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Stream Classification and Instream Objectives for Auckland's Urban Streams

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Stream classification and instream objectives for Auckland's urban streams

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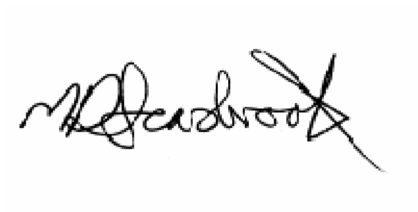

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1 Executive Summary

The maintenance of biological values in urban streams requires the recognition that the urban environment has significantly altered these streams. Flow regimes are more extreme, water quality problems exist, habitat quality can be reduced and fish passage problems are common. To manage urban streams it is necessary first to understand what biological values can be retained or enhanced and in what types of urban streams. This project set out to determine what biological values were suitable to attempt to retain or enhance in Auckland streams and to develop a classification process for the streams so that objectives could be applied to the appropriate streams.

Initial workshop sessions identified twelve potential biological objectives for fish and invertebrates in Auckland's urban streams. These ranged from objectives that were thought to be easily achievable (e.g., sustain shortfin eels) to ones that required good to high quality instream conditions (e.g., retain 6 EPT species). This then allowed the setting of higher biological targets for streams with better habitat and water quality.

Field surveys of 64 urban Auckland streams were carried out to assess the potential for each of the biology objectives to be achieved. The surveys also collected data on a wide range of habitat parameters for each stream. Eight fish species and 78 invertebrate taxa were found during the survey. The fish and invertebrate communities in each stream were analysed in conjunction with the habitat data to determine if different stream types with distinct stream communities could be recognised. Cluster and correlation analyses indicate that fish community structure was strongly related to stream slopes, stream size parameters and riparian vegetation parameters. The strong relationship between stream slope parameters and fish community was attributed to the varying ability of different migratory fish species to penetrate inland up different stream gradients. Water quality appeared to be more important in determining the invertebrate community structure. Habitat variables such as streambed substrate and habitat diversity parameters showed little relation to fish and invertebrate communities.

The stream classification developed from the survey recognised eight stream types. Nine of the original biological objectives were retained and one new objective developed. These were used to set the objectives for each stream type. It was important to recognise that each stream type had biological values associated with it and it is realistic to expect these are maintained, enhanced, or restored if absent.

Some stream types met a single biological objective whereas others fulfilled up to six different biological objectives. For each stream type management issues were identified that centred around the provision of the appropriate instream cover for fish and invertebrates, improving fish passage for migratory native fish and reducing water quality problems.

2 Introduction

Urban and other forms of development (e.g., dairy intensification, motorways) can result in deterioration of fresh-water receiving environments (Suren 2000). However, while the desire to mitigate adverse effects is a key feature of most city plans there are practical limitations to the extent to which these systems can be restored or protected given that urban land use activities are a permanent feature of the landscape. In the absence of an understanding of what level of protection for these watercourses is realistic, practical, achievable and sustainable, we risk promulgating policies that will raise unrealistic expectations and not achieve appropriate environmental objectives. The aim of this report is determine what biological values can be supported in Auckland's urban streams and link these biological objectives to stream types present in the urban area.

2.1 Urban impacts on freshwater systems

The alteration of land use from rural, or forest to urban is associated with major changes to the physical characteristics of streams and rivers. Urbanisation increases the amount of impervious surface area within a catchment and associated drainage systems quickly convey runoff to streams. Impervious surfaces also prevent rain from infiltrating into the soil layers and then to ground water. Instead the water drains rapidly off the impervious surface either directly to streams or to pervious areas. This leads to an increase in quick flow run-off, reduced water storage in ground water and hence lower base flows (Snelder and Trueman 1995, Moscrip and Montgomery 1997, Timperley and Kuschel 1999, Suren 2000). The change in hydrologic regime has also been shown to increase the frequency and depth of bed scouring, creating deeper or wider channel morphologies (Moscrip and Montgomery 1997, and references therein).

Urbanisation leads to a decrease in vegetation cover as roading and buildings replace forest and fields in catchments (Timperley and Kuschel 1999, Nagels 2000). Transpiration and evaporation from vegetated areas are known to decrease quick flow run off and hence reduce flood flows. Vegetation loss increases the impact of impervious surface run-off effects, with a loss of riparian shading the temperature regimes of streams are also altered (LeBlanc et al. 1997). More exposure to direct sunlight increases stream temperature, and a reduced base flow also allows more rapid heating of the stream during dry periods. Therefore, urban streams are more likely to attain temperatures detrimental to aquatic life. Finally, run off from urban areas carries pollutants and sediments generated from urban and industrial activities. These pollutants can have acute or chronic effects on aquatic life, while the inputs of sediments, especially fine particulate sediments, are known to reduce habitat quality (Timperley and Kuschel 1999).

In modified urban catchments engineering solutions are regularly used to contain the increased flows. Activities such as channel straightening, lining the stream and banks with concrete, culverting, and removal of instream debris are carried out to improve channel capacity and flow rate (Suren 2000). These drainage works decrease flow paths, increase water velocities and lead to more frequent bankfull discharge events. This physical alteration to the stream channel decreases the suitability of the stream for aquatic organisms. Habitat complexity that provides cover for fish and habitat for invertebrates is lost and pool and riffle habitats are removed. Barriers to the passage of aquatic organisms are also created. For example, weirs and culverts can prevent or restrict the upstream passage of fish and heated water discharges can create temperature barriers preventing dispersal of aquatic organisms.

The majority of streams within the Auckland urban area are contained within wholly urbanised catchments. The streams are also generally short with small catchment areas. This influences both base flow, and the size and frequency of flood flows. Urbanisation of whole catchments also means there is a lack of refuge areas within catchments for the retention of natural aquatic communities. Within Auckland's catchments the retention of sensitive, and desired aquatic species has to be achieved within a wholly urban environment. This requires that urban activities are managed, where possible, to avoid, remedy or mitigate the impacts of urban run-off and alteration to the aquatic habitats.

Stream management must consider and attempt to address the following impacts:

1 Flow variability. The change in flow regime with increasing urbanisation is characterised by increased flood intensity and decreased base flow.

2 Erosion/sedimentation. The increased input of sediment either during development of catchments or as a result of increased stream and bank erosion during peak flows.

3 Riparian vegetation loss. The loss of riparian vegetation that then decreases bank stability, aquatic habitat complexity, and stream shading.

4 Fish passage barriers. The construction of instream features that prevent the passage of fish (and other aquatic organisms) among areas of the stream.

5 Habitat alteration. Instream management that decreases the availability and quality of aquatic habitats, e.g. the loss of pools or riffles, or the loss of spawning habitats.

Furthermore, interactions among the various impacts in urban streams are not well understood. A lack of fish passage may be the only environmental problem that is easily remedied and the results of remediation will be predictable and measurable. It is not clear however how remediation of one urban impact will affect other impacts and in what order remedial action should occur.

The aim of this document is to provide a series of practical, realistic and achievable objectives for protection, and in some cases enhancement, of fresh water systems in urban areas of Auckland. This information will provide directions for the Air Land and Water Plan (ALW Plan) currently being developed by Auckland Regional Council (ARC), as well as numerous resource consent projects. Fresh water value protection is considered a critical programme element and the ARC therefore need to gain a better understanding of the environmental objectives and options that are appropriate in this regard.

2.2 Defining ecosystem properties and processes

The ecosystem is an abstract concept that encompasses the physical and biological components present in a habitat unit, and their interactions. Ecosystems can be defined at different scales depending on the properties and objectives being considered. For example, the capacity of a river to assimilate waste is a property dependent on catchment scale processes. In contrast, habitat of individual species may be constrained by properties of river reaches, which are determined by the processes operating at smaller scales. The problem then becomes one of subdividing ecosystems into coherent management units at scales that are appropriate for defining these properties.

A solution to this problem is to categorise ecosystems according to the physical factors that provide the context for their ecological processes. This approach emphasizes the use of characteristics that link physical factors to properties via processes at different levels of detail. For planning at regional scales it allows the grouping and mapping of environments into management units that share processes and other properties and ultimately, have similar goals and issues. The link from ecosystems to management units then comes at the level of processes that support ecosystem properties. The physically based classification system groups rivers into classes that define meaningful management units, and instream objectives have been developed through "expert" opinion to align with this classification.

An important paradigm that underpins the classification system is that of the river continuum concept (Vannote et al. 1980). This concept recognises that the physical variables at any point in a river reflect the integrated effect of controlling factors in the catchment above that point. Classification therefore changes moving down the river system as the proportions of various controlling factors change. Tributary streams may therefore have very different classifications to the main stems they meet, and tributaries may collectively change the classification of the main stem. McDowall (1996, 1998) also rightly indicates that while the river continuum processes act in an upstream to downstream direction New Zealand's widespread freshwater fish are diadromous and diversity and complexity is highest in coastal areas and decreases with altitude and inland distances. Therefore, when managing New Zealand's freshwater fish fauna there is a need to recognise that there are downstream to upstream processes to be accommodated.

3 Methods

3.1 Initial setting of instream biological objectives

Two one-day workshops were run at which expert NIWA and ARC staff assessed potential instream biological objectives for the Auckland urban area. In the assessment a number of factors were considered. These included the natural availability of habitat, the known occurrence of species in urban environments and potential physio-chemical limitations imposed by the local Auckland environment, including urban impacts (see above). The workshops resulted in the production of 12 initial instream biological objectives:

- Maintain banded kokopu populations
- Maintain giant kokopu populations
- Maintain adult inanga habitat and populations
- Maintain inanga spawning habitat
- Maintain eel populations, in particular the shortfin eel
- Maintain Crans bully populations
- Maintain diverse fish communities (five or more species constituting a diverse community)
- Reduce the spread of exotic fish
- Maintain diverse lowland invertebrate communities
- Maintain communities with at least 6 Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa
- Maintain invertebrate communities suitable for providing for fish diets
- Maintain koura populations

Fisheries objectives associated with riffle dwelling species such as koaro and torrentfish were not included due to the workshops conclusion that riffle habitat may be sparse in the Auckland urban area. Low base flow during summer was also identified as a potential limiting factor for riffle dwelling species, both fish and invertebrates. Storm-water run-off impacts associated with the increased frequency of flood flows and higher flood peaks, causing increased stream erosion and habitat disturbance were also noted as a major potential influence structuring freshwater communities. The objectives were designed to include some that were readily achievable even in the expected degraded conditions of the urban environment and others were considered more difficult to achieve, but attainable and indicative of good habitat conditions.

3.2 Stream survey

To assess the likelihood that the instream biological objectives could be achieved in urban Auckland, sixty-four stream sites were surveyed (Fig. 1a-d, Appendix I). The surveys were also designed to produce data for a stream classification method to which the biological objectives could be linked and to determine stream management needs to achieve the biological objectives.

At each site a 100-metre section of stream, where possible, was randomly selected to assess habitat, macrophytes and aquatic fauna. Habitat was assessed using a combination of a modified assessment protocol derived from the Auckland Regional Council's habitat assessment method (Maxted and Evans 2000, Appendix II) and standard stream survey techniques (Bain and Stevenson 1999). The extent of the riparian margin was scored for the following categories; riparian zone type, canopy cover, canopy height, canopy type, understory cover, understory type and understory height. Instream conditions were scored for the amount of stable habitat, diversity of habitats, hydrologic variation and bank stability. At ten cross-sections wetted widths, channel widths and five depths per cross section were measured. Substrate type was determined at up to ten points per cross-section, with reduced substrate counts streams too narrow to achieve ten samples. Macrophyte and algal abundance at each site was assessed for various forms of submerged, attached, and floating plants. Stream turbidity was visually estimated and the occurrence of fine sediment deposits estimated. Temperature, conductivity, pH and dissolved oxygen levels were measured at each site. Temperature data loggers (Onsett tidbits) were placed in 21 streams for between three and 30 days to collect information on temperature range and variation in various stream types. NZMS 260 series maps were used to determine site elevation and distance from the sea. The average stream gradient from the site to the sea was then calculated. The percentage impervious surface area in the catchment was obtained either from City Council databases, or map and aerial photographs. This data was only obtained for a subset of the sites (Appendix I).

Macroinvertebrate collections were made at each site except Newmarket Stream (site 37) where the concrete channel was not sampled. At each site the invertebrates were sampled at every stream cross section. Kick net samples (net mesh 500 µm) were collected at each cross section. The type of habitat sampled was recorded and rare habitats not sampled at cross section sites were also sampled. All the material collected at a site was combined and preserved in 70% alcohol for later sorting.

Macroinvertebrate samples were rinsed in a 250 µm Endecott sieve and placed into a white sorting tray, divided into 36 equal squares. A square was then randomly selected and all animals were removed for identification. This process was repeated until the target number of individuals was collected. An initial trial count of 300 individuals was made for 6 sites, but the target counts were subsequent reduced to 100 individuals. If the 100 mark was exceeded during the sorting of a square, all animals were still removed, counted and identified. After collection of the target number of animals the rest of the sample was sorted for "rare species", i.e. any species not previously encountered in the sample. The number of squares required to yield the target number of individuals was recorded to obtain an estimate of relative abundance. Animals were identified and enumerated with a 50x microscope using available keys (McFarlane 1951, Winterbourn 1973, Chapman and Lewis 1976, Cowley 1978, Towns and Peters 1996, Winterbourn et al. 2000). Following invertebrate identification taxa richness, the number of Emphemeroptera, Plecoptera and Trichoptera (EPT) species, Macroinvertebrate Community Index (MCI), and Urban Community Index (UCI) were calculated using formulae and taxon scores given by Boothroyd and Stark (2000) for each sample.

Fisheries observations were made at each site during habitat survey work, with the presence and absence of fish species noted. Electric fishing surveys were then carried out at each site either straight after macroinvertebrate sampling or two to three weeks later. At all sites at least 50 m of stream was sampled although the total area fished at each site varied, with larger areas fished in wider streams and sites with high habitat diversity (50-150 m2), small streams and low habitat diversity sites had smaller sampling areas (30-50 m2). Fish abundance was estimated as either absent, rare, occasional, common or abundant. The size range of fish present was also noted to distinguish sites dominated by juveniles from those with the whole range of expected size classes. For sites at which electric fishing was carried out two to three weeks after the habitat assessment any obvious changes to the riparian and stream parameters were recorded.

3.3 Data analysis

Fisheries data for each species was scored from 0-4 for the categories of absent to abundant. For individual fish species fish abundance data was examined for correlations with the habitat, physio-chemical and riparian parameters. The fish communities where then analysed using three clustering methods, Twinspan, K-means and self-organising maps (SOMs, Walley and Fontama 2000). Initial clustering runs with Twinspan were not constrained to a predetermined number of clusters, whereas later models the number of clusters was restricted to four to reduce the number of clusters with one or two samples site. SOMs were tested at three different clustering levels with the best grouping comprising five fish community groups. Two different fish communities were used in this analysis, native fish alone and native fish plus mosquito fish. The separate analyses were carried out as it was unclear whether the distribution of the introduced mosquito fish reflected its habitat preferences, or rather just the areas it has been released into and subsequently colonised. The fish community clusters produced were then used in discriminant functions analyses of the habitat data to determine if fish communities or individual species displayed particular habitat preferences. Data for the percentage of impervious surface area upstream of each sampling site was available for 38 sites (Appendix I) and was used in an analyses incorporating 35 sites (concrete channels and site 43 excluded) to test impervious surface area impacts as a surrogate for urban development.

For the 35 sites in the impervious surface area data-set the relationships between impervious area and MCI, UCI and taxa richness were regressed using linear regression. Number of EPT species was not included in the regression analysis due to the small data set available.

Figure 1a:

Sampling sites located on the North Shore (1-19).

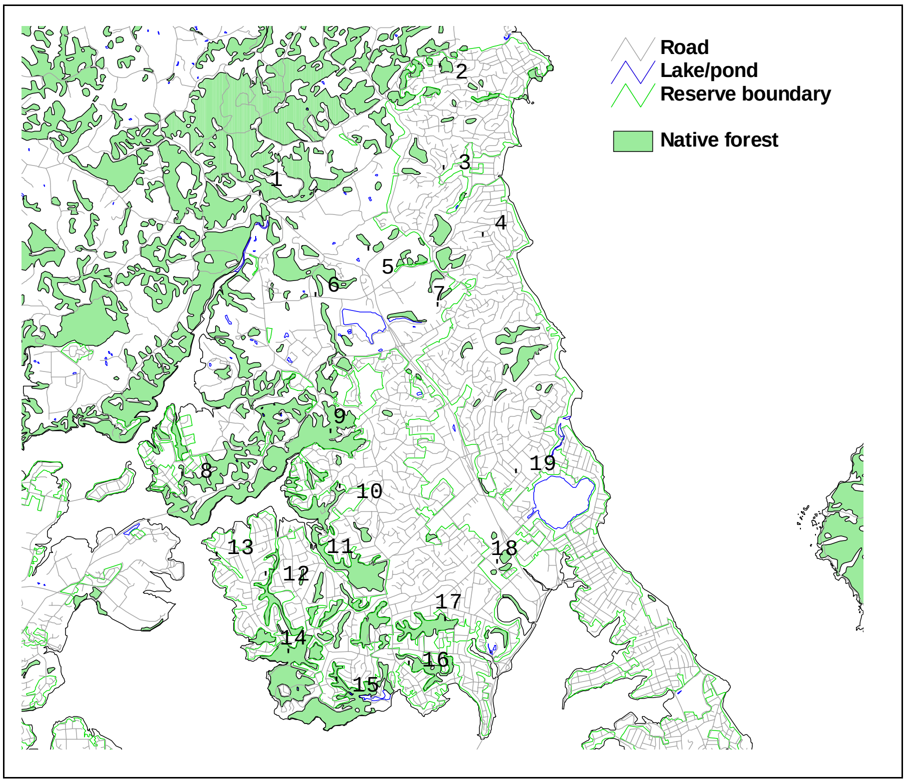


Figure 1b:

Sampling sites located in West and Central Auckland (20-35).

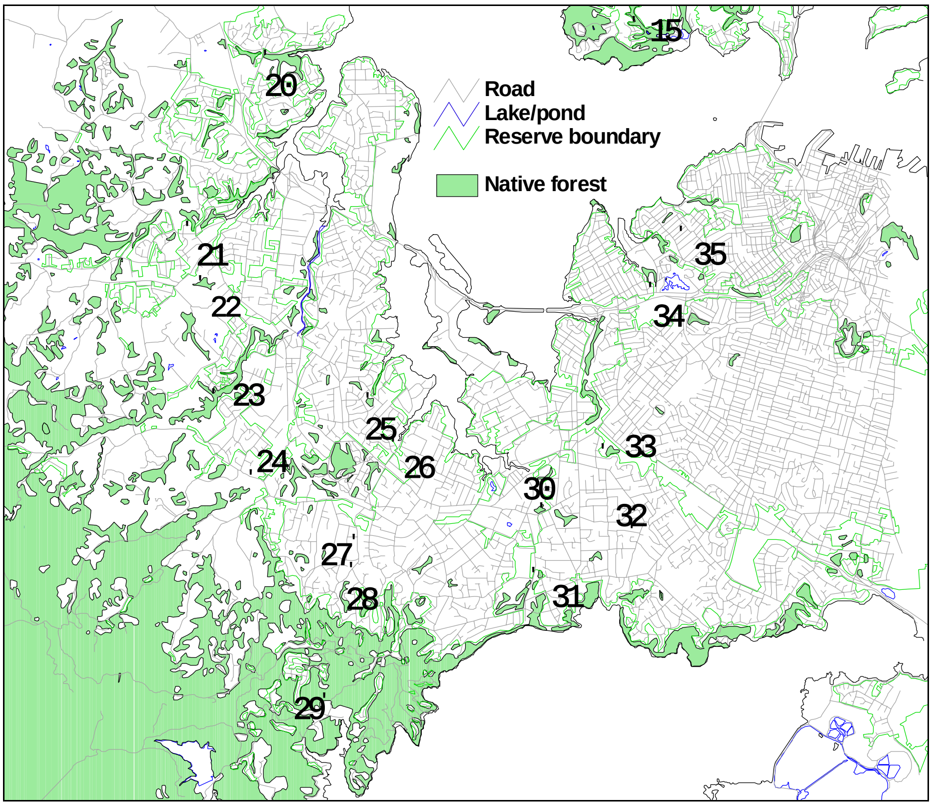


Figure 1c:

Sampling sites located in East and South Auckland (36-54).

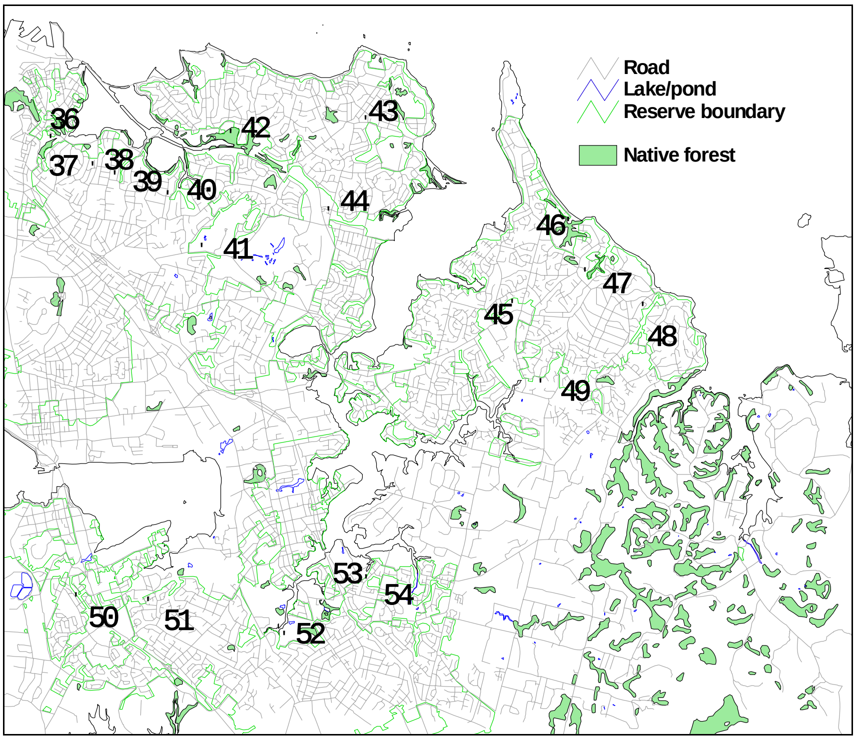
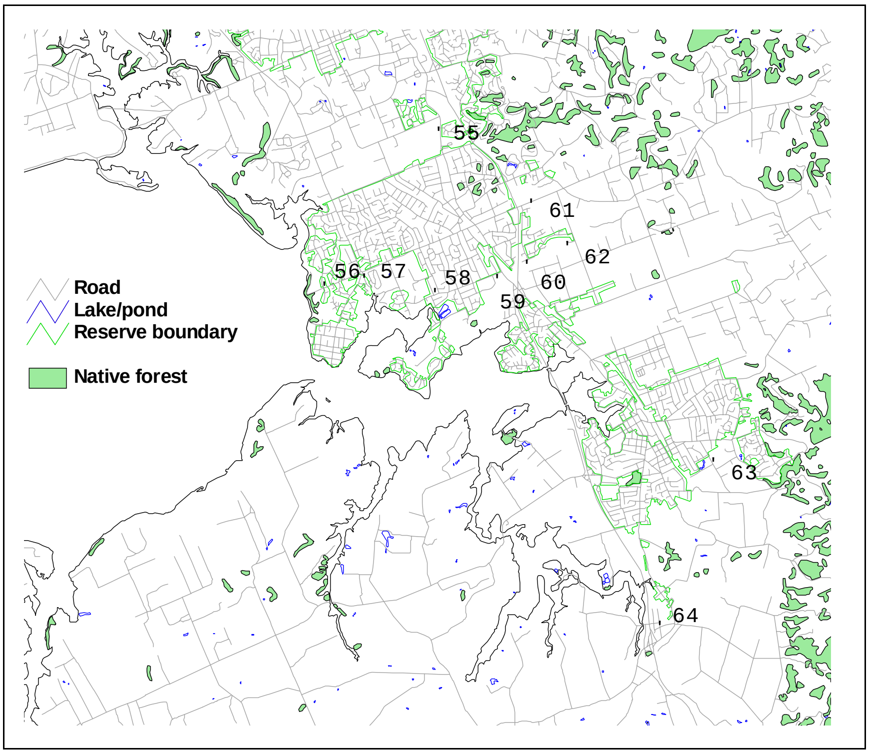


Figure 1d:

Sampling sites located in Manukau, Papakura, and Drury (55-64).



4 Results

4.1 Fisheries

Eight fish species were collected during the survey, with all species previously recorded in urban Auckland (New Zealand Freshwater Fish Database, Donovan et al. 1999). At seven sites no fish were collected. Five of these were concrete channels (sites 19, 37, 54, 55, 56), one a small first order stream approximately 40 m long with a very low dissolved oxygen level (0.6 g/l) (site 61) and the sixth an ephemeral stream (site 46). The species most commonly encountered was the shortfin eel (47 sites, 73%) and the other six species were: longfin eel (27 sites, 42%); common bully (16 sites, 25%); banded kokopu (15 sites, 23%); inanga (15 sites, 23%); mosquito fish (8 sites, 13%); redfin bully (6 sites, 9%) and common smelt (1 site, 2%) (Appendix III). Two fish species in the proposed biological objectives were not encountered during the survey, Crans bully and giant kokopu.

The number of fish species collected at a site ranged from no fish to five species. Fourteen of the sites had a single fish species present; shortfin eels at 13 sites and longfin eels at one site. Eighteen sites had two fish species present, with the two common combinations being shortfin eels and banded kokopu (8 sites), or shortfin eels and longfin eels (5 sites). Three species combinations occurred at 13 sites, with shortfin and longfin eel combinations with either banded kokopu, inanga or common bully accounting for 8 of these sites. The most common four species combination was shortfin eels, longfin eels, common bully, and inanga occurring at 4 sites out of 11. The single five species combination contained shortfin eels, longfin eels, common bully, redfin bully, and inanga. At all sites with fish at least one eel species was present.

The fish data would indicate that two communities could be used to indicate good or diverse freshwater fish communities in urban streams. In shady streams a shortfin eel, longfin eel, banded kokopu and redfin bully community should be considered high diversity. In open lower gradient streams a shortfin eel, longfin eel, common bully, inanga, and redfin bully community represents high diversity. Other migrant species such as common smelt, lamprey, giant kokopu, and giant bullies may occasionally occur and further boost community diversity. Mosquito fish was not included as a component of a diverse fish fauna because the fish is listed as an unwanted species, hence not a desired part of any stream fauna.

All the native fish species collected were migratory and are expected to recruit annually to Auckland streams. It is important to recognise that the availability of fish passage for the species and the presence of appropriate instream conditions will control their distributions.

4.1.1 Shortfin eel (*Anguila australis*)

The shortfin eel was the most commonly encountered fish at the sample sites. Densities were often high and fish of all size ranges were generally present. Lower densities were observed in areas where limited fish passage was suspected or were cover was limited. The only stream type that shortfins were always absent from was concrete channels. However the presence of large numbers of shortfins at sites such as Bryant Road (site 43) that is a reach upstream of a concrete channel indicated that elvers do successful migrate up the concrete channels. Shortfins also occurred in many areas upstream of culverted sections indicating little restriction in their ability to migrate upstream. Correlations with site parameters were most significant with riparian characters and site slope (Table 1). Streams with low water quality, including dissolved oxygen levels below 1 mg/l, and streams that at base flow consisted of a series of pools without flow contained shortfin eels. MCI scores and invertebrate taxa richness were both negatively correlated with shortfin eel abundance indicating this species is tolerant of polluted to highly polluted conditions.

4.1.2 Longfin eel (*Anguilla dieffenbachii*)

The longfin eel was widespread, but at no site was it abundant. This species was usually found in well-shaded streams with permanent flows, and it was absent from all streams with intermittent flow. Large individuals were encountered in some relatively disturbed streams if flood flow refuges were present indicating displacement during flood events does not always occur. No substrate preference was observed, but instream cover was important, with longfin eels generally utilising substrate and undercut banks for cover. This species was present in high gradient sites and upstream of significant lengths of culvert indicating a good upstream migration ability. However, longfin abundance was negatively correlated with elevation, macrophyte abundance and stream bank stability and positively correlated with dissolved oxygen levels (Table 1).

4.1.3 Common bully (*Gobiomorphus cotidianus*)

The common bully was common in streams entering the Manukau Harbour and occurred less frequently in North Shore streams. Large adult bullies were not present at some sites indicating survival was poor. These sites were generally areas where juvenile bullies were rare and may indicate unsuitable habitat or sites at the species' upstream range. With one exception, the common bully was found in streams with bedrock dominated substrates. It was also only found in sympatry with mosquito fish at one site. The presence of marcophytes did not exclude the bully, but the species did appear to prefer streams without high amounts of suspendable fine sediments. This was seen as distinct from clay bed or coarse sand streams where mobile fine sediments where uncommon. Common bullies were found a maximum of 7 km inland from the sea, but they only penetrated long distances inland in larger streams of relatively low gradient (e.g., site 27, 6.7 km upstream and site 62, 5.2 km upstream). Common bully occurred in streams that had permanent flow and its presence was positively correlated with mean channel width, mean wetted width, elevation and dissolved oxygen and an open canopy (Table 1).

4.1.4 Banded kokopu (*Galaxias fasciatus*)

Banded kokopu were usually located in streams where there was good overhead shade and riparian forest. Streambed substrate appeared unimportant and intermittent flow conditions were obviously tolerated. Very good condition, 20-22 cm long, adults were collected from pools in intermittent first order streams. Associated with the tolerance of low flows was a tolerance of lower dissolved oxygen conditions. Banded kokopu presence had strong positive correlations with site slope and stream gradient (Table 1). However, in high gradient streams with obvious flood flow disturbance the numbers of adult fish were low with the adults only occurring in areas with stable instream cover (e.g., undercuts and root wads). In these high gradient streams juvenile (0+) fish were often common, indicating good recruitment but poor survival possibly due to displacement in flood events. Banded kokopu were generally restricted to first order streams, but it is unclear whether this distribution reflects a stream size preference or the occurrence of the preferred shady riparian margins in these small streams.

4.1.5 Inanga (*Galaxias maculatus*)

Inanga occurred in a variety of streams in the survey, but most frequently in larger open streams at low elevation. Inland penetration was limited, except in the larger low gradient streams (e.g., Papakuru Creek site 62, 5.2 km upstream). Density was variable, but often large numbers of inanga (20s-100s) were observed. All the fish caught were in good to very good condition with large fish up to 100 mm often encountered. The fish showed no preference for particular streambed substrates, but was positively correlated with the presence of macrophytes (Table 1). Inanga were absent from all intermittent streams and from the higher gradient streams.

4.1.6 Redfin bully (*Gobiomorphus huttoni*)

Redfin bullies were rare, both in respect to their abundance and distribution. Furthermore, the fish encountered were often small indicating poor survival. This species is often considered to be a riffle dweller and its occurrence in the streams surveyed matched this habitat preference. Redfin bullies were collected in larger streams of low to moderate gradient at lower elevations. Riffle habitat with a rocky substrate had to be present in the stream before redfin bullies were located. However, not all rocky riffle streams had redfin bullies indicating other factors also restricted their abundance and distribution. Their geographic occurrence indicated that streams draining into both the Manukau and Waitemata harbours do receive redfin recruits.

4.1.7 Common smelt (*Retropinna retropinna*)

A single common smelt was collected in the lower reaches of Whau River (site 30). No conclusions about common smelt preference in Auckland streams were drawn from this single occurrence.

4.1.8 Mosquito fish (*Gambusia affinis*)

Mosquito fish was the only introduced species collected, and it occurred in very high densities in some streams. It appeared to show no particular preference for stream type, although it did appear more abundant in macrophyte dominated streams and was common at low altitude and low slope sites. Mosquito fish occurrence was correlated with habitat alteration, low habitat diversity, open riparian margins and fine sediments.

Table 1.

The five highest site parameter correlations with the common fish species abundance. Significant correlations (P < 0.05) are indicated in bold.

Species	Site parameters and Pearson correlation coefficients
Shortfin eel	**Canopy cover (-0.355), Bank stability (0.345), slope (-0.338), stream alteration (-0.291), canopy type (0.286)**
Longfin eel	**Elevation (-0.360), dissolved oxygen (0.294), riparian ground cover height (0.265)**, bank stability (-0.237), macrophytes (-0.203)
Common bully	**Elevation (-0.319), mean wetted width (0.318), mean channel width (0.305)**, dissolved oxygen (0.225), canopy type (0.224)
Banded kokopu	**Site slope (0.607), stream gradient (0.460), riparian canopy type (-0.440), riparian understory cover (-0.426), mean wetted width (0.415)**
Inanga	**Elevation (-0.496), mean wetted width (0.408), riparian canopy type (0.385), mean channel width (0.372) macrophytes (0.327)**
Redfin bully	**Stream alteration (0.274)**, riparian understory cover (-0.258), mean wetted width (0.231), mean channel width (0.227), elevation (-0.200)
Mosquito fish	**Habitat diversity (-0.567), canopy type (0.427), canopy cover (-0.343), alteration (-0.341), mud-sand stream substrate (0.340)**

It is important to note that site parameters correlated with fish species presence and abundance are often themselves correlated. This is most obvious with mean wetted width and mean channel width where both parameters increase together. Elevation is also negatively correlated with the width parameters as streams get larger in their lower reaches. Interpretation of the common bully, redfin bully and inanga correlations indicates that low altitude sites in larger streams are their preferred habitat. This conforms to the recognised limited migration abilities of these species.

Site slope, gradient, canopy type and mean width are also all correlated in the banded kokopu sites. The banded kokopu are common in small steep gullies that have not be converted to housing due to their steep nature, and hence retain a good canopy cover often of native bush. Given knowledge of banded kokopu distributions elsewhere in

New Zealand it is most likely that this species is selecting smaller streams in bush catchments and the correlations with site slope and stream gradient are a result of this habitat selection.

4.2 Macroinvertebrates

Seventy-eight macroinvertebrate taxa were identified from the 64 samples. The predominant taxa collected were Oligochaetes, molluscs (Potamopyrgus, Gyraulus and Physa) and dipteran larvae, especially three chironomid taxa (Chironomus, Cricotopus, and Polypedilum). The other notable species that was widespread but not as abundant was the damselfly Xanthocnemis. Other taxa that were locally abundant were crustaceans; the shrimp Paratya, amiphipods, and ostracods. Koura (Paranephrops planifrons), one of the species in the original biological objectives, was only located twice, both times as a single individual. EPT taxa richness was low, with these sensitive invertebrate taxa only occurring in 16 of the 64 sites (Table 2). Oxyethira, the pollution tolerant purse caddisfly, was present at sixteen sites (25%), but no more than six individuals were counted from any sample. Other more pollution sensitive taxa were considerably rarer, a total of 20 different EPT taxa were identified, three Plecoptera, ten Trichoptera and seven Ephemeroptera (see Appendix IV). Only one species, Triplectides obsoleta was relatively common with 99 individuals identified from six streams, all bush or urban boundary sites. The total number of individuals of any other EPT taxa collected was less than 30 and for 14 taxa below 10. Three sites (sites 9, 14, 24) had more than 6 EPT taxa, the first two sites are bush reserve areas in Birkenhead and the third an urban boundary site.

MCI scores for the 64 sites ranged from 119 to 40 with a mean of 64. The majority of the sites were ranked as "probably severely polluted" (scores between 40-80); based on interpretation of scores provided by Stark (1998) (Fig. 2). Sites with very low MCI scores included all the concrete channel sites and sites that had obvious sewage inflows (e.g., sites 52 and 53). Conversely the top ten sites had scores between 119 and 89. These top ten were all sites with native forest riparian zones or urban boundary sites that contained EPT taxa. UCI scores ranged from 17.95 to -7.91 and a significant positive regression relationship existed between the two indices (F-ratio 65.23, $P < 0.0001$). Concrete channels and a site immediately downstream from a concrete channel appear to be outliers in this relationship (Fig. 4) and UCI scores were relatively high compared with MCI scores at these sites.

Table 2.

Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa occurrences.

Site	Ephemeroptera	Plecoptera	Trichoptera (excluding *Oxyethira*)	% impervious area upstream of site
1	-	-	1	20
9	5	1	5	10
10	-	-	1	36
11	-	-	3	30
12	-	-	2	35
13	-	-	1	40
14	3	2	5	-
16	-	-	1	35
21	1	-	2	15
23	2	1	1	20
24	4	-	3	15
29	1	-	1	40
33	-	-	1	40
42	-	-	2	35
55	-	-	1	-
64	1	-	2	-

Invertebrate taxa richness at individual sites ranged from 25 to 2, with a mean of 10 taxa, and invertebrate richness was strongly correlated with the MCI score (Pearson correlation = 0.67, Fig 5). MCI score also showed some correlation with stream alteration (Pearson correlation = 0.50), bank stability (Pearson correlation = -0.40) and stream slope (Pearson correlation = 0.39). Taxa richness also showed a weak correlation with bank stability (Pearson correlation = 0.39). Neither the MCI scores nor the taxa richness showed any correlation with possible poor water quality indicators such as dissolved oxygen levels and the proportion of fines in the substrate.

Figure 2.
MCI scores for 63 sites in urban Auckland.

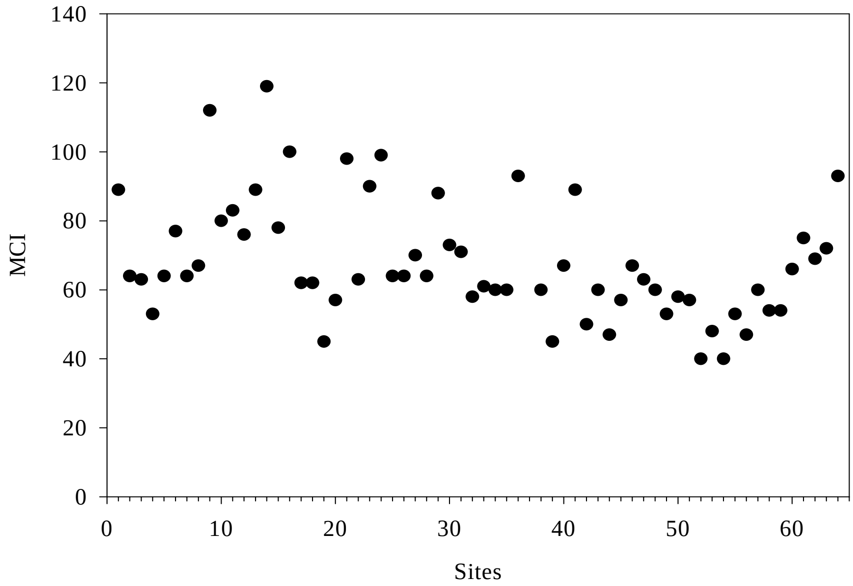


Figure 3.
Invertebrate taxa richness from 63 urban Auckland sites.

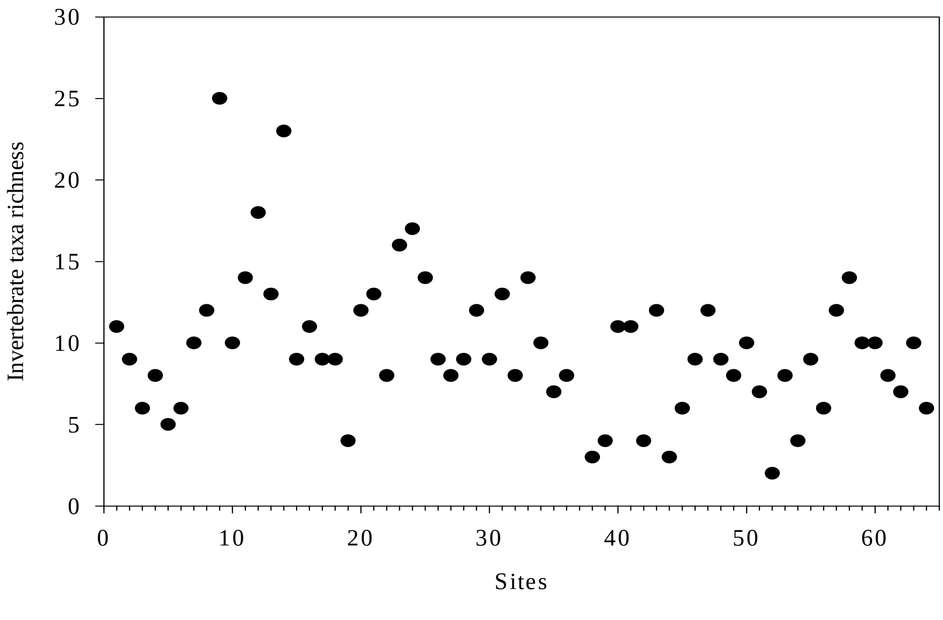


Figure 4.

UCI and MCI scores for 63 urban Auckland streams, circles indicate stream sites, triangles are concrete channels and one site immediately below a concrete channel.

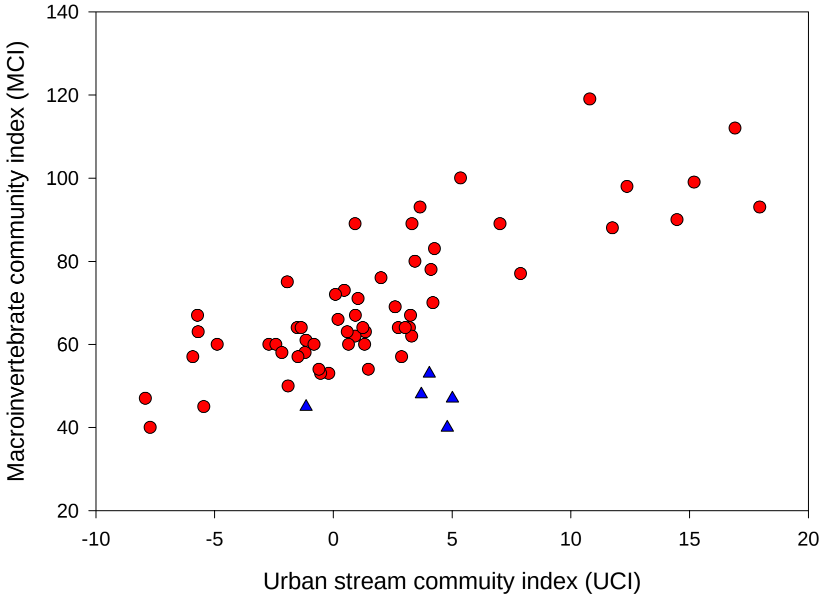
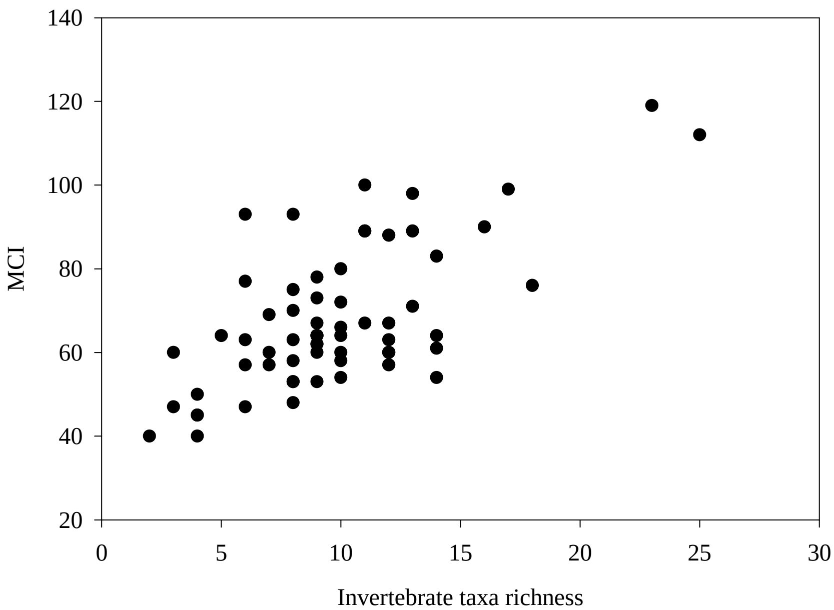


Figure 5.

Invertebrate taxa richness and MCI scores at 63 urban Auckland sites.

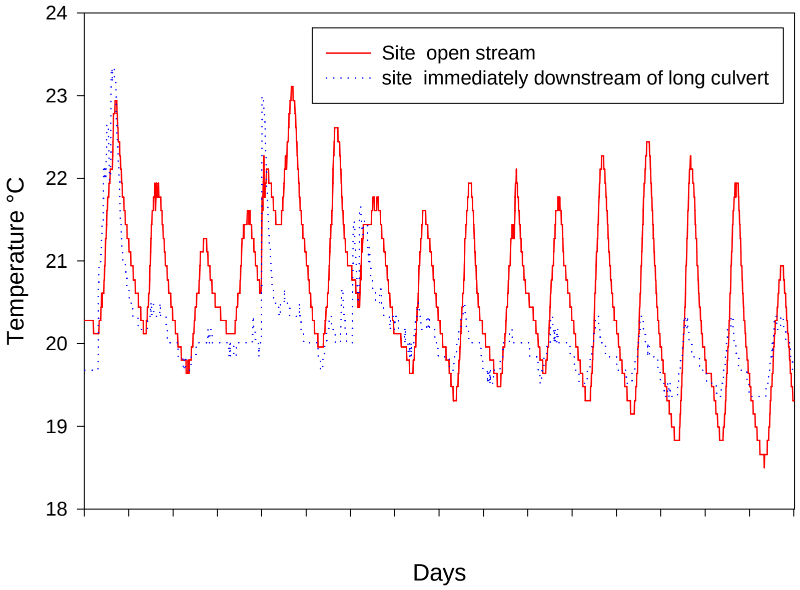


4.3 Water temperature

Water temperature monitoring results from the 21 monitored sites in February and March detected large differences in the temperature regimes. Maximum temperatures in streams ranged from 27.2 to 18.7°C and minimum temperature ranged from 17. 3 to 15.1°C. Given the time of year monitoring was carried out these maximum temperatures are likely to be close to if not the maximum yearly temperatures experience in these streams. Only two streams monitored (sites 3 and 33) had a maximum temperature greater than 24°C. Both were open unshaded channels, with site 3 being particularly small and shallow. Temperature range during diurnal fluctuations ranged from 2.7 to 11.7°C. Again sites 3 and 33 had very high diurnal temperature ranges both over ten degrees. At all other sites the difference among sites for maximum temperature was 6.1°C or less. Forested catchments were cooler, especially minimum temperatures, although streams with substantial piped inflows were also cool and had relatively limited temperature variation (Fig 6). Maximum water temperatures at all but one of the monitoring sites exceeded the indicative preferred levels of Plecoptera (19°C, Quinn and Hickey 1990). Similarly, seven streams exceeded the indicative preferred temperature for Ephemeroptera (21.5°C, Quinn and Hickey 1990). The preferred temperatures of three of the common fish species were also exceeded in most streams (banded kokopu 17.3°C, inanga 18.1°C and common bully 20.2°C, Richardson et al. 1994). For common smelt the water temperatures were regularly above the preferred level of 16.1°C (Richardson et al. 1994) and some streams were always above this preferred level. Water temperatures all sites except 3 and 33, did not exceed those preferred by shortfin and longfin eel. At sites 3 and 33 temperature only occasionally exceeded the preferred temperatures (shortfin eel 26.9°C and longfin 24.4°C, Richardson et al. 1994). However, at no sites did the water temperature exceed known lethal levels (Richardson et al. 1994) for any of the fish species found.

Figure 6.

Temperature records for the period 17/2/01 to 5/03/01 for two streams, both unshaded but one with an open upstream area and one with the upstream reach in a culvert.



5 Fisheries Values

Auckland urban stream support populations of four commercial and recreational fisheries species. Shortfin and longfin eels are major commercial fisheries and the Auckland stocks have considerable value. It is unlikely that the urban area stock is commercially fished to any degree but it does form an important breeding stock reservoir. Areas of New Zealand that retain unfished stocks of eels have a significant role in providing the breeding stock that provides recruits to all New Zealand rivers and supports the commercial fishery. Given that 88% of the sites fished in this survey contained eels and often in high abundance the retention of these stream habitats is important.

Recreational fisheries in the Auckland urban area are probably limited if they exist, but the urban streams support stocks of inanga and banded kokopu, both whitebait species. One or other of these whitebait species was found at 47% of the urban sites and they represent an important component of the Auckland freshwater fish community. The retention of these populations is important for two reasons. Firstly, in a similar fashion to the eels the resident adult stocks help support recruitment to other streams and contribute to the whitebait fishery in rural areas adjacent to Auckland. Secondly, the urban Auckland populations provide a stepping stone link between northern populations of whitebait and populations to the south. As dispersal distances for these species are unknown the retention of populations in the urban Auckland region helps guarantee continuity of the New Zealand wide stocks by ensuring the northern populations do not become isolated.

6 Stream Classification

Prior to fish community analysis six sites were excluded from the analysis, the five concrete channels without fish and the ephemeral stream site that also had no fish present. The concrete channels and ephemeral stream were identified as distinct stream types for the stream classification at this time. Fish community analyses using Twinspan, K-means and SOMs all produced two distinct communities, separating sites with and without banded kokopu. Sites with banded kokopu could be separated further into those with longfin eels and those with shortfin eels. Sites without banded kokopu could be easily divided into communities containing either inanga, or common bully or both species with shortfin eels.

Discriminant function analysis of the resultant clusters from the analysis indicated different significant parameters in the site data for predicting fish community structure. Twinspan analyses indicated the important habitat variables for predicting native fish community structure (ie. mosquito fish excluded from the analysis) were in order of importance; site slope, bank stability, riparian zone type, riparian ground cover type. Streambed substrate values, macrophyte abundance, riparian canopy height and riparian canopy width were all poor predictors. Twinspan analysis results for fish communities including mosquito fish indicated important habitat variables were, in order of importance; site slope, overall stream gradient, riparian ground cover height and habitat diversity.

The K-means clusters (without mosquito fish) when analysed using discriminant functions found that site slope, canopy type, riparian understory, riparian canopy cover and stream alteration were the five most important habitat parameters. For the fish communities including mosquito fish the most important habitat parameters were site slope, bank stability, overall stream gradient, riparian canopy type and riparian canopy cover. Stream substrate parameters, dissolved oxygen levels, riparian canopy height and riparian ground cover height were all very poor predictors of the fish community.

The discriminant functions analysis of the SOM clusters for the native fish community determined that site slope, site altitude, overall stream gradient, mean width and stream alteration where the most important site parameters. For the fish community including mosquito fish riparian ground cover height, canopy type, site altitude, site slope and riparian zone type where the most important site parameters. As with the other two cluster methods the stream bed substrate, hydrologic variability, riparian canopy width, and stable habitat had little predictive value.

The predictive power of the discriminant function models produced ranged from 70 to 91%. Fewer community clusters increased the predictive power at the cost of reduced discrimination. Jackknifed classifications had a reduced predictive power, usually reducing predictive power of any model by between 20 and 30%. All models also required more than ten parameters to attain the higher predictive success rates.

6.1 Impervious surface area analysis

The sub-set of 35 sites was re-analysed to investigate the influence of impervious surface area on the fish community and invertebrate fauna. The initial correlation analysis was repeated and the impervious surface area had a significant correlation with longfin eel (Table 3).

Table 3.

The five highest site parameter correlations in the impervious surface area analysis with the common fish species, significant correlations ($P < 0.05$) are indicated in bold.

Species	Site parameters and Pearson correlation coefficients
Shortfin eel	**Canopy cover (-0.458), Gravel (-0.434)**, inland (0.328), canopy type (0.359), stream alteration (-0.310),
Longfin eel	**Elevation (-0.466), impervious (-0.464)**, stream gradient (-0.279), mean wetted width (0.270), riparian canopy width (-0.269)
Common bully	Mean channel width (0.330), elevation (-0.298), slope (-0.271), bedrock substrate (-0.244), mean wetted width (0.318)
Banded kokopu	**Site slope (0.684), stream gradient (0.412), mean stream depth (-0.406), mean wetted width (0.415), riparian canopy type (-0.347)**
Inanga	**Elevation (-0.428)**, riparian canopy height (-0.284), riparian zone type (-0.284), dissolved oxygen (0.280), gravel (0.227)
Redfin bully	Elevation (-0.317), mean wetted width (0.301), Stream alteration (0.292), riparian understory cover (-0.291), , mean channel width (0.274),
Mosquito fish	**Habitat diversity (-0.526), stable habitat (-0.498), canopy type (0.422), canopy width (-0.349)**, gravel (-0.265)

The correlations are generally similar to the initial analysis with relationships between stream gradient, stream size and riparian conditions being common. Some results are unexpected, the longfin eel is negatively correlated with elevation and stream gradient. This result is unusual as this species is a strong migrant and very common inland and at altitudes much greater than the Auckland urban area (New Zealand Freshwater Fish Database).

The cluster analyses and discriminant function analyses when repeated, showed again that stream substrate had little influence apart from rubbish and gravel in one clustering trial each. Dominant factors were stream slope parameters, elevation and riparian vegetation parameters. One Twinspan model did score impervious surface area as the second most important predictive parameter behind site slope. The discriminant ability of the discriminant functions produced was varied, most had high prediction success rates for the data set used, but jackknifed functions were very poor, often with less than 30% of the sites predicted correctly. Predictive power was improved if the fish community structure was limited to four groups and the influence of impervious surface area declined in these discriminant functions.

For the macroinvertebrate communities the impervious surface area regressions with the invertebrate MCI scores, UCI scores and taxa richness produced significant negative relationships (MCI regression, F-ratio = 17.178, $P < 0.001$ $R2 = 0.342$; UCI regression, F-ratio = 21.034, $P < 0.001$ $R2 = 0.389$; taxa richness regression, F-ratio = 22.5, $P < 0.001$ $R2 = 0.405$) (Fig. 7). However, the invertebrate abundance class regression was not significant (F-ratio 2.669, $P = 0.112$ $R2 = 0.075$) (Fig. 8). This would indicate that while sensitive invertebrate taxa are absent from urban streams the tolerant taxa can occur in high densities. The EPT taxa richness also showed a rapid decline with increasing impervious surface area (Fig. 9).

Interpretation of the correlations and discriminant function analyses results provides a good indication of important habitat features for each fish species (Table 4). This information together with knowledge of the ability of fish species to migrate inland can be used to set the appropriate biological objectives for streams.

Table 4.

Fish habitat preferences and migration ability.

Species	Substrate	Permanent or intermittent flow	Type of instream cover	Riparian shade	Migration ability
Shortfin eel	No preference	No preference	No preference	No preference	Very good
Longfin eel	No preference	Permanent	No preference	No preference	Very good
Common bully	Little suspendable fines	Permanent	No preference	No preference	Limited
Banded kokopu	No preference	No preference	No preference	Good shade required	Very good
Inanga	No preference	Permanent	No preference	No preference	Limited
Redfin bully	Cobble	Permanent	Substrate/ wood debris	No preference	Moderate
Mosquito fish	Shallow water, macrophytes	No preference	No preference	No preference	Very limited

Figure 7.

Impervious surface area relationships with invertebrate UCI scores, MCI scores and taxa richness for 35 urban Auckland sites. The relationships excludes concrete channel water courses.

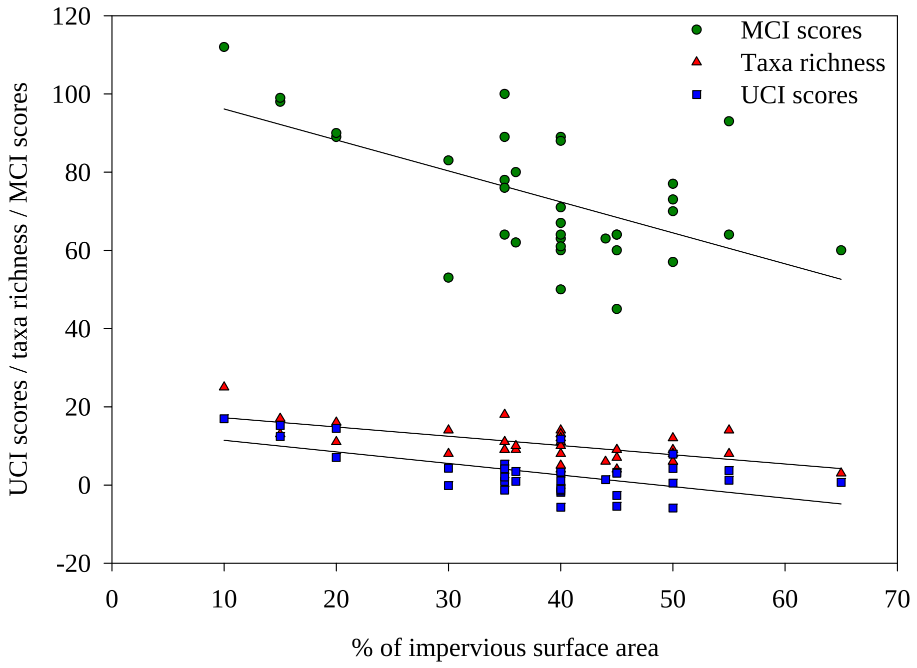


Figure 8.

Invertebrate abundance class impervious surface area plot, including concrete channel streams.

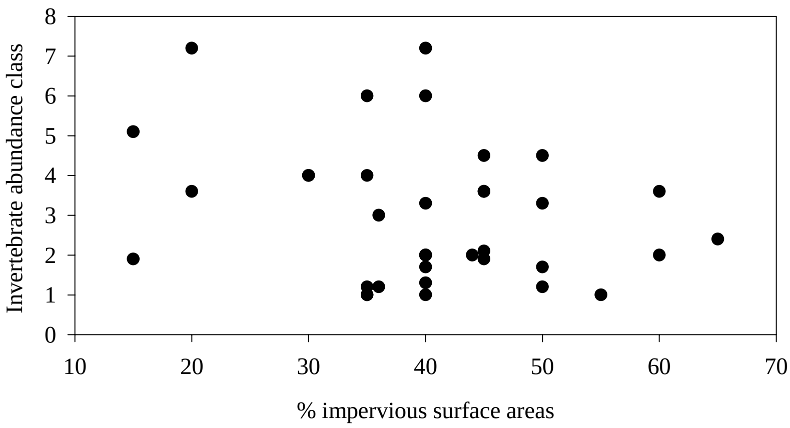
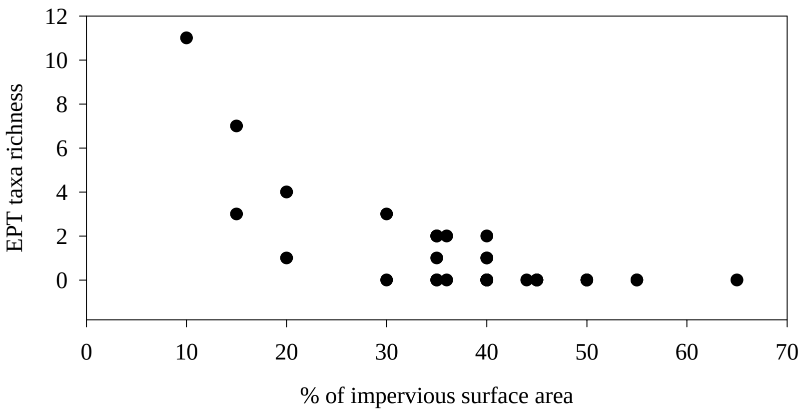


Figure 9.

Impervious surface area EPT taxa richness for 35 urban Auckland streams, the plot excludes concrete channel water courses.



6.2 Stream classes

Without any data analysis three stream classes can be identified with little difficulty, concrete channels and ephemeral streams form obvious classes that fulfill none of the initially proposed biological objectives. A third stream category would be estuarine zones, that while not examined specifically in this field study, are important as inanga spawning habitat.

The over-riding theme in the correlation analyses and discriminant function analyses were the site slope, site elevation, overall stream gradient, stream size (wetted and channel width) and riparian parameters associated with stream canopy cover and understory cover. The predictive power of site slope and elevation is not surprising given the migratory nature of the fish fauna. It has long been recognised that the distribution of New Zealand's migratory fishes is related to the individual species' ability to migrate inland (McDowall and Taylor 2000, Joy et al. 2000). This together with the above-mentioned correlation between elevation and stream size makes these parameters relatively powerful predictors of fish occurrence. Chadderton and Allibone (unpub. data) also found that the native fish in the undisturbed streams of Stewart Island had distinct preferences for stream gradients. Maximum gradients ascended by different fish species and preferred gradient occupied can be evaluated. Given that the Auckland stream data supports gradient, elevation and site slope as relatively good predictors of occurrence a gradient/site slope rule was used to define some stream categories.

6.3 Biological objectives unlikely to be possible in urban streams

One of the initial biological objectives does not appear possible in the urban Auckland streams. Maintenance of koura populations is unlikely to be achieved under present conditions. Single koura were collected at two sites during this survey, Swanson Stream, site 21 and Opanuku Stream, site 23 (Appendix III). Both these sites are on the present urban boundary and have comparatively little urban land use occurring upstream. Given the environmentally sensitive nature of this species it is unlikely that populations will persist in urban streams.

The Crans bully objective also appears unlikely to be possible in urban streams. None were encountered during survey work although populations do occur on the periphery of the urban zone. However, at present is it not possible to determine whether their absence is due to either a natural lack of their preferred habitat or to the impacts of urbanisation.

The giant kokopu objective is possible in urban streams, individuals have been collected, albeit very rarely. Recruitment from outside the urban area is possible and streams with good water quality and riparian cover may retain this species in small numbers. Restrictions due to habitat preference (Appendix IV) may restrict the fish to lower reaches of low gradient streams.

Maintaining invertebrates suitable for fish food also appears to be an un-necessary objective. All populations of fish appeared to contain large, well-fed individuals indicating that food was not a limiting factor, hence the objective is being achieved without any action being required.

7 Stream Classes

Eight stream class were defined:

1. Estuarine area
2. Concrete channels
3. Highly disturbed streams
4. Low gradient coastal streams
5. Restricted fish passage streams
6. Steep forested streams
7. Degraded water quality streams
8. Ephemeral streams

7.1 Stream type 1: Estuarine areas

This stream class includes all tidal estuaries apart from steep streams flowing into the sea without any appreciable tidal zone.

7.1.1 Biological objectives possible in estuarine areas

Inanga spawning habitat is contained within certain estuarine areas and is readily managed. Retention of undisturbed vegetated areas will provide suitable habitat for inanga spawning. The initial steps for management are the confirmation of adult inanga in a catchment and then the spawning sites need to be located. (see Appendix IV, Mitchell and Eldon 1991 for methods). The standard management procedure for inanga spawning sites is to prevent disturbance and maintain a bank of rank introduced grasses or native vegetation in the upper tidal zone. Protection is especially important from late summer to mid winter when the bulk of inanga spawning occurs.

7.1.2 Estuarine area sample sites

None.

7.2 Stream type 2: Concrete channels.

Concrete channels are all streams where the bed and banks of the stream are formed by concrete. Channels can be an open shallow V shape or rectangular in cross-section (Fig. 10). This category does not include streams with any form of reinforced concrete banks and a natural streambed. There are no restrictions on stream size in this category. Water depth is likely to be very shallow at base flow (Fig. 10). This may restrict the movement of large fish or those requiring deep water to migrate (possibly common bully and inanga). For elvers shallow water will provide fish passage and good examples of elver passage were located in Auckland.

Figure 10.
Janese Park Stream (left), Otara Creek (middle) and Wairau Creek (right) concrete channels.
Note, no natural instream cover and little or no riparian shading, but fish passage is available.

7.2.1 Biological objectives possible in concrete channels

Maintain fish passage for eels, banded kokopu, inanga and common bully. There is no expectation that resident fish will be present in concrete channels. Eels may take up residence in area where the concrete channel has been broken, where instream rubbish provides cover or where water depth substitutes for cover (especially in turbid areas). Residence by any fish species will be limited by temperature tolerance during summer base flow periods.

Remedial action to provide improved habitat for fish and invertebrates to support the proposed biological objectives must aim to reduce instream water temperature (ie. provide stream shading), provide instream cover appropriate for fish and invertebrates (possibly cobble boulder substrate cemented into the concrete stream bed) and increase water depth at base flow. Placement of any stable cover forming substrate in the stream channel will allow shortfin eels to colonise the channels. Examples of short sections of concrete channel with cover were found and shortfin eels were common to abundant at these sites (e.g., site 42).

The shallow water present in many concrete channels at base flow presents one biological risk. Predation of elvers occurs in shallow streams and fish passes (Boubée et al. 1998). The urban concrete channels will provide good opportunities for rats and birds to prey upon migrating fish. The lack of cover will most certainly reduce the ability of the migrating fish to avoid predation.

7.2.2 Concrete channel sample sites

Wairau Creek site 19; Newmarket Park Stream site 37; Otara Creek 2 site 54; Puhiuni Stream site 55 and Janese Park Stream site 56.

7.3 Stream type 3: Highly disturbed streams

Highly disturbed streams are streams in which the stream banks and bed are obviously eroding (Fig. 11), stable habitat appears limited if present, and a highly mobile bed is likely to be present. There is no size restriction for disturbed streams. The stream may be turbid even at base flow. Disturbed streams are likely to be of moderate to steep gradient (2% gradient or greater) and have storm-water inputs from highly urbanised areas with high levels of impervious surface area (possibly greater than 45%) in the catchment. Disturbed streams will be difficult to distinguish from steep forested streams (stream type 6) that are eroding. Decisions on stream classification for such cases may be made using in stream biota. Macroinvertebrate indices such as UCI, MCI and number of EPT species are considerably less in disturbed streams than the steep forest streams. EPT taxa are expected in forest streams and the MCI score should be greater than 80 and the UCI score greater than zero. These criteria should only be used to classify streams in doubt due to their erosion condition. There is the possibility of incorrect classification if undetected pollution events has removed pollution sensitive taxa in a forest stream.

7.3.1 Biological objectives possible in disturbed streams

Disturbed streams may support small populations of shortfin eels, but other fish species are unlikely. Similarly macroinvertebrate abundance and species richness will be poor and MCI and UCI scores will indicate a polluted stream. Fish passage at base flow is possible and it is likely that strongly migratory species utilise disturbed channels as pathways to less disturbed habitats in the upper reaches or tributaries.

Restoration activity must determine if the disturbance regime is natural or driven by the processes associated with urbanisation. Storm-water run-off is highly likely to cause erosion problems in steeper catchments. If the stream has a high bed load of fine sediments, locate the sediment source. If it is derived from the eroding stream banks it may not be possible to reduce inputs. However, if the sediment is transported into the stream by the storm-water, then control at source may be possible. Measures to reduce the instream water velocity or delivery rate of storm-water to the stream would be appropriate to reduce the high energy environment in the stream.

7.3.2 Disturbed stream samples sites

Manutewhau Stream, site 20.

Figure 11.
A highly disturbed stream Manutewhau Stream. Habitat for a small number of shortfin eels.

7.4 Stream type 4: low gradient coastal streams

Low gradient coastal streams (Fig. 12) are unrestricted in size, but natural and artificial stream channels can be separated. Classification criteria are that there must be unimpeded fish passage from the sea, downstream areas must have slopes no greater than 1.5% or the site must be within 50 m of the sea. By definition this class of stream cannot be upstream of either a steep forested stream or an impeded fish passage stream.

For management purposes these streams could be separated into fine sediment (mud to sand) dominated streams and coarse sediment (gravel to bedrock) dominated streams. Erosion of stream banks should be localised if present, and the banks well vegetated in unmanaged areas. Stream shading in this category will be variable, with shade naturally declining as stream size increases. Fully shaded small streams in this category may be rare, due to urban development. It is likely that stream appearance in residential areas is highly variable as streamside management changes with individual property owners. This uncontrolled management will influence instream communities.

7.4.1 Biological objectives possible in low gradient coastal streams

Low gradient streams provide habitat for all of the freshwater fish in the Auckland urban area. Inanga, common smelt and common bully are found exclusively in this class of stream. These species are weak migrants that have a limited ability to ascend steeper gradients and are therefore restricted to the low gradient lower reaches of stream and rivers. Shortfin eel, longfin eels, banded kokopu and redfin bullies were all found in some of the low gradient streams and giant kokopu is another possible inhabitant.

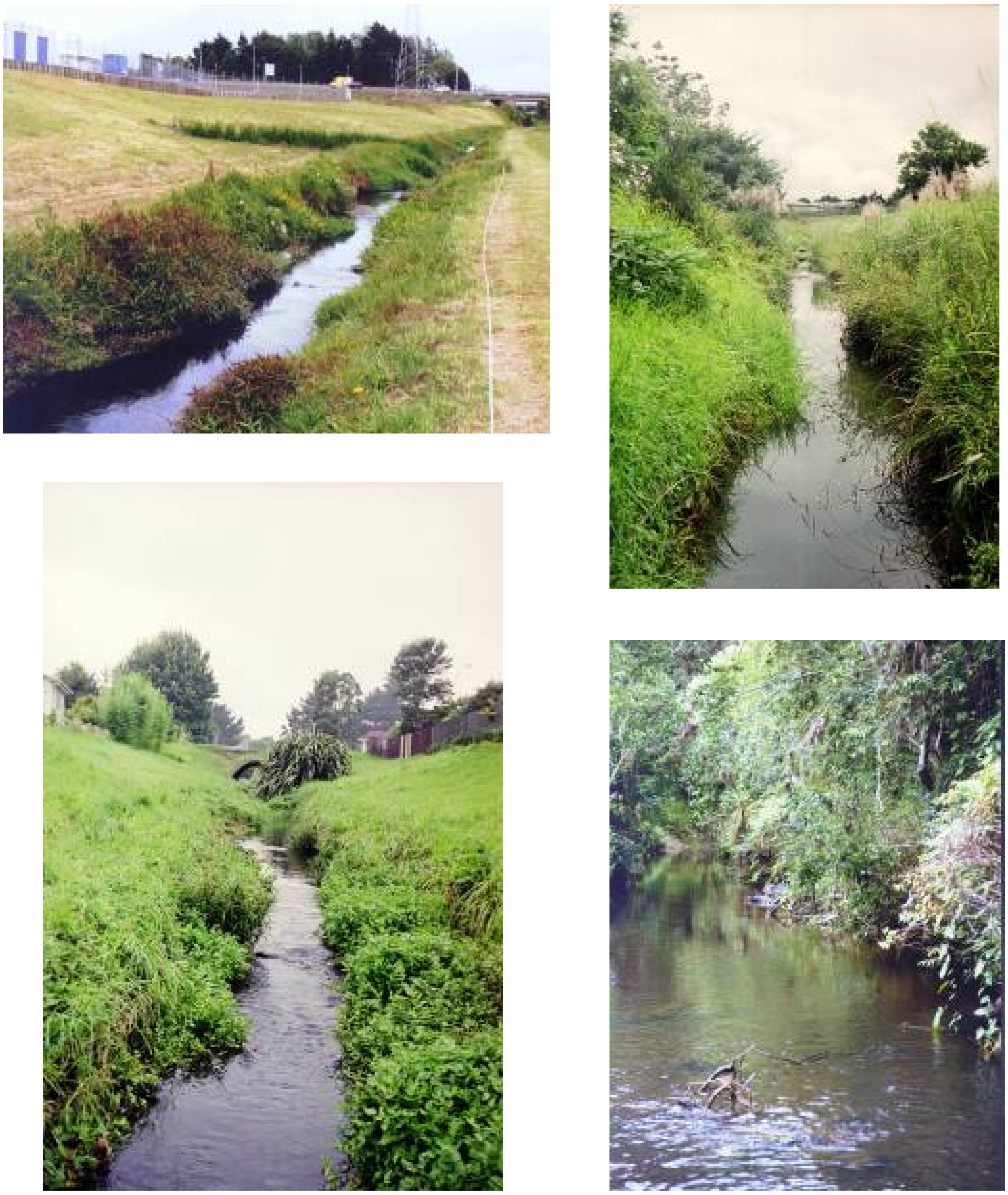
The low gradient streams provide the habitat for five or possibly six biological objectives; sustain giant kokopu; sustain adult inanga; sustain shortfin eels; maintain a diverse fish community, sustain 6 or more EPT taxa and maintain a diverse lowland invertebrate community. In the context of the Auckland urban environment a diverse fish community would be four or five fish species and for invertebrates greater than ten taxa. Management action should seek to reduce suspended sediment supply in streams recognised to contain high fine sediment bed loads, and seek to retain rank grass, shrubs, trees and flaxes along the stream margin to provide some shading and habitat diversity. Riparian vegetation is important habitat for adult stream insects (Collier and Scarsbrook 2000) and nectar providing species could be planted. Retention of undercut banks and instream wood debris should be promoted to maintain fish and invertebrate cover diversity. Bank reinforcing on eroding stream bends should be allowed, especially if this reduces fine sediment inputs. Complete removal of macrophytes in macrophyte dominated channels will lead to declines in fish abundance and retention of at least some macrophytes (20% cover) is recommended if macrophyte control is carried out. Base flow conditions in summer will be a significant factor influencing the aquatic community structure diversity and abundance will decline as water temperature increases and dissolved oxygen levels decreases (See fish species and invertebrate requirements in Appendix IV).

7.4.2 Low gradient coastal stream sample sites

Awaruku Stream site 2; Taiotea Stream site 3; Murrays Bay Stream site 4; Kaipatiki Stream 1 site 10; Kauri-Glen Reserve Stream site 17; Un-named Stream 3 site 18; Swanson Stream site 21; Paramuku Stream site 22; Opanuku Stream site 23; Oratia Stream site 24; Sabulite Road site 26; Waikumete Stream site 27; Bishop Stream site 28; Waituna Stream site 29; Whau River site 30; Un-named Stream 4 site 31; Un-named Stream site 32; Oakley Creek site 33; Motions Creek site 34; Omaru Creek site 44; Pakurunga Stream site 45; Pakuranga Stream trib. Site 49; Tararata Creek site 50; Un-named Stream 9 site 51; Otara Creek 1 site 53; Un-named Stream 10 site 57, Waimania Creek site 58; Papakuru Stream 1 site 59; Papakuru Stream 2 site 60; Papakuru Stream site 62; Slippery Creek site 63; Hingaia Stream site 64.

Figure. 12

Low gradient coastal streams, Papakuru Stream (top left), Un-named Stream 13 (top right), Waimania Creek (bottom left) and Opanuku Stream (bottom right). All streams contained inanga, common bully and shortfin eels; redfin bullies, longfin eels and mosquito fish were also present in some streams.



7.5 Stream type 5: Restricted fish passage streams

Restricted fish passage streams are defined as all streams above artificial barriers to fish passage and stream sections upstream of areas with slopes greater than 1.5% over 50 metres. Streams can be either natural channels or modified channels, stream size is unrestricted and flows either permanent or intermittent (Fig. 13). Streambed substrate is highly varied, as is the presence of macrophytes. Two sub-categories of this stream type are present, a) fish passage restrictions formed by a natural feature (e.g., waterfall, bedrock chute), or b) fish passage restriction formed by an artificial barrier (e.g., culvert, weir). The distinction between the two sub-categories recognises that the artificial fish passage restrictions can be removed or mitigated whereas the natural fish passage restriction should remain in place. This stream class cannot, by definition, occur downstream of a low gradient stream. It may occur upstream or downstream of steep forested streams. Stream slope upstream of fish passage restriction is irrelevant. This class can contain both high and low gradient streams and is distinguished from the steep shaded streams by the stream shade level less than 60%.

7.5.1 Biological objectives possible in restricted fish passage streams

Shortfin eels, longfin eels and banded kokopu have very good climbing ability and will be the species most often encountered upstream of fish passage impediments. However banded kokopu and to some extent longfin eels will be restricted to the steep forest stream type due to habitat preferences. The restricted fish passage class of stream is widespread and contributes significantly to the biological objective of sustaining shortfin eels populations. This category of stream will also be appropriate for two invertebrate objectives, sustain 6 or more EPT species and maintain a diverse lowland stream invertebrate community.

7.5.2 Restricted fish passage sample sites

Naturally restricted fish passage (estimated from mean stream gradient): Lucas Creek site 1; Un-named Stream 5 site 38; Un-named Stream 6 site 39;

Artificially restricted fish passage known or suspected: Oteha Stream trib 1 site 5; Oteha Stream site 6; Oteha Stream trib 2 site 7; Un-named Stream 6 site 35; Orakei

Stream site 40; Un-named Stream 7 site 42; Un-named Stream 8 site 44; Omana Park Stream site 52; Papakuru Stream trib. Site 61.

Figure 13.
Streams upstream of fish passage impediments, Omana Park Stream (left) and Oteha Stream trib 2 (right), both habitat for shortfin eels.

7.6 Stream type 6: Steep forested streams

Steep forested streams are a subset of the restricted fish passage streams that have good riparian shading (canopy shade > 60%) (Fig. 14) and a downstream reach with a gradient of 1.5% or greater. Streams can be shaded by native and or exotic trees and understory. Stream width is generally small (less than 3 m wide) so that the riparian vegetation can achieve full canopy cover over the stream. The stream may have permanent or intermittent flow as long as permanent pools exist. Stream bank erosion problems may be present in steeper streams or those receiving large volumes of storm-water. The more eroded streams in this category will grade into the disturbed stream class. An exact cut off point cannot be defined between the two categories at present. This stream category may encompass the whole length of short steep Auckland streams or only the steeper forested sections of a stream.

Figure 14.
Steep forested streams, Mellons Bay Stream (left) with exotic vegetation and Howick Beach Stream (right) with native riparian vegetation. Habitat for shortfin eels, banded kokopu and mosquito fish.

7.6.1 Biological objectives possible in steep forested streams

The steep forested streams principally provide habitat for banded kokopu and secondarily shortfin eels and longfin eels. No inanga or common bullies are expected in these steep streams due to migrational limitations. Therefore this stream category supports the banded kokopu biological objective and to a lesser extent the shortfin eel objective. Streams with permanent flow will also potentially provide habitat to sustain 6 or more EPT taxa in a stream.

The stream canopy cover appears to play a vital role for providing habitat for banded kokopu and adult EPTs and it is essential that this riparian vegetation be retained. Instream cover is also important especially as site slope increases. The understory vegetation is important for bank stabilisation and where it overhangs the stream provides good fish cover. This understory vegetation should be protected about the stream edges. Cover also provides important refuge habitat to avoid displacement in flood flows. The steeper streams on Birkenhead with banded kokopu populations have size frequencies skewed to the smaller size classes indicating adult mortality is high. A lack of stable cover and high proportions of bedrock in the streambed is probably reducing the available flood refugia. This is at least partially due to the sandstone bedrock eroding into a chute like channel without producing cobble and boulder substrate for cover. Displacement of fish in these environments is natural in flood events, but storm-water run-off effect will increase the mortality rate of fish and invertebrates. Water quality can be limiting at base flow periods in summer in the intermittent streams, and banded kokopu will actively seek oxygen rich areas or gulp air at the water surface. Drainage away from streams should be avoided and ground water levels protected when possible.

7.6.2 Steep forested stream sample sites

Un-named Stream 1 site 8; Kaipatiki Creek 3 site 12; Un-named Stream site 13; Kauri Park Stream site 14; Duck Creek site 15; LeRoys Bush Stream site 16; Glendene Stream site 25; Un-named Stream site 36; Kepa Bush Stream site 41; Mellons Bay Stream site 47; Howick Beach Stream site 48.

7.7 Stream type 7: Degraded water quality streams

Degraded water quality streams are a sub-category in all previous stream types. Any or all of the following parameters can be used to define degraded, MCI and or UCI score, elevated water temperature, algal blooms and/or poor water clarity (Fig. 15). It is highly likely that degraded streams are unshaded and have low to no flow at summer base flow periods. Degraded streams can be present anywhere in a catchment, poor water quality tributaries can be diluted at stream confluences with higher water quality streams. Shaded sections can reduce temperature related water quality problems from upstream sites. Conversely good water quality headwaters can degrade as the streams flow through urban areas. It is unknown whether fish passage can be maintained through degraded sections, but it is unlikely that sensitive species will attempt fish passage, therefore degraded streams in mid and lower stream areas can be viewed as artificial fish passage barriers.

7.7.1 Biological objectives possible in degraded streams

Shortfin eels are regularly present in degraded streams with poor water quality. Therefore despite being classed as degraded these streams do support at least one important biological objective.

Figure 15.
Pakuranga Stream site 45, a degraded water quality stream

7.7.2 Degraded water quality streams sampled

Taiotea stream site 3 (water temperature); Oakley Creek site 33 (water temperature); Omaru Creek site 44 (extremely low dissolved oxygen level); Pakuranga Creek site 45 (generally water quality); Pakuranga Creek trib site 49 (MCI, UCI scores low for such good habitat); Omana Park Stream site 52 (sewage inputs); Otara Creek 1 and 2 sites 53, 54 (sewage inputs); Papakuru Stream trib site 61 (extremely low dissolved oxygen level).

7.8 Stream type 8: Ephemeral streams

Ephemeral streams are any stream section that has no permanent water during summer base flow conditions. There are no restrictions on stream size or position in catchment, however, it is expected that ephemeral streams will be small streams either in headwater areas or coastal streams with small catchments.

7.8.1 Biological objectives possible in ephemeral streams

Nil

Figure 16.
An ephemeral stream, McLeans Park Stream site 46, with no permanent water in pools during summer base flow.

7.8.2 Ephemeral stream sample sites

McLean Park Stream site 46.

8 Possible ALW plan policy, rules and Guidelines

8.1 General policy, rules and guidelines for all stream classes

- Terminate or reduce sewage inputs to all stream classes.
- Seek improvement in water quality in all streams.
- Promote fish passage to upstream habitats and seek the removal of artificial fish passage restrictions.
- Allow no new works that create fish passage barriers that are not appropriate for the stream class.
- Promote the use of herbicides that are non-toxic to aquatic life for noxious weed control.
- Promote the creation of riparian margins that shade streams; restrict shade plant reduction or pruning to winter months to provide maximum shade during summer base flow periods.
- Promote riparian values to residential property owners.
- Prevent as far as possible the input of fine sediments to streams from construction works.
- Seek to retain all present above ground water courses in urbanised areas.
- Quick flow run-off to be minimised and/or mitigated in newly created urban areas.

8.1.1 Possible ALW plan policy, rules and guidelines for estuarine areas.

- No disturbance of any areas identified as inanga spawning areas.
    - Exclude public access from 1st December to 1st July.
    - No grazing or mowing from 1st December to 1st July.
    - No herbicide or pesticide use from 1st December to 1st July.
    - Herbicide use only permitted to control noxious weeds.
- No new construction activity permitted in estuarine areas unless it can be demonstrated to be out-side of spawning habitat.

8.1.2 Possible ALW plan policy, rules and guidelines for concrete channels

- Ensure fish passage to upstream habitats is possible if upstream habitats are available.
- Remedial work to create instream habitat for fish (mainly eels) and promote fish passage for other species or alternatively a trap and transfer programme to collect migrant elvers and whitebait and transfer to appropriate designated habitats either upstream or in nearby catchments.

8.1.3 Possible ALW plan policy, rules and guidelines for disturbed streams

- Seek mitigation of disturbance regime if caused by anthroprogenic impacts.
    - storm-water mitigation by reducing quick flow run-off.
- Maintain fish passage to upstream habitats if these are undisturbed.
- No new storm-water discharges allowed (to prevent further decline in stream quality), particularly if downstream reaches have other stream classifications with better biological objectives.

8.1.4 Possible ALW plan policy, rules and guidelines for low gradient streams

- No instream works that create fish passage barriers to the passage of limited ability migrant fish.
- Retain an incomplete riparian canopy with shade plants (up to 40% shade), with no reduction or removal of shade plants from 1st December to 1st April.
- Identify artificial fish passage barriers and seek remedial works or removal.
- Noxious weed control in the riparian margin to be carried out using herbicides with no toxic effects to aquatic life.
- Macrophyte removal to be a consented activity.
- Allow bank retention work to restrict erosion, but seek the protection of fish cover by either promoting gabion baskets, or erosion preventing riparian plantings or other methods.

8.1.5 Possible ALW plan policy, rules and guidelines for restricted fish passage streams

- Seek the removal of all artificial fish passage barriers.
- Allow bank retention work to restrict erosion, but seek the protection of fish cover by either promoting gabion baskets, or erosion preventing riparian plantings or other methods.

8.1.6 Possible ALW plan policy, rules and guidelines for steep forested streams

- Riparian tree removal on all forested streams to be a consented activity, consents not to be granted if banded kokopu are present and shade declines to less than 75%.
- Promote the protection of a riparian understory for banded kokopu spawning habitat.
- allow no new storm-water discharges in eroding steep forest streams.
- Seek quick-flow run-off reduction in eroding steep forest streams.

9 General Stream Management

9.1 Fish passage

To complete the stream classification, fish passage barriers do need to be identified and categorised as natural or artificial. Natural, slope related barriers might be determined from maps or available elevation data and GIS approaches, whichever is considered to be the most accurate. Artificial barriers may be encountered at any road crossing, or instream structure. For both natural and artificial passage impediments the initial classification should locate the first barrier upstream from the sea as this will determine the upstream limit of any low gradient streams.

Subsequent barrier identification should concentrate on streams with artificial barriers. Barrier identification should proceed in an upstream direction until a natural barrier is encountered. This process will identify all barriers requiring remedial work to allow fish of limited migratory ability passage upstream to the pre-urban natural limits. It is important to note that the natural barrier for low gradient streams to naturally restricted fish passage streams is a stream section of 50 m length with a slope of 1.5%. In streams above the first low gradient fish passage restriction, fish passage restriction then become free-fall water falls (eel species and banded kokopu are capable of climbing sheer faces).

Fish passage mitigation work should prioritise barrier mitigation so that any barrier removal or modification provides the maximum return in terms of newly available habitat. For example, removing barriers immediately below long concrete stream sections would serve little purpose, but removing a single barrier below a large area of good habitat would have high value. It would also be possible to prioritise passage mitigation work with respect to species. Fish passage improvements should prioritise removals that allow rarer species access to new habitats rather than common species if all other factors are equal.

9.2 Concrete channels

Mitigation work for large concrete channels can proceed in two ways. In the large square channels the placement of a coarse cobble and boulder substrate would promote fish and invertebrate life. To prevent displacement of the substrate and aquatic organisms in flood flows larger substrate items can be cemented in place to create stable areas. Where habitat improvements cannot be made elver and whitebait trap and transfer programs should be considered as mitigation. The upstream migration of these fish can be trapped at the lower end of concrete channels and fish either transferred to suitable habitat upstream, or to other catchments above presently existing artificial fish passage restrictions.

9.3 Riparian management

Riparian management is a high priority for the management of water quality and stream bank erosion. For open bank streams instream priorities must be determined and the appropriate riparian planting instigated (see Collier et al. 1995 for riparian guidelines). Management of riparian zones to provide stream shade and habitat for adult aquatic insects (see Collier and Scarsbrook 2000 for insect requirements) are possible priority issues. Improving the state of the riparian margin should increase the possibility of achieving the diverse lowland invertebrate fauna and EPT biological objectives.

9.4 Storm water management

The reduction or mitigation of storm water inputs is required in eroding or potentially erodable steeper streams. The creation of further impervious surfaces should not occur unless quick flow run-off to the streams is reduced. Areas of natural vegetation in these catchments should be retained to reduce quick flow run-off and improve base flow conditions. In catchments that are already eroding a reduction in impervious surfaces would be beneficial in reducing storm water run-off and hence erosion.

10 References

Bain, M.B. & Stevenson, N.J. (ed.) 1999: Aquatic habitat assessment: common methods. Bethesda, Maryland: American Fisheries Society.

Boothroyd, I. & Stark, J. 2000: Use of invertebrates in monitoring. In K. J. Collier & M. J. Winterbourn eds. New Zealand stream invertebrates: ecology and implications for management : New Zealand Limnological Society, pp. 344-373.

Boubée, J. Reynolds, A. & Roper, D. 1998: Improvements to the Matahina Dam elver pass and options for enhancing elver passage. NIWA/ECNZ report.

Chapman, A. and Lewis, M. 1976: An introduction to the freshwater Crustacea of New Zealand. Auckland, Collins.

Collier, K.J. & Scarsbrook, M. 2000: Use of riparian and hyporheic habitats. In K. J. Collier & M. J. Winterbourn eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, pp. 179-206.

Collier, K.J., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C., Smith, C.M. & Williamson, R.B. 1995: Managing riparian zones: a contribution to protecting New Zealand's rivers and streams. Wellington: Department of Conservation.

Cowley, D.R. 1978: Studies on the larvae of New Zealand Trichoptera. New Zealand Journal of Zoology 5: 639-750.

Donovan, W.F., Sides, E.S., Smith, T.V. & Bennett, K.V. 1998: Mid-Waitemata harbour catchment representative streams survey. Bioresearchers, Auckland.

Gustav, R.S., Sovern, D.T. & Washington, P. M. 1994: Maintaining fish habitat in urban streams. Water Environment & Technology June 1994: 48-53.

Joy, M.K., Henderson, I.M. & Death, R.G. 2000: Diadromy and longitudinal patterns of upstream penetration of freshwater fish in Taranaki, New Zealand. New Zealand Journal of Marine and Freshwater Research 34: 531-543.

LeBlanc, R.T., Brown, R.D. & FitzGibbon, J.E. 1997: Modelling the effects of land use change on the water temperature in unregulated urban streams. Journal of Environmental Management 49: 445-469.

Maxted, J., & Evans, B 2000: Standard Methods for macroinvertebrate and habitat assessment of wadeable streams in the Auckland Region. Internal report, Environmental Research, Auckland Regional Council.

McDowall, R.M. & Taylor, M.J. 2000: Environmental indicators of habitat quality in a migratory freshwater fish fauna. Environmental Management 25: 357-374.

McDowall, R.M. 1996: Diadromy and the assembly and restoration of riverine fish communities: a downstream view. Canadian Journal of Fisheries and Aquatic Science 53: 219-236.

McDowall, R.M. 1998: Fighting the flow: downstream-upstream linkages in the ecology of diadromous fish fauns in West Coast New Zealand rivers. Freshwater Biology 40: 111-122.

McFarlane, A.G. 1951: Caddisfly larvae (Trichoptera) of the family Rhyacophilidae. Records of the Canterbury Museum 5: 267-289.

Mitchell, C.P. & Eldon, G.A. 1991: How to locate and protect whitebait spawning grounds: Freshwater Fisheries Centre Publication.

Moscrip, A.L. & Montgomery, D.R. 1997: Urbanization, flood frequency, and salmon abundance in Puget lowland streams. Journal of the American Water Resources Association 33: 1289-1297.

Nagels, P. 2000: The human footprint: turtle-top cities. Forest & Bird November 2000: 34-35.

Quinn, J.M., Steele, G.L., Hickey, C.W. & Vickers, M.L. 1994: Upper thermal tolerances of twelve New Zealand stream invertebrate species. New Zealand Journal of Marine and Freshwater Research 28: 391-397.

Richardson, J., Boubée, J.A.T. & West, D.W. 1994: Thermal tolerance and preference of some native New Zealand freshwater fish. New Zealand Journal of Marine and Freshwater Research 28: 399-407.

Snelder, T. & Trueman, S. 1995: The environmental impacts of urban stormwater runoff. Auckland: Auckland Regional Council.

Stark J.D. (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. New Zealand Journal of Marine and Freshwater Research 32, 55-66.

Suren, A. 2000: Effects of urbanisation. In K. J. Collier & M. J. Winterbourn eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, pp. 260-288.

Timperley, M. & Kuschel, G. 1999: SWAT's up Doc? The effects of storm water and transport on urban streams and estuaries. Water & Atmosphere 7: 22-25.

Towns, D.R. & Peters, W.L. 1996: Leptophlebiidae (Insecta: Ephemeroptera). Fauna of New Zealand 36: 37-50.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Seddel, J.R.. & Cushing, C.E. 1980: The river continuum concept. The Canadian Journal of Fisheries and Aquatic Science 37: 130-137.

Walley, W.J., & Fontama, V.N. 2000: New approaches to river quality classification based upon Artificial Intelligence. Wright, J.F., Sutcliffe, D.W., Furse, M.T. ed. in Assessing biological quality of freshwaters: RIVPACS and other techniques. Pp. 263-280 Ambleside, Cumbria. Freshwater Biological Association.

Winterbourn, M.J. 1973: A guide to the freshwater Mollusca of New Zealand. Tuatara 20: 141-159.

Winterbourn, M.J.; Gregson, K.L.W., & Dolphin, C.H. 2000: Guide to the Aquatic Insects of New Zealand (Third Edition). Bulletin of the Entomological Society of New Zealand 13. Pp. 102.

11 Appendix 1: Stream site names and map references

Site	Site Name	Pathfinders Street map, map number and grid reference	NZMS 260 series map number and grid reference	% Impervious surface area estimates
1	Lucas Creek	Map 23, Grid box 15-U, 2.0 cm right, 2.0 cm up	R10 616963	20
2	Awaruku Creek	Map 24, Grid box 19-R, 1.0 cm right, 1.3 cm up	R10 654990	45
3	Taiotea Stream	Map 24, Grid box 19-T, 1.5 cm right, 0.6 cm up	R10 656968	44
4	Murrays Bay Stream	Map 24, Grid box 19-V, 3.8 cm right, 2.3 cm up	R10 663954	30
5	Oteha Stream trib 1	Map 23, Grid box 17-V, 3.0 cm right, 1.6 cm up	R10 639951	40
6	Oteha Stream	Map 29, Grid box 16-W, 2.0 cm right, 1.5 cm up	R10 627940	50
7	Oteha Stream trib 2	Map 30, Grid box 19-W 0.5 cm right, 1.5 cm up	R10 654938	
8	Un-named Stream 1	Map 28, Grid box 13-A, 2.5 cm right, 2.0 cm up	R10 599902	
9	Daldys Bush Stream	Map 29, Grid box 16-Z, 2.3 cm right, 1.9 cm up	R10 631911	10
10	Kaipatiki Creek 1	Map 29, Grid box 16-A, 3.9 cm right, 0.8 cm up	R11 633899	36
11	Kaipatiki Creek 2	Map 34, Grid box 16-C, 2.5 cm right, 2.6 cm up	R11 627886	30
12	Kaipatiki Creek 3	Map 34, Grid box 15-C, 1.8 cm right, 1.7 cm up	R11 617880	35
13	Un-named Stream 2	Map 33, Grid box 14-C, 1.4 cm right, 2.6 cm up	R11 606884	40
14	Kauri Park Stream	Map 34, Grid box 16-E, 0.1 cm right, 2.0 cm up	R11 622863	
15	Duck Creek	Map 34, Grid box 16-E, 3.6 cm right, 0.4 cm up	R11 632857	35
16	LeRoy's Bush Stream	Map 34, Grid box 18-E, 2.4 cm right, 1.8 cm up	R11 648860	35
17	Kauri Glen Stream	Map 35, Grid box 19-D, 1.7 cm right, 1.0 cm up	R11 656870	36
18	Un-named Stream 3	Map 35, Grid box 20-C, 1.8 cm right, 2.1 cm up	R11 667883	
19	Wairau Creek	Map 30, Grid box 20-A, 3.6 cm right, 2.o cm up	R10 671902	60

Site	Site Name	Pathfinders Street map, map number and grid reference	NZMS 260 series map number and grid reference	% Impervious surface area estimates
20	Manutewhau Stream	Map 38, grid box 9-F, 0.1 cm right, 1.2 cm up	R11 554850	50
21	Swanson Stream	Map 38, grid box 7-K 1.8 cm right, 3.3 cm up	R11 538814	15
22	Paremuku Stream	Map 38, grid box 7-L, 2.5 cm right, 2.5 cm up	R11 541803	45
23	Opanuku Stream	Map 46, Grid box 8-N, 0.2 cm right, 1.0 cm up	R11 543779	20
24	Oratia Stream	Map 46, Grid box 8-Q, 3.4 cm right, 0.9 cm up	R11 551762	15
25	Glendene Stream	Map 47, Grid box 11-N, 0.9 cm right, 0.5 cm up	R11 576778	55
26	Gaden Stream	Map 47, Grid box 11-P, 3.0 cm right, 1.0 cm up	R11 581769	45
27	Waikumete Steam	Map 47, Grid box 10-R, 3.9 cm right, 0.8 cm up	R11 573748	50
28	Bishop Stream	Map 47, Grid box 10-S 3.5 cm right, 2.6 cm up	R11 573742	35
29	Waituna Stream	Map 56, Grid box 10-V, 1.2 cm right, 2.7 cm up	R11 567715	40
30	Whau River	Map 48, Grid box 14-R, 3.8 cm right, 3.6 cm up	R11 613715	50
31	Un-named Stream 4	Map 48, Grid box 14-S, 3.8 cm right, 2.0 cm up	R11 611741	40
32	Un-named Stream 5	Map 48, Grid box 16-R, 3.4 cm right, 1.8 cm up	R11 632751	
33	Oakley Creek	Map 48, Grid box 16-P, 1.6 cm right, 0.0 cm up	R11 626767	40
34	Meola Creek	Map 40, Grid box 1-J, 1.0 cm right, 1.5 cm up	R11 636801	40
35	Un-named Stream 6	Map 41 Grid box 18-K, 0.0 cm right, 2.2. cm up	R11 641813	45
36	Un-named Stream 7	Map 42, Grid box 23-L, 1 cm right, 3.7 cm up	R11 697806	55
37	Newmarket Stream	Map 42, grid box 22-L, 3.9 cm right, 1.9 cm up	R11 695803	65
38	Un-named Stream 8	Map 50, Grid box 24-M, 0.1 cm right, 2.7 cm up	R11 705927	65
39	Un-named Stream 9	Map 51, Grid box 24-M, 2.1 cm right, 2.0 cm up	R11 710795	45
40	Oraki Creek	Map 51, Grid box 25-M, 3.5 cm right, 1.1 cm up	R11 722790	40
41	Kepa Bush Stream	Map 51, Grid box 26-N, 2.1 cm right, 0.9 cm up	R11 730778	35

Site	Site Name	Pathfinders Street map, map number and grid reference	NZMS 260 series map number and grid reference	% Impervious surface area estimates
42	Un-named Stream 10	Map 43, Grid box 27-L, 1.2 cm right, 2.8 cm up	R11 737804	40
43	Un-named Stream 11	Map 44, Grid box 30 K, 1.6 cm right, 0.0 cm up	R11 768807	60
44	Omaru Stream	Map 52, Grid box 29-N, 2.0 cm right, 3.6 cm up	R11 759786	
45	Pakuranga Stream	Map 53, Grid box 33-Q, 2.7 cm right, 3.3 cm up	R11 801765	
46	McLeans Park Stream	Map 54, Grid box 35-P, 1.7 cm right, 2.3 cm up	R11 814784	
47	Mellons Bay Stream	Map 54, Grid box 35-N, 0.1 cm right, 2.3 cm up	R11 818772	
48	Howick Beach Stream	Map 54, Grid box 36-Q, 3.1 cm right, 3.3 cm up	R11 832765	
49	Pakuranga Stream trib.	Map 54, Grid box 34-S, 0.6 cm right, 3.7 cm up	R11 808747	
50	Tararata Creek	Map 60, Grid box 23-W, 2.6 cm right, 0.2 cm up	R11 701698	
51	UN-named Stream 12	Map 61, Grid box 25-X, 0.5 cm right, 3.5 cm up	R11 717697	
52	Omana Park Stream	Map 67, Grid box 29-X, 0.4 cm right, 0.2 cm up	R11 749683	
53	Otara Creek 1	Map 68, Grid box 31-X, 0.9 cm right, 2.6 cm up	R11 767703	
54	Otara Creek 2	Map 68, Grid box 31-X 0.8 cm right, 2.1 cm up	R11 768702	
55	Puhinui Stream	Map 69, Grid box 32-C 0.0 cm right, 3.0 cm up	R11 785645	
56	Janese Park Stream	Map 71, Grid box 29-F, 1.5 cm right, 1.2 xm up	R11 759610	
57	Un-named Stream 13	Map 71, Grid box 30-F, 1.5 cm right, 2.3 cm up	R11 768612	
58	Waimania Creek	Map 72, Grid box 32-F, 0.7 cm right, 1.0 cm up	R11 784609	
59	Pakakuru Stream 1	Map 72, Grid box 33-F 1.2 cm right, 2.1 cm up	R11 798612	
60	Papakura Stream 2	Map 72, Grid box 33-F, 3.7 cm right, 3.2 cm up	R11 805615	
61	Papakura Stream trib.	Map 72, Grid box 34-D, 0.5 cm right, 0.4 cm up	R11 806629	
62	Pakakuru Stream 3	Map 73, Grid box 34-E, 3.5 cm right, 0.8 cm up	R11 815620	
63	Slippery Creek trib	Map 75, Grid box 38-K, 0.7 cm right, 1.0 cm up	R12 847571	

Site	Site Name	Pathfinders Street map, map number and grid reference	NZMS 260 series map number and grid reference	% Impervious surface area estimates
64	Hingaia Stream	Map 76, Grid box 39-M, 2.4 cm right, 2.5 cm up	R12 835534	

12 Appendix 2: Stream Assessment Forms

Urban Stream Habitat Assessment Form

Site……………………… **Map ref**………………… **Date**……………… **Investigators**………………………………

Location description……………………………………………………………………………………**Time**……………

Weather conditions [clear / cloudy / showers] **Heavy rain** in the last 48 hrs? yes / no

Photo's: Film & Shot number……………… **Shots taken**……………………………………………

Litter: Abundant / Common / Rare / Absent **Predominant surrounding land-use**: Residential / Commercial / Industrial

Water odours: normal / petrol / fishy/ sewage / chemical / other………………………

Surface oils (describe): none /……….. **Sediment deposition** (channel): none / minor / moderate / prolific

Substrate packing: loose 1 2 3 4 5 hard

Turbidity: clear / slightly turbid / moderate / very turbid **Colour:** stained / opaque / other……………

Conductivity………… **pH**…………

DO………………… **Slope**…………

Temp (water)…………

Cobble periphyton

Diatom slime / Bryophyte / Light algae /

Heavy algae / None

Dominant macrophyte spp………………………

Aquatic vegetation	None	Rare	Sparse	Com.	Abun.
Rooted emergent					
Floating algae					
Rooted submergent					
Attached algae					
Rooted floating					
Free floating					

Depth at transect: 1……………… 2……………… 3……………… 4……………… 5………………

Depth at transect: 6……………… 7……………… 8……………… 9……………… 10………………

Width at transect: 1……… 2……… 3……… 4……… 5……… 6……… 7……… 8……… 9……… 10………

Substrate ↓ **Channel** →					

Fish spp. →					
Abundance→					

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1 Aquatic Habitat Abundance	> 50% of channel favorable for epifaunal colonisation and fish cover. Cover may include woody debris, undercut banks, root mats, rooted aquatic vegetation, cobble or other stable habitat.	30-50% of channel contains stable habitat.	10-30% of channel contains stable habitat.	< 10% of channel contains stable habitat.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2 Aquatic Habitat Diversity	Wide variety of stable aquatic habitat types present including: woody debris, riffles, undercut banks, root mats, rooted aquatic vegetation, cobble or other stable habitat.	Moderate variety of habitat types; 3-4 habitats present including woody debris.	Habitat diversity limited to 1-2 types; woody debris absent or may be smothered by sediment.	Stable habitats lacking or limited to macrophytes (a few macrophyte species scores lower than several).
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3 Hydrologic Heterogeneity	Mixture of hydrologic conditions i.e. pool, riffle, run, chute, waterfalls; variety of pool sizes and depths.	Moderate variety of hydrologic conditions; deep and shallow pools present. Deep > 0.5 m Shallow 0.2-0.5 m	Limited variety of hydrologic conditions.	Uniform hydrologic conditions; uniform depth and velocity.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4 Channel Alteration	Natural channel and meander pattern; no evidence of channelisation, dredging, stabilisation, or other human alteration.	Minimal channel alteration; < 10% channelised or culverted; past channelisation healed over with vegetation.	Moderate channel alteration; 10-50% channelised or culverted with man-made materials (gabions, rip-rap, concrete, pilings)	Extensive channel alteration; > 50% channelised or culverted.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5 Bank Stability	Stable < 5% bank affected; evidence of erosion or bank failure absent or minimal potential for future problems.	Moderately stable 5-30% affected; areas of erosion mostly healed over; some potential for future problems.	Moderately unstable 30-60% affected; high erosion potential during floods.	Unstable 60-100% affected; eroded areas along runs and bends, bank sloughing and erosion scars common.
Left bank	10 9	8 7 6	5 4 3	2 1 0
Right bank	10 9	8 7 6	5 4 3	2 1 0

Riparian Zone Assessment

Riparian Zone type:

1. No vegetation
2. Grassland or park
3. Suburban/gardens
4 Planted riparian zone (exotic plants)
5. Planted riparian zone (native plants)
6. Unmanaged or natural native bush
7. Unmanaged exotic trees
8. Long grass and weeds

Width of vegetated zone:

Height of riparian canopy:

Height of understory:

Canopy cover over the streambed

1. 0%
2. < 25%
3. 26-50%
4. 51-75%
5. > 75%

Streamside understory cover

1. Long grasses, flaxes and herds > 50%
2. Long grasses, flaxes and herds < 50%
3. Short grass > 50%
4. Short grass < 50%
5. Predominantly bare substrate

Canopy cover

1. Native or evergreen trees/ shrubs > 50%
2. Deciduous trees > 50%
3. Native or evergreen trees/ shrubs < 50%
4. Deciduous tress < 50%
5. No canopy

Streambed substrate assessment

Cross section	Silt sand <2mm	Small gravel 2-8 mm	Small medium gravel 8-16 mm	Medium large gravel 16-32 mm	Large gravel 32-64 mm	Small cobble 64-128 mm	Large cobble 128-256 mm	Boulder > 256 mm	Bedrock	Small wood	Large wood	Other (rubbish, concrete, root mat)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

13 Appendix 3: Fisheries and Invertebrate Data

Fisheries data from electric fishing surveys and visual observations; - no detected, r = rare, o = occasional, c = common, a = abundant.

Site Number	Shortfin eel	Longfin eel	Common bully	Redfin bully	Banded kokopu	Inanga	Common smelt	Mosquito fish
1	O	-	-	-	-	-	-	-
2	-	C	-	-	O	-	-	-
3	A	-	R	-	-	O	-	A
4	-	C	R	-	-	O	-	-
5	O	-	-	-	-	-	-	-
6	C	-	-	-	-	-	-	-
7	O							
8	O	-	-	-	O	-	-	-
9	-	C	-	R	O	-	-	-
10	C	-	-	-	O	-	-	-
11	C	O	-	-	-	-	-	-
12	R	O	-	R	R	-	-	-
13	R	R	-	-	C	-	-	-
14	-	R	-	-	O	-	-	-
15	O	R	-	-	-	-	-	-
16	R	-	-	-	R	-	-	-
17	C	C	-	-	-	O	-	-
18	A	-	-	-	-	R	-	-
19	-	-	-	-	-	-	-	-
20	O	-	-	-	-	-	-	-
21	O	O	O	-	-	-	-	-
22	C	C	-	-	-	O	-	C
23	C	C	O	R	-	O	-	-
24	O	O	R	-	-	-	-	-
25	C	-	-	-	C	-	-	-
26	A	-	R	R	-	R	-	-
27	C	R	R	-	-	-	-	-
28	A	-	-	-	-	-	-	-
29	-	C	C	R	-	C	-	-
30	C	R	R	-	-	-	R	-
31	O	R	-	-	O	-	-	-
32	A	-	R	-	-	-	-	-
33	A	R	-	-	-	-	-	-
34	C	R	-	-	-	-	-	-
35	-	R	-	-	-	-	-	-

36	O	-	-	-	A	-	-	-
37	-	-	-	-	-	-	-	-
38	C	-	-	-	-	-	-	-
39	C	-	-	-	-	-	-	-
40	C	R	C	-	-	-	-	-
41	R	-	-	-	O	-	-	-
42	C	R	-	-	R	-	-	-
43	O?	-	-	-	-	-	-	A
44	O	-	-	-	-	-	-	-
45	C	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-
47	C	-	-	-	O	-	-	-
48	C	-	-	-	C	-	-	R
49	C	-	-	-	-	-	-	-
50	A	-	-	-	-	C	-	A
51	A	C	-	-	-	-	-	-
52	O	-	-	-	-	-	-	-
53	O	C	C	-	-	C	-	-
54	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-
57	C	R	O	-	-	C	-	-
58	C	R	C	-	-	C	-	-
59	C	C	R	-	-	C	-	-
60	C	-	-	-	-	O	-	O
61	-	-	-	-	-	-	-	-
62	C	-	C	R	-	C	-	-
63	C	-	-	-	-	-	-	C
64	C	-	-	-	-	-	-	-

Invertebrate data from kick samples, shaded cells indicate species detected in the rare species counts, * indicates the trial 300 invertebrates count sites.

Taxa **Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Odonata																				
Procordulia spp.											1	1				1				
Xanthocnemis sp.		3		10		5	34	3	1		6	1			6	3	2	4		16
Megaloptera	1								1											
Ephemeroptera																				
Acanthophlebia cruentata									1					1						
Coloburiscus humeralis									1					1						
Zephlebia dentata									12					1						
Zephlebia inconspicuosa																				
Zephlebia spectabilis									1											
Zephlebia versicolor									1											
Nesameletus sp.																				
Deleatidium spp.																				
Plecoptera																				
Acroperla trivacuata																				
Austroperla cyrene									1					1						
Spaniocercoides sp.														1						
Trichoptera																				
Psilochorema spp.									1					1						
Pycnocentria spp.									1					1						
Triplectides cephalotes																				
Triplectides obsoletus									28		6	24								
Costachorema xanthopterum																				
Oecetis sp.																				
Oeconesus sp.											1	1		3						
Orthopsyche spp.	1								4		2			4		2				
Oxyethira albiceps	1										1									
Polyplectropus sp.									3	2			9	9						
Aoteapsyche spp.																				
Hemiptera																				
Anisops sp.																				1
Sigara sp.	1																			5
Coleoptera																				
Elmidae									2											
Homeodytes sp.																				
Hydraenidae										1										
Hydrophilidae														1						
Lepidoptera sp.																				
Ptilodactylidae									1					1		1				
Liodessus sp.																				
Scirtidae								1												
Diptera																				

Taxa Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Aphrophila neozelandica														3		1				
Austrosimulium australense		1							1											
Chironomus spp.		2					22	3	6	2	8	1						1		6
Cricotopus spp.	3		1				1					3					1			
Culex sp.					3			3			1									1
Empididae																				
Eriopterini sp.																				
Eukiefferiella spp.				2															94	
Harrisius sp. (Chironomidae)																				
Limonia nigrescens													2		4	9		6		
Molophilus sp.																				
Muscidae								1		3		3			1				2	1
Naonella spp.																				
Nothodixa sp.																				
Paralimnophila skusei										4		3		7						
Polypedilum spp.								1	6		1	8		17	10			3		
Psychodidae				1																
Sciomyzidae														1						
Tabanidae																2				
Tanyderidae										7		1	4		1					
Tanypodinae	1	2							3	1	5	5	15	2			6			2
Tanytarsini spp.									2											
Tipulidae																				
Zelandotipula sp.	1		1			1	2	2					1		1	1				
Stratiomyidae													1		1					
Ephydridae																				
Mollusca																				
Ferrissia sp.				1					2											
Gyraulus sp.				23														3		
Latia sp.																				
Lymnaea sp.			1			4	2	5									1			
Physa sp.	1			45	15	22	32		1	4	1	1			36		1	3		10
Glyptophsa variabilis																				
Sphaeriidae								2	1			1	10	1		1	1			2
Potamopyrgus sp.	95	95	18	1	37	83	13	97		30	65	52	22	45		17	34	4		21
Hirudinea		1	1				2						1	1					1	
Oligochaeta		4		4	30		3	3		47	2	6	31	6	4	13		1	3	29
Polychaeta																				
Crustacea																				
Halicarcinus sp.																				
Paranephrops planifrons																				
Paratya sp.	2	1				2			3		1	3	2	1			16	3		
Ostracoda			84					1				1					55			2
Amphipoda		1							13			2	4	3						
Isopoda	1				1		2						1							

Taxa Site	21	22	23	24	25	26	27	28	29	30*	31	32	33*	34*	35	36	37	38*	39	40
Odonata																				
Procordulia spp.									1											
Xanthocnemis sp.	1	6			1	2	1			6	2		32	14		16		4	33	1
Megaloptera																				
Ephemeroptera																				
Acanthophlebia cruentata																				
Coloburiscus humeralis																				
Zephlebia dentata			1	2					1											
Zephlebia inconspicuosa	1			2																
Zephlebia spectabilis																				
Zephlebia versicolor																				
Nesameletus sp.				3																
Deleatidium spp.			1	2																
Plecoptera																				
Acroperla trivacuata			1																	
Austroperla cyrene																				
Spaniocercoides sp.																				
Trichoptera																				
Psilochorema spp.																				
Pycnocentria spp.																				
Triplectides cephalotes	2												2							
Triplectides obsoletus			22	3					16											
Costachorema xanthopterum				2																
Oecetis sp.				1																
Oeconesus sp.																				
Orthopsyche spp.	2																			
Oxyethira albiceps					6			1		1			3	1						
Polyplectropus sp.																				
Aoteapsyche spp.																				
Hemiptera																				
Anisops sp.																				
Sigara sp.		3					1			1		1	3							
Coleoptera																				
Elmidae			7	9					6											
Homeodytes sp.																				
Hydraenidae																				
Hydrophilidae						1														
Lepidoptera sp.													2							
Ptilodactylidae			1																	
Liodessus sp.																				
Scirtidae																				
Diptera																				
Aphrophila neozelandica											2									
Austrosimulium australense	1						3	4												
Chironomus spp.			8	30	16	7			3		1	1	2		11					6

Taxa Site	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30***	**31**	**32**	**33***	**34***	**35**	**36**	**37**	**38***	**39**	**40**
Cricotopus spp.	2	1		1	37	24					32	1	12	1						74
Culex sp.																				
Empididae																				
Eriopterini sp.				1																
Eukiefferiella spp.												5								
Harrisius sp. (Chironomidae)	1																			
Limonia nigrescens	1				4						1									1
Molophilus sp.																				
Muscidae					4						12	5			2					2
Naonella spp.																				
Nothodixa sp.			1																	
Paralimnophila skusei									1	1					1	1				
Polypedilum spp.			1	6	20	13		5	1		10									
Psychodidae																				
Sciomyzidae																				
Tabanidae																				
Tanyderidae			1	2			1		1							5				
Tanypodinae	1	1		3	2	3	1	5		1	1		6							
Tanytarsini spp.													5							
Tipulidae											1									
Zelandotipula sp.											2					3				
Stratiomyidae																2				
Ephydridae																				
Mollusca																				
Ferrissia sp.					1									3						1
Gyraulus sp.					2	1			1				98	5						
Latia sp.			1																	
Lymnaea sp.																				
Physa sp.					2	1		9			4	7	6	15	33	18			2	3
Glyptophsa variabilis																				
Sphaeriidae		18													1					
Potamopyrgus sp.	87	12	42	22	8			59	24	417	16	10	99	175	34	42		131		4
Hirudinea		11						1					1	4						
Oligochaeta		59	24		16		13	5		8	15		40	4	31			6	3	13
Polycheata																				
Crustacea																				
Halicarcinus sp.			1	2																
Paranephrops planifrons	1		1																	
Paratya sp.	2			14		56	1		50	155										
Ostracoda																			69	
Amphipoda	4		1				84	20	4	86		69		138		3				2
Isopoda					2															1

Taxa **Site**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53***	**54**	**55**	**56**	**57**	**58**	**59**	**60***
Odonata																				
Procordulia spp.						1				1										3
Xanthocnemis sp.	5	3			24	6		3	1	30	1						32	13	7	4
Megaloptera																				
Ephemeroptera																				
Acanthophlebia cruentata																				
Coloburiscus humeralis																				
Zephlebia dentata																				
Zephlebia inconspicuosa																				
Zephlebia spectabilis																				
Zephlebia versicolor																				
Nesameletus sp.																				
Deleatidium spp.																				
Plecoptera																				
Acroperla trivacuata																				
Austroperla cyrene																				
Spaniocercoides sp.																				
Trichoptera																				
Psilochorema spp.																				
Pycnocentria spp.																				
Triplectides cephalotes																				
Triplectides obsoletus																				
Costachorema xanthopterum																				
Oecetis sp.																				
Oeconesus sp.		1																		
Orthopsyche spp.																				
Oxyethira albiceps										3			2	1	2	3	2	5		5
Polyplectropus sp.		5																		
Aoteapsyche spp.															1					
Hemiptera																				
Anisops sp.																		1		
Sigara sp.	7									5					1		1	1	1	
Coleoptera																				
Elmidae																				
Homeodytes sp.	1																			
Hydraenidae																				
Hydrophilidae																				
Lepidoptera sp.																				
Ptilodactylidae																				
Liodessus sp.																				
Scirtidae																				
Diptera																				
Aphrophila neozelandica																				
Austrosimulium australense																	5			
Chironomus spp.	13	4				20	1	3	2	5			84	2	1		17	1	46	

Taxa **Site**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53***	**54**	**55**	**56**	**57**	**58**	**59**	**60***
Cricotopus spp.	17				20					23			13		83			16	6	12
Culex sp.							1													
Empididae																				
Eriopterini sp.																				
Eukiefferiella spp.						3			16					63	10	92	2	3		
Harrisius sp. (Chironomidae)																				
Limonia nigrescens																				
Molophilus sp.		1																		
Muscidae									3				3		1		3	9	1	
Naonella spp.	2		106								3									
Nothodixa sp.																				
Paralimnophila skusei		1																		
Polypedilum spp.						4								66	11	2		1	5	
Psychodidae																				
Sciomyzidae		1																		
Tabanidae																				
Tanyderidae																				
Tanypodinae	11					40	1	16												
Tanytarsini spp.																				
Tipulidae																				
Zelandotipula sp.																	2			
Stratiomyidae																				
Ephydridae	1																			
Mollusca																				
Ferrissia sp.																				21
Gyraulus sp.	1		1		20						5		2				32	21	7	2
Latia sp.																				
Lymnaea sp.	4																			
Physa sp.				2			1	4	8	7		1				2	3	4		
Glyptophsa variabilis							6													
Sphaeriidae		3					1													
Potamopyrgus sp.		51	5		3	4	45	15	51	6	84		169		1				8	201
Hirudinea	3			12	2	4		1	2	5	1							1		3
Oligochaeta	31	29	3	34	25	2	18	9	18	2	6	106	13			2	4	19	3	1
Polycheata																				
Crustacea																				
Halicarcinus sp.																				
Paranephrops planifrons																				
Paratya sp.						8					6		2			1			14	
Ostracoda						1		4												
Amphipoda		8				4	40	48												22
Isopoda																	6	8		

Taxa Site	61	62	63	64	Taxa Site	61	62	63	64
Odonata					Coleoptera				
Procordulia spp.			3		Elmidae				
Xanthocnemis sp.		1	6		*Homeodytes* sp.				
Megaloptera					Hydraenidae				
Ephemeroptera					Hydrophilidae				
Acanthophlebia cruentata					*Lepidoptera* sp.				
Coloburiscus humeralis					Ptilodactylidae				
Zephlebia dentata					*Liodessus* sp.	1			
Zephlebia inconspicuosa				2	Scirtidae	2			
Zephlebia spectabilis					**Diptera**				
Zephlebia versicolor					*Aphrophila neozelandica*				
Nesameletus sp.					*Austrosimulium australense*				
Deleatidium spp.					*Chironomus* spp.			2	
Plecoptera					*Cricotopus* spp.			63	
Acroperla trivacuata					*Culex* sp.	74			
Austroperla cyrene					Empididae			1	
Spaniocercoides sp.					Eriopterini sp.				
Trichoptera					*Eukiefferiella* spp.				
Psilochorema spp.					*Harrisius* sp. (Chironomidae)				
Pycnocentria spp.					*Limonia nigrescens*				
Triplectides cephalotes				3	*Molophilus* sp.				
Triplectides obsoletus					Muscidae			1	
Costachorema xanthopterum					*Naonella* spp.				
Oecetis sp.					*Nothodixa* sp.				
Oeconesus sp.					*Paralimnophila skusei*				
Orthopsyche spp.					*Polypedilum* spp.			14	
Oxyethira albiceps		1			Psychodidae	1			
Polyplectropus sp.					Sciomyzidae				
Aoteapsyche spp.				1	Tabanidae				
Hemiptera					Tanyderidae				
Anisops sp.					Tanypodinae			2	
Sigara sp.			7		Tanytarsini spp.				

Taxa **Site**	**61**	**62**	**63**	**64**
Tipulidae				
Zelandotipula sp.	1		1	
Stratiomyidae				
Ephydridae				
Mollusca				
Ferrissia sp.				
Gyraulus sp.				
Latia sp.				
Lymnaea sp.				
Physa sp.		5		
Glyptophsa variabilis				
Sphaeriidae		1		
Potamopyrgus sp.		73		67
Hirudinea				
Oligochaeta	2			
Polycheata				
Crustacea				
Halicarcinus sp.				
Paranephrops planifrons				
Paratya sp.		1		21
Ostracoda	1			
Amphipoda	13	64		43
Isopoda				

14 Appendix 5: Fish and Invertebrate Management Information

Banded kokopu requirements

Adult habitat: pool and backwater habitats in small to medium sized streams 0.3-3.0 m wide. Good riparian shade required and instream cover is very important. Cover can rock substrate, overhanging banks or log debris.

Migration pathway: spring time whitebait runs require fish passage from the sea to adult habitat areas. Larval fish require downstream passage in late autumn and early winter from adult habitat to the sea. Whitebait have the ability to climb and to migrate through culverts up to 200 long if velocities are sufficiently low.

Spawning habitat and requirements: spate/flood flows are required for spawning. It is unknown if the cue to commence spawning is temperature or flow related. Spawning is carried out in late autumn during flood events. Fish spawn in areas inundated by flood flows and eggs are left on the bank to develop. Riparian shade is highly important to prevent desiccation and protection from trampling/gardening activity is also required. Eggs hatch on flood flows when they are re-submerged and larvae are assumed to drift out to sea on the same flood flow.

Dietary requirements: adults are aquatic and terrestrial invertebrate predators. Considerable proportions of prey items are of terrestrial origin and the riparian margin plants are an important source for providing terrestrial invertebrate inputs. Aquatic prey is varied and fish could be considered to be generalists.

Environmental tolerances: tolerant of low flows, banded kokopu will reside in pools with little if any flow during drought periods.

Biological interactions: giant kokopu and large eels may exclude banded kokopu from deeper pool habitats.

Giant kokopu requirements

Adult habitat: pool and run habitats in streams and rivers 0.5-10.0 m wide. Instream cover is extremely important. Cover can be rock substrate, overhanging vegetation that lies on or under the water surface or log debris, but cover only needs to be provided in part of any habitat section.

Migration pathway: springtime whitebait runs require fish passage from the sea to adult habitat areas. Larval fish require downstream passage in late autumn and early winter from adult habitat to the sea. Climbing ability of whitebait is unknown, some fish have been found above substantial waterfalls.

Spawning habitat and requirements: spawning habitat and behaviour is unknown. Anecdotal evidence indicates that spawning migration of adult fish may occur to the downstream reaches of rivers and streams. If so upstream passage needs to be maintained year round for whitebait movements and adult fish movements

Dietary requirements: adults are aquatic and terrestrial invertebrate predators and piscovores. Considerable proportions of prey items are of terrestrial origin. Aquatic prey is varied and the fish could be considered to be generalists, they eat anything that they can capture.

Environmental tolerances: Unknown

Biological interactions: adults are though to be aggressive and territorial and will displace other fish when the available habitat is limited. As an opportunistic piscivore they may also impact on the abundance of other fish species.

Inanga requirements

Adult habitat: pool, backwater, lake and pond habitats in streams and rivers 0.3- wide or greater. Shade is not essential but instream cover is required. Cover can be overhanging vegetation, log debris or macrophytes, and only needs to be provided in less than half the habitat area.

Migration pathway: springtime whitebait runs require fish passage from the sea to adult habitat areas. Adult fish require downstream passage in autumn and early winter from adult habitat to the estuaries for spawning. Climbing ability is extremely restricted and whitebait are unlikely to pass any vertical falls.

Spawning habitat: see objective 4

Dietary requirements: adults are aquatic and terrestrial invertebrate predators. Prey is varied and generally limited by the small gape of inanga, planktonic crustaceans, and small insects are common dietary items. However, diet reflects availability and will vary with habitat.

Environmental tolerances: adult inanga are tolerant of reduced dissolved oxygen conditions (0.1 mg/litre) in the short term (two days) and do not require saturated oxygen levels.

Biological interactions: adults and juveniles are possibly limited by the presence of piscivores (eels, giant kokopu). Cover is important to provide predation refuges in small streams

Inanga spawning habitat requirements

Location: upper tidal zones above the area of saltwater intrusion in any small streams to large rivers. Spawning occurs at the margins of the stream in areas flooded by spring tides.

Spawning habitat: High humidity areas are required to prevent egg desiccation and areas of rank vegetation such as introduced grasses (e.g., Festuca arundinacea, Apium nodiflorum, Agropyron repens, Lotus pendunculatus) or native wetland vegetation (e.g., Juncus gregiflorus Ranunculus spp, Carex geminata) are appropriate.

Timing: spawning is known to occur at all times of the year, but peak activity is from March through to June. Spawning occurs on or just after high spring tides, usually on only one or two days a month. Eggs will remain on the spawning site until submerged by high tides 24-27 days after spawning. Spawning may occur at a single spawning site on two or more occasion a year.

Other: Inanga will use the same spawning site each year if these areas are undisturbed.

Shortfin eel / longfin eel requirements

Habitat: Instream habitat requires cover, either amongst the substrate, under overhanging banks, overhanging vegetation, macrophytes and submerged woody material. Water depth is important, maintaining areas of deep water will potentially increase the abundance of larger eels.

Migratory pathway: Passageway from the sea should be maintained at all times apart from when natural low flows prevent passage. Upstream migration is promoted by increasing water temperatures in late spring. Eels are good climbers but some barriers can still prevent migration. Elvers will migrate through areas of poor habitat, (i.e. culverts, channellised streams) to upstream areas of suitable habitat. Downstream migration of mature eels occurs during spate flows generally in autumn and migration is assisted by these high flows.

Spawning habitat: There are no spawning habitat requirements for eels in freshwater.

Dietary requirements: As eels are generalist predators with no specific food requirements. Food resources are unlikely to limit population density, but will influence growth rates.

Environmental tolerances: Shortfin eels are highly tolerant of poor water quality including high water temperatures and low dissolved oxygen concentration. Longfin eels require lower water temperatures and high dissolved oxygen conditions, but will still tolerate conditions other fish will not.

Biological interactions: Shortfin eels –unknown. Longfin eels are thought to limit the abundance and habitat use by banded kokopu.

A diverse fish assemblage requirements

A diverse assemblage is to some extent controlled by recruitment. Freshwater fisheries in the Auckland urban area are dominated by migratory species and recruitment reflects dispersion from source populations. Therefore achieving diverse native fish assemblages will not only rely on the provision of suitable freshwater habitat, but on the dispersion and abundance of marine migratory life history phases. Within the Auckland urban environment a diverse native freshwater fish assemblage would consist of five or more species on a reach scale (100-200 m of stream) in the lowland streams and three or more species in the steep forested streams. A diverse assemblage may also only occur at one time of year, inanga and common smelt do not occur in large numbers all year round in freshwater. Therefore, in summer a diverse assemblage may be present, but not in winter as species presence and absence changes. Furthermore, it has been shown throughout New Zealand that the most diverse native fish communities occur in the lower reaches of stream in areas all migratory species have access.

Habitat: varied habitats within the stream or river, i.e. wetland, pool, riffle, run and backwater/still habitats maintained. Provide good instream cover using log debris, macrophytes and stream bed substrate so that large and small fish are catered for. Moderate level of riparian shading with reaches being 30-60% shaded but with high shade levels (80%+) provided in smaller patches. The flow regime should provide good water flow in riffle habitat during low flow periods to maintain riffle fish communities (i.e. redfin bullies, juvenile longfin eels, koaro).

Migration pathway: Provide fish passage for all migratory fish species to promote assemblage diversity, this requires no barriers are present to weak swimming and non-climbing fish species. Fish passage is required in an upstream direction from August to March and downstream passage from February to July.

Spawning habitat: the provision of a diversity of adult fish habitats and natural flow condition should provide the spawning habitats for species within the assemblage.

Dietary requirements: the provision of a diversity of adult fish habitats will promote the occurrence of aquatic prey species. Riparian shading will provide habitat for terrestrial invertebrate inputs. Some fish species in the assemblage will also be prey items for larger native fishes.

Environmental tolerances: a diverse community will require good water quality some species such as common bully and common smelt do not tolerate poor water quality conditions such as low dissolved oxygen levels. Water quality parameters should aim to provide high dissolved oxygen levels, avoid high summer water temperatures, low levels of suspended sediment, and little sediment input

Biological interactions: diversity habitats are required so that refuge areas for small fishes are available from larger piscivorous species.

Diverse assemblage of lowland invertebrates requirements

Habitat: small streams with variable habitats, good riparian vegetation on the banks for erosion control, temperature reduction and for adult insect habitat. Clean rock substrates algal grazers and leaf and wood material for habitat and food substrates. Habitats must be stabilised to prevent large scale displacement during stormwater run off events. Shading will be important during summer low flow periods to maintain cool water temperatures. Water depths do not have to be exceed 5 cm. Some sedimentation desired, in pool habitats as this promotes habitat diversity, but sediments must not smother riffle and run substrates. Achieving the desired riparian vegetation for shading may also be difficult in residential urban areas.

Reproduction requirements: many adult aquatic invertebrates are terrestrial winged insects and these require shelter amongst riparian margin shrubs and grasses. Removal of riparian margins in urban environments will have a major impact on the survival of some aquatic insects. Egg laying sites are often on the hard substrates, cobbles and boulders on the streambed. Excessive siltation may degrade the egg laying habitat and also reduce aquatic invertebrate diversity. Suitable habitat can be provided in urban environments but not without riparian management.

EPT species (excluding Hydroptilidae) requirements.

Adult habitat: Good riparian vegetation to provide refuge from adverse elements (storms, high winds); cool temperatures (range < 20ºC), moderate humidity.

Habitat for immature stages: Cool stream temperatures (<20ºC); diverse habitat of hard substrates (rocks, woody debris); moderate-low sedimentation in stream; moderate-high levels of oxygen; low-moderate levels of eutrophication and contamination; moderate algal growth.

Dietary requirements: Varies but elements include wood and leaf debris from riparian vegetation, moderate shade (~70%) for moderate algal growth.