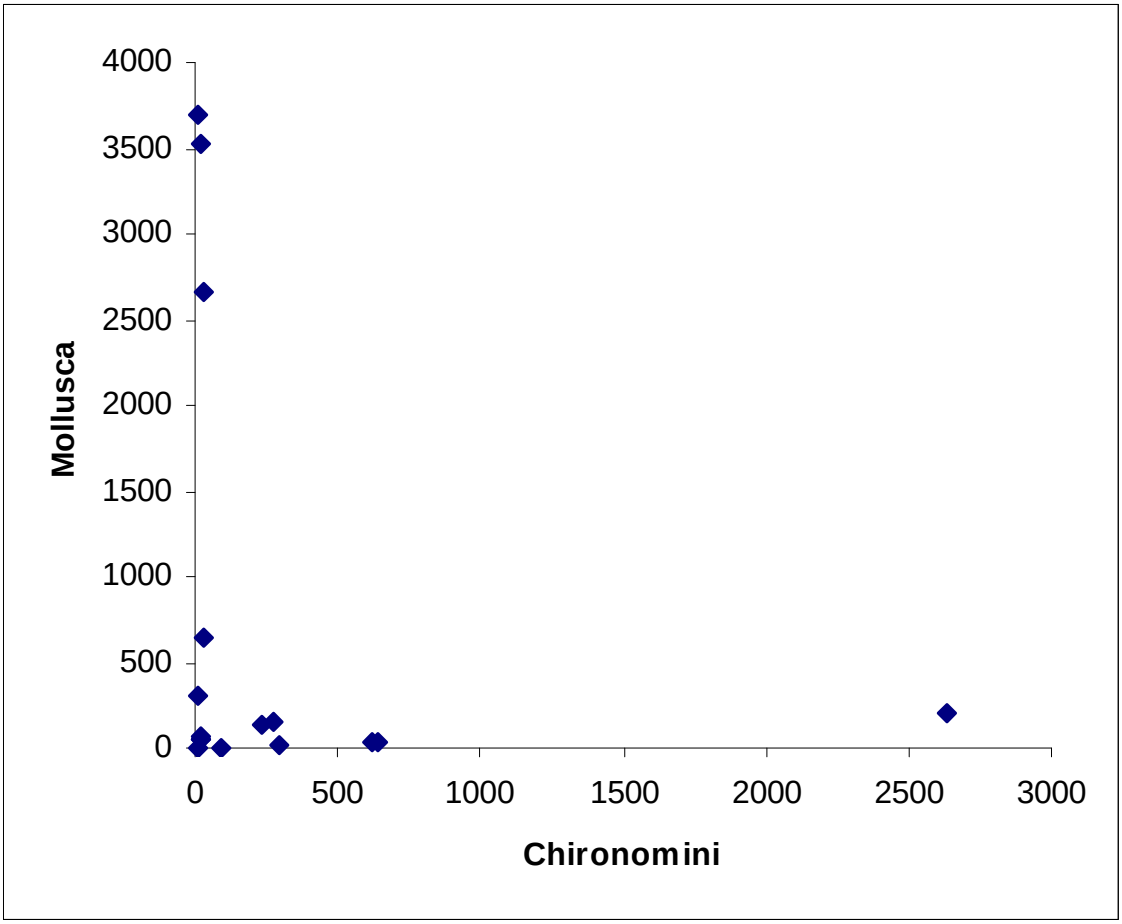

Figure 8. The percentage of Mollusca (snails and bivalves) in lake samples plotted against the percentage of Chironomini.

6. Conclusions

The Aupouri Peninsula lakes had diverse littoral invertebrate faunas dominated by insects and molluscs. However faunal abundance varied considerably among lakes as did the relative abundances of species and major faunal groups. Much of the fauna was typical of lakes in other parts of New Zealand where many of the same species (e.g. Chironomidae, Hemiptera and Coleoptera) are common.

The most notable feature is the diverse fauna of Odonata and Mollusca. Elsewhere in New Zealand many lakes are inhabited by one dragonfly species, whereas up to five dragonflies occurred in the Aupouri lakes. Furthermore, two of them (and the damselfly *Ischnura*) are restricted to the North Island and all are most common there.

The diverse gastropod fauna, and the patchy distribution of *Potamopyrgus* (frequently the most abundant snail in New Zealand lakes) was also a feature of the fauna. Two of three introduced gastropods were widely distributed and a third species (*Planorbella*) is almost certainly a very recent introduction. The numerical dominance of different species in different lakes was unexpected, especially that of the native *Gyraulus* in Te Paki Dune and the native pea mussel *Musculium* in Waipara and Bulrush. Notable too is that *Musculium* and the native snail *Glyptophysa* included numerous very large individuals in the Aupouri lakes. Te Kahika lacked a mollusc fauna altogether, but its unusually low pH almost certainly precludes their presence.

The composition of the littoral fauna was not clearly associated with catchment land-use/vegetation or indicators of trophic condition, and total faunal abundance was not related to measures of trophic enrichment tested. However, the faunas of the three most eutrophic lakes included a high proportion of Chironomini (midge) larvae. Chironomini including *Chironomus zealandicus*, the most abundant species found in the lakes, are well-known indicators of enriched and organically polluted conditions in streams and rivers (Stark 1985). Their high absolute and relative abundance in the lake littoral fauna can indicate elevated lake trophic state, but as shown by lakes Te Kahika (oligotrophic) and Ngatu (mesotrophic-eutrophic) other factors can also result in high abundance of Chironomini. Although many of the lakes not dominated by Chironomini had high abundances of Mollusca, neither they nor other invertebrate species appeared to be useful for assessing lake condition. Despite its limited values as an indicator of lake “health” the littoral fauna of the Aupouri lakes is diverse and species-rich, and can be expected to have an important role in supporting the diverse fish and aquatic bird populations of the lakes.

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Appendix 1. Major vegetation types on land surrounding Aupouri dune lakes.

Pastoral land (Lake Rotoroa)

Pine plantation (Lake Morehurehu)

Scrub (Ngakeketa South)

Appendix 2. Abundances of macroinvertebrate taxa found in 17 lakes on Aupouri Peninsula.

		Ngakeketa North	Ngakeketa South	Te Paki dune	Waipara	Te Kahika	Kihona	Morehurehu	Bulrush	Waihopo	Waiparera	Rotokawau	Ngakapua North	Ngakapua South	Ngatu	West Coast Rd	Heather	Rotoroa	No. of lakes	Sum
Odonata																				
Aeshnidae	*Aeshna brevistyla*	19	7	40	8	32	15	3		3		1	11	4	3	1	33	1	**15**	**181**
	Hemianax papuensis								1		1		2						**3**	**4**
Coenagrionidae	*Ischnura aurora*										present				2				**1**	**2**
	Xanthocnemis zealandica	131	43	58	48	379	85	19	131	143	145	6	87	52	4	2	229	91	**17**	**1653**
Corduliidae	*Hemicordulia australiae*	10	2	57	88	154	43	31	10	230	5	50	33	14	16	10	72	37	**17**	**862**
Lestidae	*Austrolestes colensonis*						2												**1**	**2**
Libellulidae	*Diplacodes bipunctata*			11	3	5				16		1	2				17		**7**	**55**
	Tramea loewii				11					7		1	28	17	1	1	19		**8**	**85**
Coleoptera																				
Dytiscidae	*Antiporus femoralis*		1	9			1	1	20			1	1						**7**	**34**
	Hyphydrus elegans				2														**1**	**2**
	Lancetes lanceolatus			7								1							**2**	**8**
	Liodessus sp.								1							1			**2**	**2**
	Onychohydrus hookeri			29	29								15	10			1	3	**6**	**87**
	Rhantus suturalis			1	1													1	**3**	**3**
Gyrinidae	*Gyrinus convexiusculus*			1	2	19											9		**4**	**31**
Hydraenidae	*Podaena* sp.		1				1												**2**	**2**
Hydrophilidae	*Enochrus tritus*			1					1	1	2		3	2			1		**7**	**11**
	Hydrophilid indet.		1		1				2								2	7	**5**	**13**
	Hydrophilid sp. D						1												**1**	**1**
	Laccobius arrowi	1														1			**2**	**2**
	Paracymus sp.								2										**1**	**2**
Scirtidae							3												**1**	**3**
Hemiptera																				
Corixidae	*Diaprepocoris zealandiae*	785	6	144	265		13	73		81		89	119	56	14		169	417	**13**	**2231**
	Sigara spp.	81	9	70	39		6	11	745	276	19	15	154	23	2	15	116	347	**16**	**1928**
Notonectidae	*Anisops assimilis*	19	6	300	316	112	21	1	619	245	64		23	23		36	31	4	**15**	**1820**
Veliidae	*Microvelia macgregori*	1	7				3	2									1		**5**	**14**
Diptera																				
Ceratopogonidae				2	1		1								4				**4**	**8**
Chironomidae	Chironomini	28	19	33	6	828	12	10	2636	275	639	234	19	88	616	299	22	20	**17**	**5784**
	Orthocladiinae	20	49	10	8		13	1	16	70	1	5	49	15	6	2	45	6	**16**	**316**
	Tanypodinae	2		27	20	28		4	4			1	2		1		8	1	**11**	**98**
	Tanytarsini	2		18		11		12	4	18		10	5	4	46	9	7	9	**13**	**155**
Culicidae	*Coquillettidia* sp.						1							2					**2**	**3**
Dixidae	*Paradixa neozelandica*	2	6	1			14						3						**5**	**26**
Ephydridae		7	1	1	1		4	1					2	3					**8**	**20**
Muscidae												1							**1**	**1**
Stratiomyidae		1																	**1**	**1**
Tipulidae	*Zelandotipula* sp.						3												**1**	**3**
Trichoptera																				
Hydroptilidae	*Paroxyethira hendersoni*	24	3	3	30		83	6	1	62	6		19	9	15	2	9	88	**15**	**360**
	Paroxyethira sp. B*			10	8		5	13			4		3	3			2		**8**	**48**
Leptoceridae	*Oecetis unicolor*	1			1				22		29				4			54	**6**	**111**
	Triplectides cephalotes	5	7		1	7		4	69	1	5	1		1			3	4	**12**	**108**
Neuroptera																				
Sisyridae	*Sisyra* sp.	1					2												**2**	**3**
Lepidoptera																				
Crambidae	*Hygraula nitens*	29		48									7	2			15	4	**6**	**105**

		Ngakeketa North	Ngakeketa South	Te Paki dune	Waipara	Te Kahika	Kihona	Morehurehu	Bulrush	Waihopo	Waiparera	Rotokawau	Ngakapua North	Ngakapua South	Ngatu	West Coast Rd	Heather	Rotoroa	No. of lakes	Sum
Mollusca																				
Hydrobiidae	*Potamopyrgus antipodarum*	2540	37				3559		2	3	26	1						3397	**8**	**9565**
Lymnaeidae	*Pseudosuccinea columella*	18	14	9	1		37			8		28	12		3	7	13	11	**12**	**161**
Physidae	*Physa acuta*		21				43		2	93	5	99	12		1	13	32	73	**11**	**394**
Planorbidae	*Glyptophysa variabilis*		1															34	**2**	**35**
	Gyraulus corinna			515			1			5									**3**	**521**
	Planorbella sp.												24	1	21				**3**	**46**
Sphaeriidae	*Musculium novaezelandiae*	106		113	302		61		191	45		10	7		15			11	**10**	**861**
Crustacea																				
Cladocera		1			5		2			1					1		1		**6**	**11**
Copepoda		3					3									1			**3**	**7**
Isopoda	Sphaeromatoidea		3																**1**	**3**
Ostracoda	*Herpetocypris pascheri*				1					6		2	6						**4**	**15**
	Ilyodromus sp.												2	8					**2**	**10**
	Ostracod indet.												2						**1**	**2**
Acari																				
Hydrachnidae	*Hydrachna maramauensis*				5				1									1	**3**	**7**
Oribatida				1		1		1			2		6	1			1	1	**8**	**14**
Porifera																				
Spongillidae		1						2											**2**	**3**
Hirudinea																				
Glossiphoniidae	*Alboglossiphonia multistriata*								1	2	15					8			**4**	**26**
Oligochaeta																				
Tubificidae		3								1					1	45			**4**	**50**
Turbellaria																				
Dugesiidae	*Cura pinguis*						9			1	1		1		2		1		**6**	**15**
Turbellaria indet.		3																	**1**	**3**
Individuals		**3844**	**244**	**1519**	**1203**	**1576**	**4047**	**195**	**4481**	**1593**	**969**	**557**	**659**	**338**	**778**	**453**	**859**	**4622**	**1643.4**	**27937**
Total taxa		**28**	**21**	**27**	**27**	**11**	**30**	**18**	**22**	**24**	**18**	**20**	**30**	**21**	**21**	**17**	**26**	**24**	**22.6**	
Total species		**28**	**21**	**27**	**27**	**12**	**30**	**18**	**23**	**25**	**20**	**20**	**32**	**22**	**22**	**19**	**27**	**25**	**23.4**	

* case has no spines