From:	Hilary Lennox
To:	Natasha Pritchard
Cc:	Tony Jack Pioneer (tony.jack@pioneerenergy.co.nz)
Subject:	FW: FW: Onslow supplementary information.
Date:	Wednesday, 2 May 2018 12:44:12 p.m.
Attachments:	cawthron stark strickland 97.pdf

Hi Natasha

Here's the last report that Jason asked for. It'd be great if you could please give an update on where Jason is at with reviewing the additional info sent through because F&G have been asking me where this one is at.

Thanks so much!

Hilary

From: Hilary Lennox
Sent: Monday, 9 April 2018 12:13 PM
To: 'Natasha Pritchard'
Subject: FW: FW: Onslow supplementary information.

Hi Natasha

PEL have manager to find one of those reports electronically (attached) and we're still hunting down the last one (Stark J and Strickland R,1997. Assessment of Impacts ...hydro and irrigation schemes on the Teviot River Catchment)

Cheers

Hilary

From: Tony Jack <tony.jack@pioneerenergy.co.nz>
Sent: Monday, 9 April 2018 11:23 AM
To: Hilary Lennox <Hilary@landpro.co.nz>
Cc: Ross Dungey <Ross.d.consult@gmail.com>
Subject: Re: FW: Onslow supplementary information.

Stark & Hayes 1997 attahced

Tony Jack
Development Engineer
11 Ellis Street, Alexandra, PO Box 275
Alexandra 9304, New Zealand
P: **+64 3 440 0801**
F: **+64 3 448 9439**
M: +**6427 733 2555**
W: **www.pioneerenergy.co.nz**

On 5 April 2018 at 13:22, Hilary Lennox <Hilary@landpro.co.nz> wrote:

> Hi Ross
>
> Thanks for the attached info, which I have sent to ORC for consideration – just waiting to hear back from them.
>
> Can you please also send through copies of the following reports:
>
> - Stark J 1993, Cawthron report 229, A survey of macroinvertebrates in seventeen South Island lakes.
> - Stark J and J Hayes 1997; Cawthron report 389, Freshwater biological assessment of environmental effects for the proposed Central Electric Ltd Horseshoe bend hydroelectric

scheme on the Teviot River.

- Stark J and Strickland R,1997. Assessment of Impacts …hydro and irrigation schemes on the Teviot River Catchment. Cawthron report 401, for Central electric

Thanks
Hilary

From: Tony Jack <tony.jack@pioneerenergy.co.nz>
Sent: Thursday, 22 March 2018 12:39 PM
To: Hilary Lennox <Hilary@landpro.co.nz>
Subject: Fwd: Onslow supplementary information.

---------- Forwarded message ---------
From: Ross Dungey <ross.d.consult@gmail.com>
Date: Thu, 22 Mar 2018 at 11:59 AM
Subject: Onslow supplementary information.
To: Tony Jack <tony.jack@pioneerenergy.co.nz>

Hi Tony, report attached, I hope this answers the questions.It seems to be a small variation and therefore with few detectable affects other than the positive to the Teviot River. But the whole scheme currently seems to operate well with few discernible adverse effects so there is little to moderate even with late season increased flows. Rainfall seems likely to limit your opportunity to utilise the advantage the increased draw down may give.

Regards
Ross

--

Tony Jack
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2/0/1/1 16 ... 2008

Cawthron Report No. 401

CAWTHRON

DRAFT

Assessment of the impacts of existing hydroelectric and irrigation schemes on aquatic biology in the Teviot catchment

Report for: Central Electric Ltd

Authors: John D. Stark
Rowan R. Strickland

26 May 1997

98 HALIFAX ST EAST ■ PRIVATE BAG 2 NELSON NEW ZEALAND ■ TEL 0-3-548 2319 FAX 0-3-546 9464

CAWTHRON

1.0 INTRODUCTION

The Teviot River drains steep open tussock and pasture on the eastern side of the Clutha valley. The Teviot's headwaters accumulate in an artificially formed lake (Lake Onslow) before descending 29 kilometres through a series of deep gorges to join the Clutha River adjacent to the town of Roxburgh. From Lake Onslow to the Clutha River, there is an altitude difference of approximately 584 metres, with an average gradient of 1 in 20. The Teviot River's channel is deeply entrenched in bedrock, and has no meanders or braided sections, but rather a relentless series of cascades, small waterfalls, and deep pools, interrupted occasionally by swift bouldery runs.

The Teviot's rapid drop in altitude has lent itself ideally to hydroelectric development. Lake Onslow was formed originally for mining, and then irrigation purposes. It has since been raised in height and has a control structure for increased hydroelectric and irrigation use. In the lower Teviot, water is diverted at the Marslin dam by Central Electric Limited (CEL) for electrical generation from three power stations. Across the Teviot River just downstream of the Marslin dam is an intake weir for the Teviot Irrigation Company (TIC). Manipulation of flows in the Teviot for .rrigation and hydroelectric use are integrated, and controlled by various agreements and conditions between CEL and TIC. As a condition of these operations, both companies will soon be required to renew their various consents under the Resource Management Act 1991.

The Fourth Schedule of the Resource Management Act (1991) requires that the effects of any development on the environment must be assessed. Specifically, in Clause 2(c) an assessment is required to consider "any effect on ecosystems, including effects on plants or animals and any physical disturbance of habitats in the vicinity" and in Clause 2(d) " any effect on natural and physical resources having ... scientific .. or other special value for present or future generations."

The purpose of this report, therefore, is to describe the distribution of fish and macroinvertebrates in the Teviot River, and to assess the impact that hydroelectric and irrigation use of the river may have had on the aquatic ecosystem.

2.0 METHODS

)ata for this report was obtained from previous Cawthron investigations which looked at the effects of a proposal by CEL to build another hydroelectric dam on the Teviot at Horseshoe Bend (Stark and Hayes, 1997). For this report, further macroinvertebrate sampling and electric fishing in December 1996, mainly in the lower half of the catchment, augmented these existing data. Relevant data has also been extracted from fisheries studies in the Clutha River (Jellyman 1984; Pack & Jellyman 1988).

Electric fishing in December 1996 was done with a 300-watt battery powered backpack machine. Fish were sampled in a single pass and caught in a downstream hand-held stop-net or in clear shallows by fishing upstream and capturing fish in scoop nets. After analysis of the catch all fish were returned live.

Twenty sites in the Teviot River between Lake Onslow and the Clutha River (Figure 1) have been electric fished by Cawthron staff. For comparative purposes three sites outside the area shown in Figure 1 were also fished as follows:

North Branch Teviot River	NZMS 260 G43 468172
Ruby Creek	NZMS 260 G43 265043
Tima Burn	NZMS 260 G43 293003

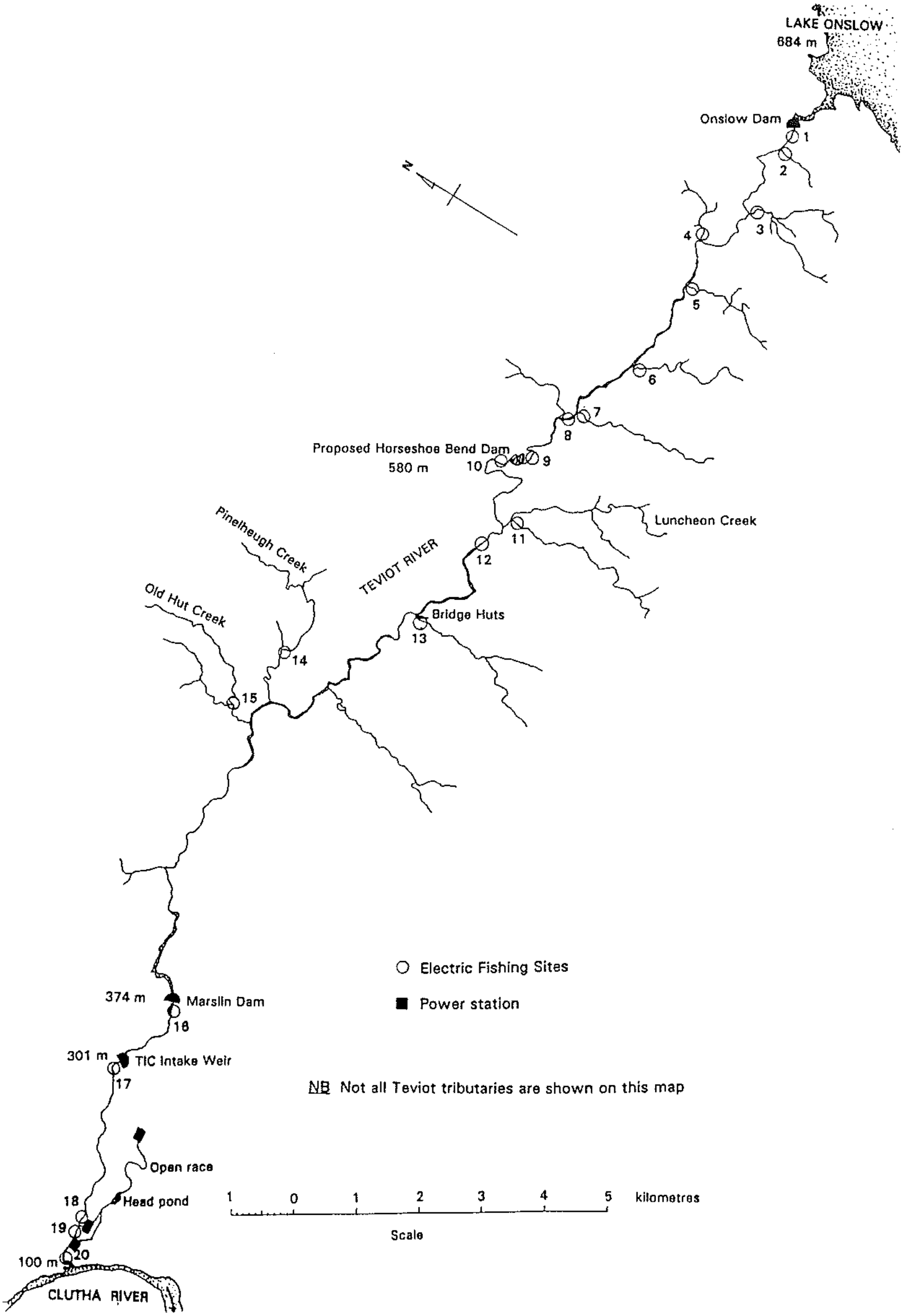

Figure 1: Map showing sites electric fished by Cawthron in the Teviot River

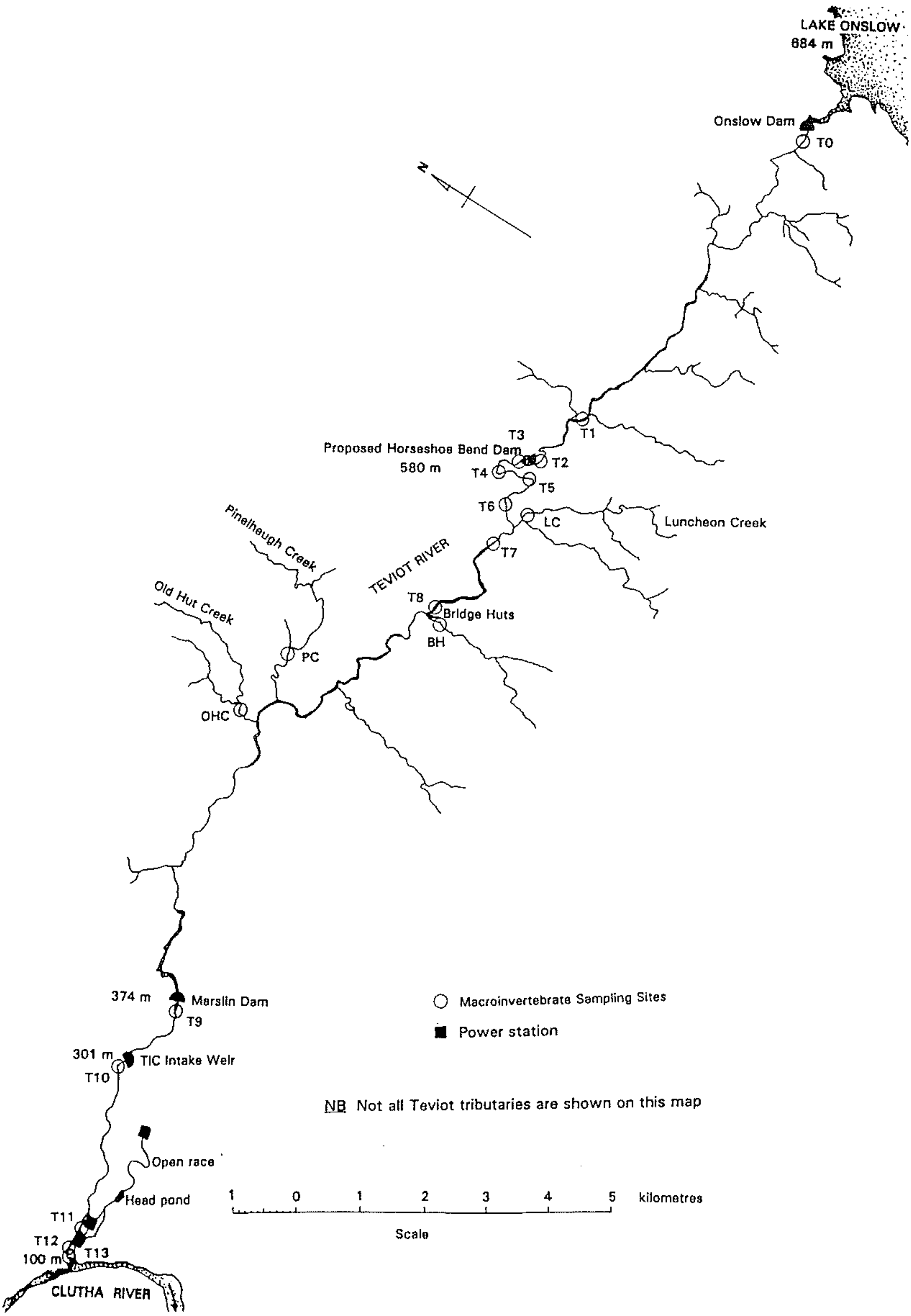

Figure 2: Map showing sites sampled for macroinvertebrates by Cawthron in the Teviot River

Macroinvertebrate sampling has been undertaken at 14 sites in the Teviot River mainstem (T0 – T13), and four tributary streams (Table 1) as well as in Lake Onslow (Stark & Hayes 1997). Sampling was undertaken in September 1992, March 1993, July 1996, and December 1996. Three different macroinvertebrate sampling methods have been employed. Samples collected include 0.1m^2 Surber samples, 0.0135m^2 core samples (in Lake Onslow) and semi-quantitative hand-net samples. The mesh size on all sampling devices was 0.5 mm.

Table 1: Macroinvertebrate sampling site locations in the Teviot catchment (see Figure 2 for map of site locations).

Code	Location
T0	Teviot River 300 m downstream of the Lake Onslow Dam. Infomap 260 G43 22435 55119
T1	Teviot River at upstream limit of proposed impoundment (near Moir's Bridge). Infomap 260 G43: 22379 55127.
T2	Teviot River within the proposed impoundment a few hundred metres upstream of the dam site. Infomap 260 G43: 22371 55128.
T3	Teviot River downstream of the dam site (i.e. within the proposed residual river). Infomap 260 G43: 22369 55131.
T4	Teviot River within the gorge. Infomap 260 G43: 22365 55132.
T5	Teviot River within the gorge opposite proposed tunnel outlet. Infomap 260 G43: 22368 55127.
T6	Teviot River within the gorge just upstream of proposed powerhouse tailrace discharge. Infomap 260 G43: 22362 55128.
T7	Teviot River downstream of the proposed power station. Infomap 260 G43: 22355 55127.
T8	Teviot River at Bridge Huts. Infomap 260 G43: 22341 55129.
T9	Teviot River downstream of Marslin Dam. Infomap 260 G43: 22268 55131.
T10	Teviot River downstream of Teviot Irrigation Company Intake. Infomap 260 G43: 22256 55133.
T11	Teviot River upstream of Teviot Bridge/Ellis power house. Infomap 260 G43: 22233 55125.
T12	Teviot River downstream of Roxburgh Hydro - Millers Flat Road bridge. Infomap 260 G43: 22226 55125.
T13	Teviot River upstream of Clutha River confluence. Infomap 260 G43: 22225 55124.
LC	Luncheon Creek between the ford and the confluence of the left and right branches of Luncheon Creek. Infomap 260 G43: 22362 55125.
PC	Pinelheugh Creek at bridge upstream of Teviot River confluence. Infomap 260 G43: 22323 55145.
BH	Unnamed tributary at Bridge Huts. Infomap 260 G43: 22340 55129.
OHC	Old Hut Creek. Infomap 260 G43 22314 55147

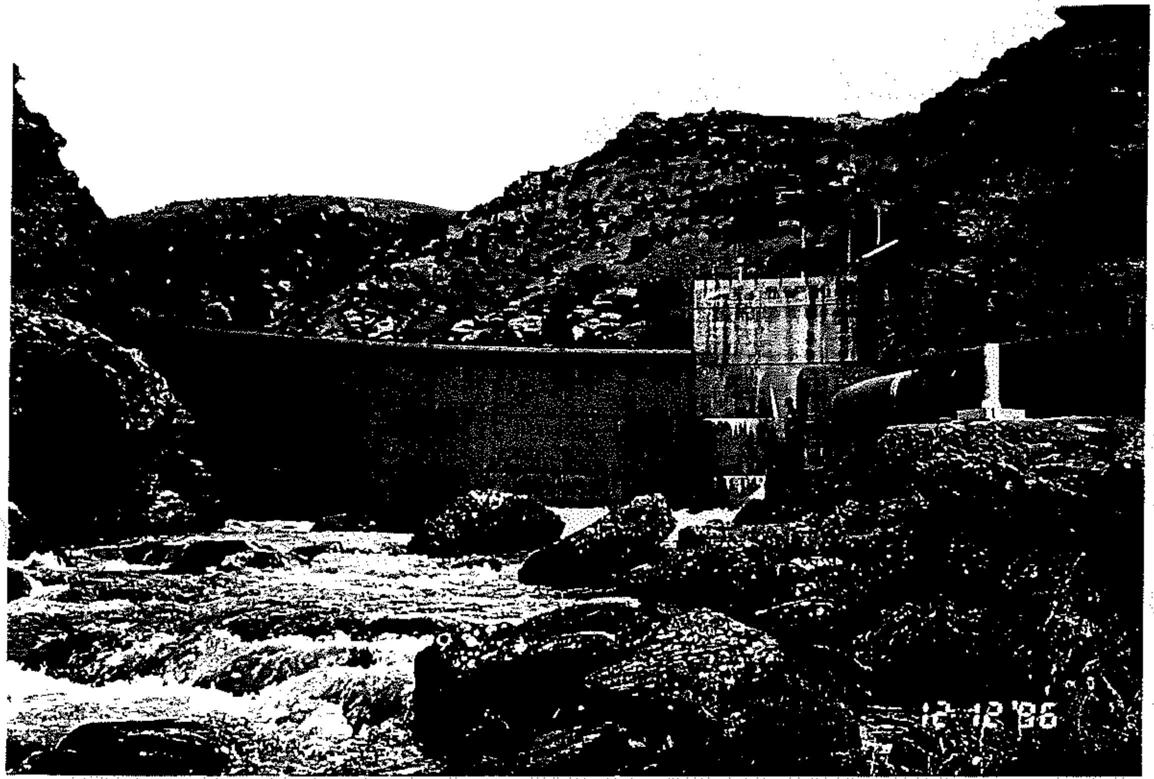

Plate 1: The Marslin Dam on the Teviot River. Macroinvertebrate sampling site T9 was located here.

Plate 2: The Teviot Irrigation Company (TIC) weir. Macroinvertebrate sampling site T10 was located at lower left.

Plate 3: Typical habitat in steeper sections of the Teviot River

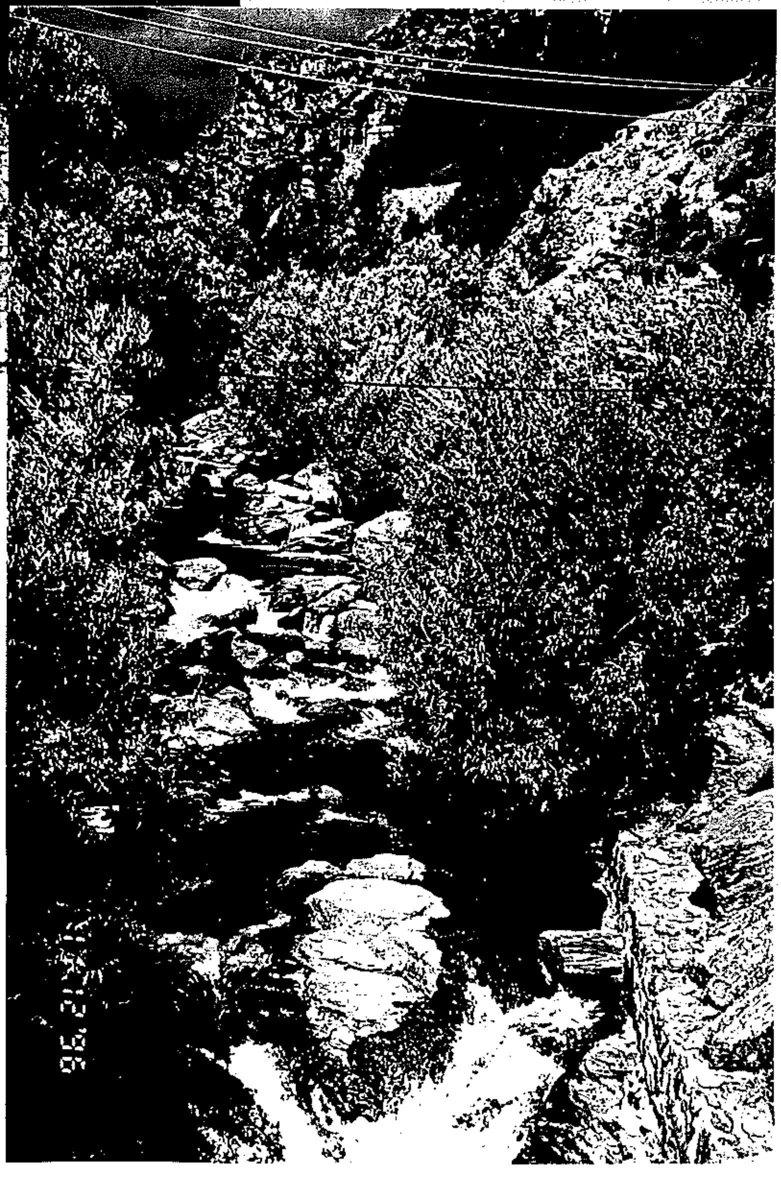

Plate 4: Site T11 immediately upstream of the Teviot Bridge/Ellis power house.

Plate 5: Old Hut Creek where *Galaxias anomalus* were found.

3.0 RESULTS

3.1 Fish populations

Six fish species and one crustacean have been recorded by electric fishing in the Teviot River. These were longfinned eel (*Anguilla dieffenbachii*), roundhead galaxias (*Galaxias anomalus*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), quinnat salmon (*Oncorhynchus tshawytscha*), common bully (*Gobiomorphus cotidianus*), and koura (*Paranephrops zealandicus*). With the exception of rainbow trout and quinnat salmon, these species were all found in the Teviot River during the December 1996 survey. Jellyman (1984) records rainbow trout having been caught in the lower Teviot River, but Pack and Jellyman (1988) indicated they were not abundant in the Clutha and had decreased substantially since cessation of stocking. The record of rainbow trout in the Teviot probably relates to original stocking attempts. A single spent quinnat salmon was found at the confluence of the Teviot and Clutha Rivers (Pack & Jellyman, 1988).

3.1.1 *Teviot River between Lake Onslow and the Clutha River*

Of the twenty sites sampled in the Teviot River between Lake Onslow and the Clutha, only two (sites 2 and 3) had no fish present. Both these sites were in particularly steep tributaries and site 3 was above a waterfall.

Brown trout, particularly juveniles, were the most common fish, and were found at 14 of the sites (absent only at sites 2, 3, 4, 15, 18, 19). They were most abundant in tributaries, and in margins of the main river below Lake Onslow. The highest density of brown trout juveniles (170 per 100 m^2) was recorded at site 11.

Longfinned eels were found at only the three lower sites (sites 18, 19, 20). A farmer spoken to at Bridge Huts reported having occasionally seen an eel in several of the tributaries between there and the Marslin Dam. Eels have also occasionally been seen in the head pond and open race between CEL's power stations (D. Wright, pers. comm.). The highest density of longfinned eels (20/100 m^2) found in the Teviot were near the mouth amongst bouldery shallows. Immediately upstream of this point, longfinned eel density dropped to about two per 100 m^2, and was similar upstream to site 18. Their drop in density coincided with deep, swift habitat to the first power station. However eel density did not increase above the power station, where the river flow decreases to a variable residual flow, and becomes characterised by boulder pools and cascades.

Common bullies were only found at site 1. They were common (13/100 m^2) along the river margins.

Roundhead galaxiids were caught in tributaries (sites 4 and 15) where trout were precluded by downstream falls. Six were caught in a 5 m^2 area fished at site 4, and one was caught in a similar area fished at site 15. Sites 4 and 15 (Old Hut Creek: Plate 5) were small steep streams with small cascades, moderately fast shallow runs and rapids, short deep pools, and undercut banks with overhanging tussocks.

Koura were found only in tributaries, and then in only four of the ten sampled (sites 4, 5, 6, 15).

3.1.2 *Other areas sampled*

To assess the impact of development on fish distribution in the Teviot River it was necessary to determine the range of species that may penetrate the Clutha River as far upstream as the Teviot confluence. To do this, several streams just downstream of the Teviot were sampled, or had data obtained for them.

3.1.2.1 North Branch Teviot

A section of the North Branch Teviot several kilometres above where it enters Lake Onslow was fished. At this site, brown trout fingerlings were present in abundance. Common bullies had also been recorded at this site in the past (Jellyman, 1984).

3.1.2.2 Ruby Creek

Ruby Creek, a small tributary stream of the Clutha 12 kilometres downstream of the Teviot confluence, was fished to compare with the range and abundance of species in the Teviot. By comparison with the Teviot River, Ruby Creek has far less flow, and gradient. It is agriculturally modified, with little riparian protection, and appears flood prone through the reach sampled.

Approximately 400 metres of stream were randomly fished from the Clutha confluence upstream to Millers Flat Road. Longfinned eels were abundant through the reach, and in some instances were found in densities of up to two per m^2. Brown trout fingerlings were common in runs and riffles, but only one common bully was found.

3.1.2.3 Tima Burn

Tima Burn, another small Clutha tributary six kilometres below Ruby Creek, was also sampled for comparative purposes. An approximately 100 m reach was randomly sampled. Although the Tima Burn had a slightly higher flow and gradient than Ruby Creek, it had a more stable substrate with extensive beds of *Elodea canadensis* and *Potamogeton cheesmanii.* Once again longfinned eels were very abundant, but so too were brown trout fingerlings. There were also several larger brown trout up to 300 mm in length present through the reach. A single quinnat salmon, 85 mm in length, was the only other species encountered. Pack & Jellyman (1988) sampled two reaches of the Tima Burn and recorded an additional five species: 1 torrentfish (*Cheimarrichthys fosteri*), 2 common bullies, 3 shortfinned eels (*Anguilla australis*), 6 upland bullies (*Gobiomorphus breviceps*), and an unknown number of koaro (*Galaxias brevipinnis*). Jellyman (1984) also recorded bluegilled bullies in Tima Burn.

3.1.2.4 Benger Burn

Apart from torrentfish, all fish species found in Tima Burn have also been recorded in Benger Burn. Benger Burn is another tributary that enters the Clutha on the true right between Ruby Creek and Tima Burn, though it is much larger.

In summary, fish found in Clutha River tributaries near the Teviot River, and those found in the Teviot River, are shown in Table 2.

Table 2: Fish found in Clutha River tributaries near the Teviot River, compared with those found in the Teviot River catchment. (* = diadromous, ✓ = present).

Species		Teviot River catchment	Other Clutha tributaries
Longfinned eel	*	✓	✓
Shortfinned eel	*		✓
Roundhead *Galaxias*		✓	
Koaro	*		✓
Rainbow trout		✓	
Brown trout		✓	✓
Quinnat salmon	*	✓	✓
Torrentfish	*		✓
Common bully	*	✓	✓
Bluegilled bully	*		✓
Upland bully			✓

3.2 Macroinvertebrate communities

Boud & Cunningham (no date, but likely to be mid 1960's) undertook the earliest macroinvertebrate survey of the Teviot River. They collected a total of 72 "square-foot" samples (almost equivalent to present-day $0.1 m^2$ Surber samples) from three sections of the river. Section 1 (7.2 km) extended from the Roxburgh Hydro - Millers Flat Road bridge to about halfway to Bridge Huts; Section 2 (9.4 km) extended from the top of Section 1 to approximately 2.4 km upstream of

Bridge Huts (near Luncheon Creek); and Section 3 (10.5 km) extended from Reach 2 to the Onslow Dam.

However, they only identified macroinvertebrates to the major group (Order) level and reduced data from all samples to percentage community composition for each of three sections of the Teviot River (Table 3). Unfortunately, these percentages (which are repeated in Table 3) were calculated incorrectly and cannot be recalculated because original data were not given.

Table 3: Percentage composition of invertebrate communities expressed as major groups in three sections of the Teviot River. Total average densities are given also. Section 1 was from the Roxburgh East Hydro Road to halfway to Bridge Huts, Section 2 from there to about Luncheon Creek and Section 3 from near Luncheon Creek to the Onslow Dam (After Boud & Cunningham, no date). N.B. The percentages in this table do not add to 100%. This error was present in the original data, and Boud & Cunningham presented insufficient information for any correction to be made.

	Section 1	Section 2	Section 3
Mayflies	10.2	33.2	29.2
Dobsonflies	<1	<1	<1
Beetles	<1	<1	<1
True flies	2.7	7.8	7.4
Caddisflies	23.5	20.1	15.7
Molluscs	42.3	47.3	46.3
Worms	4.3	4.1	20.4
Number of samples	34	29	9
Average density (No m^{-2})	2228	2701	1561

Boud & Cunningham (no date) found that macroinvertebrate communities in the Teviot River were dominated by snails (almost entirely *Potamopyrgus antipodarum*). Mayflies (10.27 – 33.2%) and caddisflies (15.7 – 23.5%) were also well represented, but most other groups (except worms in Section 3) were present only in low numbers (Table 3). Average densities ranged from 1561 to 2701 animals m^{-2}, although, since the mesh size used was not specified, these densities are of limited comparative value. No data on species richness were presented (because animals were not identified to the species level).

On 21 February 1984, Biggs & Shand (1987) surveyed macroinvertebrate communities in the lower reaches of the Teviot River about 500 m upstream of its confluence with the Clutha River. Five 0.0625 m^2 (0.425 mm mesh) Surber samples were collected from riffle habitat.

Table 4: Percentage composition of invertebrate communities in the lower Teviot River 500 m upstream of its confluence with the Clutha River. Total average densities (No. m^{-2}) are given also. (After Biggs & Shand, 1987).

Taxon	Mean percentage
Mayflies	
Deleatidium sp.	2.2
Stoneflies	
Zelandobius furcillatus	<0.1
True flies	
Maoridiamesa spp.	2.9
Orthocladiinae	4.4
Tanytarsus vespertinus	4.4
Caddisflies	
Aoteapsyche colonica	4.4
Psilochorema sp.	1.5
Pycnocentria evecta	1.5
Worms	present but not quantified
Molluscs	
Potamopyrgus antipodarum	77.9
Number of taxa	10
Average density (No. m^{-2})	725

Only ten macroinvertebrate taxa were collected from the Teviot River by Biggs & Shand (1985) (Table 4). Once again, community composition was dominated by *Potamopyrgus antipodarum* (77.9%) with no other animals contributing more than 5% by numbers to community composition. Densities were relatively low (725 animals m^{-2}) and only 34% of the mean density recorded by Boud & Cunningham (no date) from Section 1 (which would have included the reach that Biggs & Shand (1985) sampled).

Cawthron personnel sampled stream and lake sites in the Teviot catchment in September 1992, March 1993, and July 1996 in relation to the proposed Horseshoe Bend power scheme (Stark & Hayes 1997), and in December 1996 (mainly in the lower Teviot River) specifically for this report.

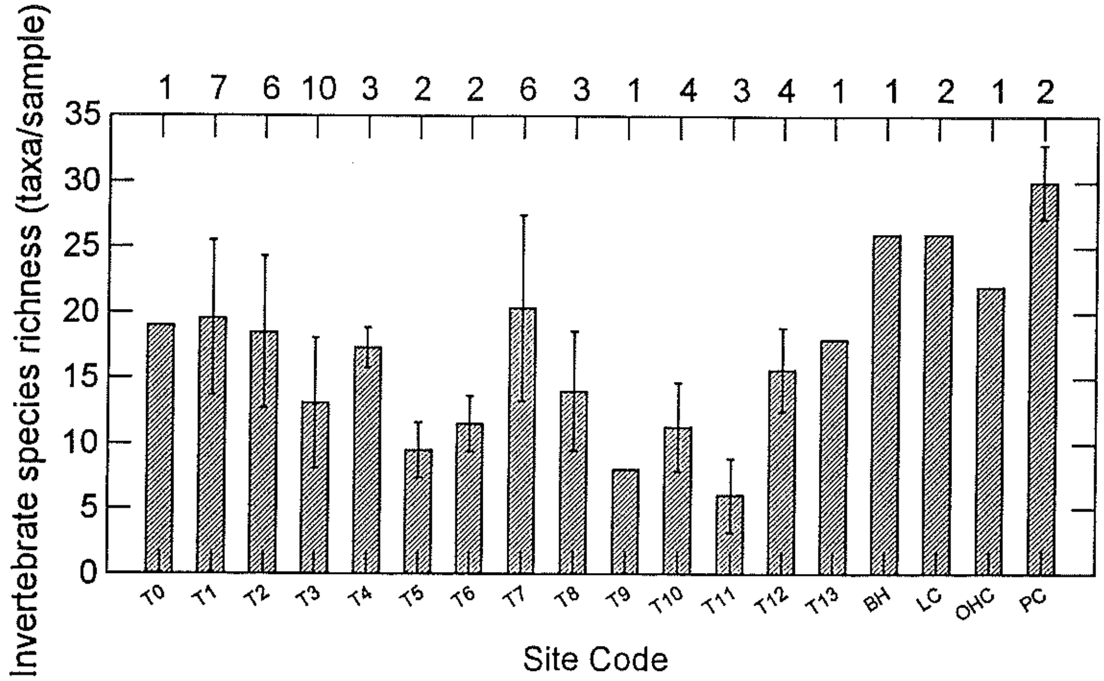

Figure 3: Mean macroinvertebrate species richness per sample (± standard deviation) at 14 sites in the Teviot River (T0 – T13) and in four tributary streams. (Data from all times and samples combined). See Figure 2 and Table 1 for details of site locations. The number of replicate samples collected is shown along the top of the graph.

Cawthron sampling has revealed a total of 87 different kinds (taxa) of macroinvertebrate from the Teviot River catchment (including Lake Onslow) (Appendix 1). Caddisflies (22 kinds) were represented in the greatest variety, with true flies (17), Crustacea (9), beetles (8), stoneflies (6), and mayflies (6) also represented by a reasonable variety of different taxa. All of the macroinvertebrates recorded in earlier surveys (i.e. Boud & Cunningham (no date), Biggs & Shand (1985)) were recorded in our surveys. Our data indicate that snails and worms continue to dominate macroinvertebrate communities in the lower reaches of the Teviot River (Sites T11 – T13).(Appendix 1)

Macroinvertebrate species richness (defined as number of taxa per sample) was quite variable between different places in the Teviot catchment ranging from a low of 6 taxa per sample (Site T11) to a high of 30 taxa per sample (Pinelheugh Creek) (Figure 3). In general, species richness was higher in the smaller tributary streams (e.g. Pinelheugh Creek, Luncheon Creek, the tributary at Bridge Huts, and Old Hut Creek), than in the mainstem of the Teviot River. The poorest variety of macroinvertebrates was associated with bedrock substrates, steep streambed slopes, and/or torrential water velocities (e.g. Sites T5, T6, T9 – T11).

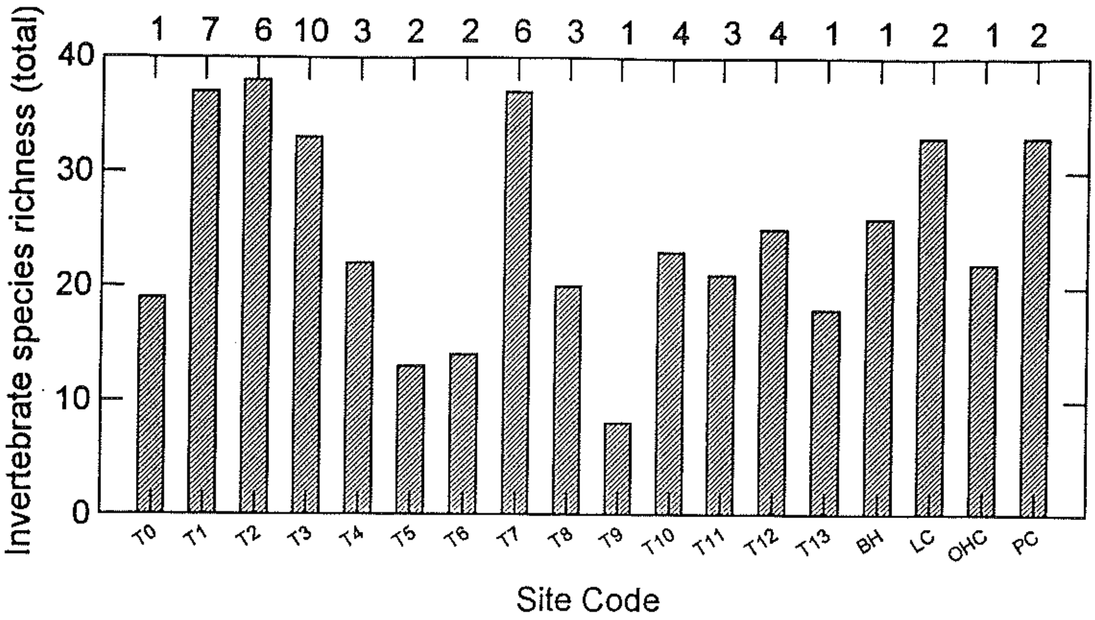

Figure 4: Total number of macroinvertebrate species recorded from 14 sites in the Teviot River (T0 – T13) and in four tributary streams. (Data from all times and samples combined). See Figure 2 and Table 1 for details of site locations. The number of replicate samples collected is shown along the top of the graph.

Total numbers of taxa collected from each sampling site varied between 8 (Site T9) and 38 (Site T2) with the pattern strongly influenced by sampling effort (Figures 4 & 5). However, it is noteworthy that more intensive sampling at some places on the Teviot mainstem did yield a great variety of species. For example, at Site T2, six samples yielded twice as many taxa as the average number per sample (Figure 4 cf. Figure 3).

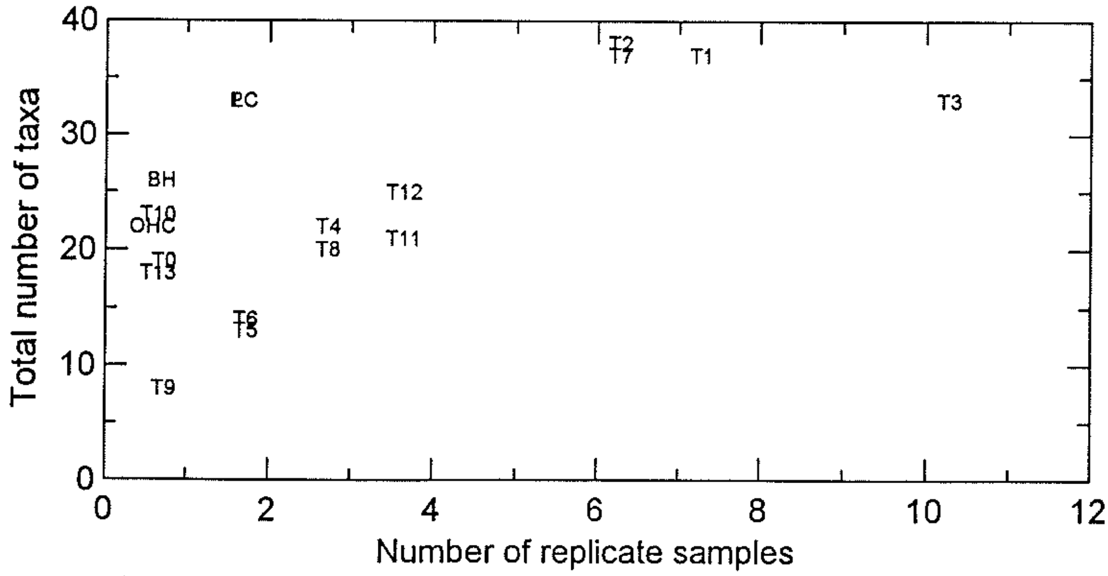

Figure 5: Relationship between the total number macroinvertebrate species collected and sampling effort for 13 sites in the Teviot River and four tributary streams.

Figure 5 shows the influence of sampling effort more clearly. Species-rich sites are plotted towards the top left on Figure 5 (i.e. many taxa collected in few samples), and species-poor sites would be plotted towards the lower right (i.e. many samples but few taxa). Tributary streams (especially Luncheon and Pinelheugh Creeks, the tributary at Bridge Huts and Old Hut Creek) generally are more species-rich than Teviot mainstem habitats (with the exception of T10 downstream of the TIC intake). At the other extreme, it took 10 samples from Site T3 (downstream of the proposed

Horseshoe Bend dam site) to collect as many taxa as were collected in duplicate samples from Luncheon and Pinelheugh Creeks (Figure 5).

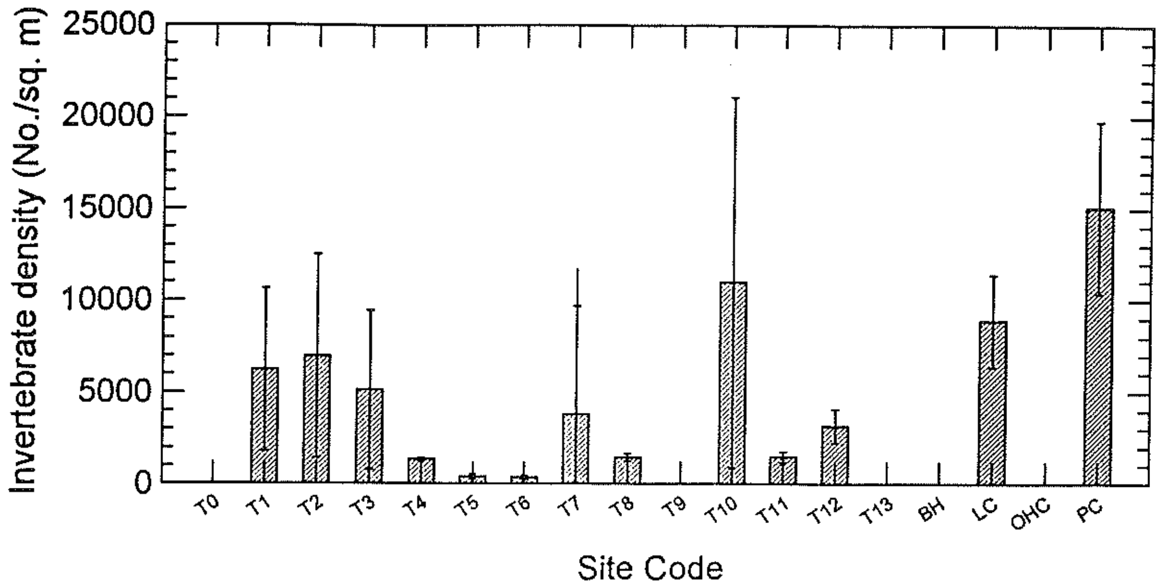

Figure 6: Mean macroinvertebrate densities per square metre of streambed (± standard deviation) at 11 sites in the Teviot River and in two tributary streams. (Data from all times and samples combined). Quantitative samples were not collected from Sites T0, T9, T13, BH and OHC. See Figure 2 and Table 1 for details of site locations.

The presence of a great variety of taxa, and high densities of macroinvertebrates in tributary streams such as Luncheon and Pinelheugh Creeks is likely to provide good juvenile rearing habitat for trout and a source of macroinvertebrate colonists for the Teviot River mainstem downstream.

Macroinvertebrate densities in the Teviot River catchment are quite variable (370 – 15,110 animals per square metre), not only between sites (e.g. Pinelheugh Creek cf. T5) but also between replicates (e.g. large error bars at T10) (Figure 6). Quantitative data were not collected from five sites (viz. T0, T9, T13, BH & OHC).

Given the fact that temporal vairation in macroinvertebrate densities can be high due to the influences of flow variability and season, and given the limited quantitative sampling at different times for different sites, it probably is unwise to examine between-site differences in densities too closely. Rather, we may conclude that:-

- macroinvertebrate densities in the Teviot catchment appear to be within normal limits for New Zealand streams.
- densities in tributary streams, in general, are higher than in the Teviot River mainstem.
- densities in the swift and turbulent gorge (e.g. Sites T4 – T6) or on steep bedrock habitat (e.g. T11) are comparatively low.

The Correspondence Analysis Ordination (Figure 7) summarises the composition of macroinvertebrate communities in the Teviot River catchment (including Lake Onslow). The ordination reveals that macroinvertebrate communities in Lake Onslow were dominated by oligochaete worms, and that worms were also dominant amongst silt entrapped in algal or moss mats, or in fine sediments, at three sites in the lower reaches of the Teviot River (Sites T10, T12, T13). The Teviot River immediately downstream of Lake Onslow (T0) was the only other riverine site to stand out from the remaining sites due to high numbers of sphaeriid clams. These bivalves generally are more common in lakes, ponds or sluggish rivers, so are likely to be derived from the lake upstream. The remaining Teviot River sites and the tributaries all grouped together on the ordination suggesting that their communities were all quite similar in character. Orthoclad midges (Chironomidae) generally were dominant at these sites (Figure 7, Appendix 1).

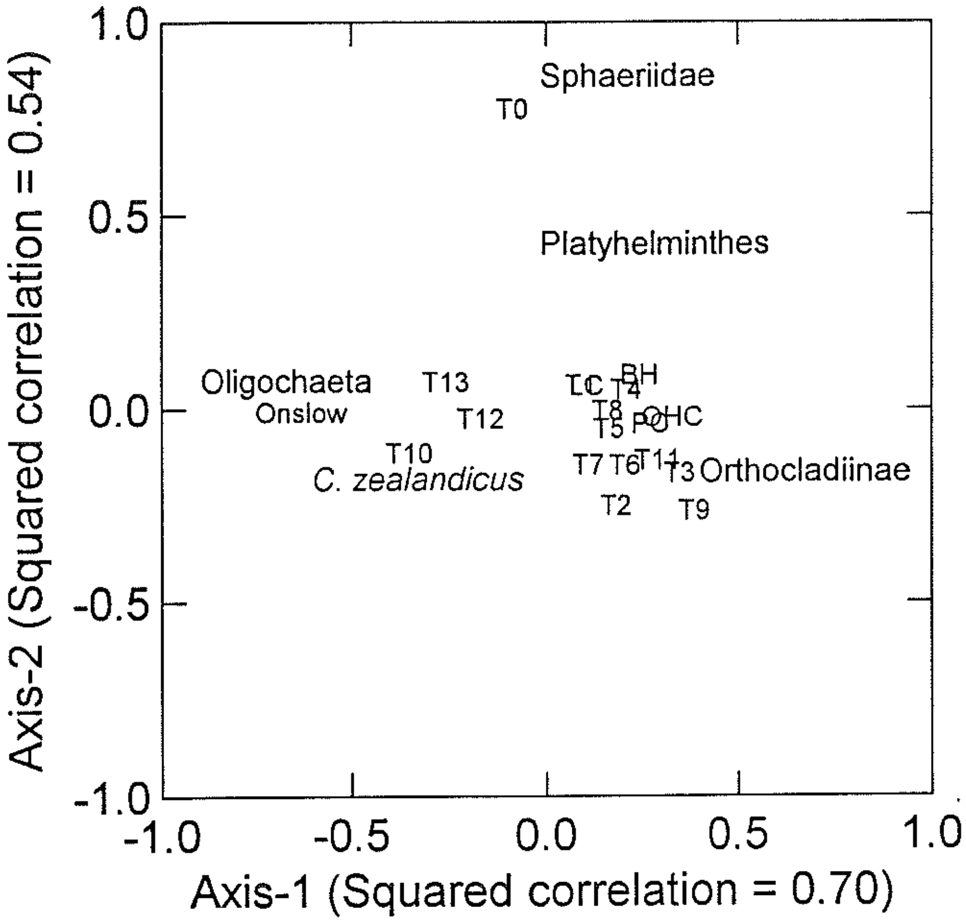

Figure 7: Correspondence Analysis Ordination of macroinvertebrates based upon data collected from the Teviot River catchment (1992 – 1996).

4.0 DISCUSSION

Compared with other nearby tributaries of the Clutha River, the Teviot River is of significantly steeper gradient and higher flow. Generally, a river of this nature proves either, difficult for fish to penetrate, or offers little suitable habitat.

4.1 Factors determining fish distribution

Most New Zealand freshwater fish are diadromous, which means that they require access to and from the sea to complete their life cycle. The distribution of fish within any river system is therefore dependent on the ability of each species to negotiate obstacles that may be present. The most significant natural obstacles are waterfalls, but velocity barriers also occur. Artificial obstructions such as dams, weirs, and overhanging culverts may also cause significant disruption to fish movements. Several species have the ability to climb quite substantial falls and man-made structures. Some structures, or a high frequency of falls and cascades, quite often exclude upstream access for all species. Even the most insignificant of these obstacles can have an effect on further upstream migration for most fish. For species able to recruit areas above these obstacles, their rate of recruitment is often limited and densities low.

Besides the more dramatic effect of natural obstacles such as waterfalls limiting fish access, increasing river gradient plays a similar but subtler role. Species diversity therefore usually tends to taper off in an upstream direction as river gradient increases and weaker swimming species drop out. In some rivers, gradient is gradual and there are long distances of river that can be penetrated by fish. In others, it is more abrupt and quite often characterised by waterfalls or cascades. Presence of species above significant migratory barriers, can often be attributed to artificial stocking by man. This is particularly so for species with high recreational value such as trout. Where access to and from the sea is not possible, some migratory species, such as common bullies, common smelt, and koaro, are able to form landlocked populations. Instances of both natural, and artificially stocked, lake populations of these species are not uncommon throughout New Zealand.

In addition to the need for unrestricted access, many of the species have quite specific habitat requirements, which if not present in the system, further determine that particular species presence or abundance.

4.2 Fish distribution in the Teviot River

The likely range of species which could be expected to occur naturally in the Teviot River can be determined from the list of anadromous species found in other Clutha tributaries close-by (Table 2). Of this list, only longfinned eels, quinnat salmon, and common bullies have been found in the Teviot. The only record of salmon from the Teviot was that of a single spent fish at the mouth (Pack and Jellyman 1988) – rather too little evidence to suggest that salmon do utilise the Teviot River. The absence from the Teviot of migratory species found in other Clutha tributaries close-by is most likely attributable to the severe nature of the Teviot, or a lack of suitable habitat. The severe physical characteristics associated with the Teviot's much steeper gradient (especially in its lower reaches) suggests this is the primary limiting factor.

The presence of common bullies appears limited to Lake Onslow, and the top of the Teviot River immediately below Lake Onslow. Their absence from all other sample sites downstream indicates that those found are a landlocked population, rather than anadromous. Because of the steep nature of the Teviot downstream of where common bullies were present, it seems unlikely that they would have populated this far upstream naturally (i.e. even if the existing dams had not been present). If common bullies had been able to penetrate this far upstream, koaro (which are even better climbers) should also have done so, and formed a landlocked population. However, koaro have never been recorded in the catchment, despite the presence of suitable habitat. It seems most likely therefore, that common bullies were introduced into Lake Onslow after the introduction of brown trout in 1915 as a food source for trout.

The only true migratory species found in the Teviot, and which dams or weirs may affect, was the longfinned eel. This species is the most aggressive migrant of all New Zealand freshwater fish, and can sometimes be found above quite substantial waterfalls (McDowall, 1990). Longfinned eels have even been able to occasionally migrate above the Roxburgh Dam (Pack and Jellyman, 1988). Longfinned eels were found in reasonable density near the mouth of the Teviot but decreased to about 2 per 100 m^2 within 200 metres upstream. These densities were very low compared with densities of longfinned eels found in other Clutha tributaries nearby. Although none were found upstream of site 18, anecdotal evidence suggests that eels are able to penetrate the Teviot beyond Marslin dam. Because longfinned eels are so long-lived, presence of very low densities, or an occasional sighting, suggests limited recruitment. While the TIC weir and Marslin dam no doubt limit some natural recruitment of longfinned eels, the absence of these structures is unlikely to significantly increase eel density upstream. Their low density, even well downstream of these structures, suggests that the physical nature of the Teviot is too severe for the presence of more than an occasional longfinned eel.

The physical features of the Teviot River do not limit the distribution of brown trout as much as they limit the distribution of diadromous species. Brown trout were successfully established in Lake Onslow, and have subsequently filtered downstream through the Teviot River system. Significant natural recruitment for this species now occurs from tributaries of Lake Onslow, the mainstem of the Teviot below the lake, and in every suitable tributary downstream. Brown trout are only absent from a few tributaries where waterfalls preclude further upstream distribution. Consequently, brown trout are the most common and abundant species in the Teviot system.

The presence of rainbow trout in the Teviot appears to stem from unsuccessful attempts at establishing them in Lake Onslow (Whiting, 1986), as none appear to have been recorded in the Teviot since. In the Clutha River below Roxburgh, rainbow trout only constitute only about 5% of the anglers' catch of trout (Pack and Jellyman, 1988). Rainbow trout are, therefore, unlikely to be more than occasional visitors from the Clutha River to the Teviot's lower reaches.

Discovery of the recently redescribed roundhead *Galaxias* (McDowall and Wallis, 1996) in several of the Teviot tributaries is of scientific interest. Distribution of this species is at present only known from Otago and Southland. It is an entirely river dwelling species. In the Teviot, roundhead *Galaxias* was found in only two of the ten tributaries sampled. Brown trout were excluded from both sites by waterfalls. It would therefore appear that presence of roundhead *Galaxias* in the Teviot is likely to be limited to areas only where trout are absent. Because of this, it would be essential that any new impoundments do not create water levels that allow trout access into tributaries where this species is present. The impoundment created by the proposed Horseshoe Bend dam does not appear to have this potential: the only tributaries entering the Teviot River along the reach to be impounded are ephemeral streams, which are most unlikely to support roundhead *Galaxias* populations.

4.3 The trout fishery in the presence and absence of hydro electric structures

Much has recently been written on the Lake Onslow and Teviot River trout fisheries (Stark and Hayes, 1997). Their conclusions are summarised:

> Lake Onslow has a brown trout fishery notable for the high percentage of anglers who catch fish and the relatively high catch rates, although fish are only of moderate size. It was regarded as an "important" fishery by 23 of the 34 members of the Teviot Angling Club surveyed in 1984 (Whiting 1986).
>
> The Teviot River is notable for its brown trout population dominated by small fish (<300 mm), although large trout (>500 mm) are caught occasionally. The fishery generally is not regarded as "important", except by a very small number of fishermen who live nearby. Only two (of 34) members of the Teviot Angling Club surveyed in 1984 regarded the fishery as "important" (Whiting 1986).
>
> Information on the fisheries values of the Teviot River resulting from angler surveys undertaken during the 1978/79 fishing season was compiled by Richardson *et al.* (1984). Only 10 anglers fished the Teviot River and of the total of 13,175 respondent angler visits to Otago rivers during the 1978/79 season only 0.31% (n=41) were made to the Teviot River. This ranked 33rd of the 41 rivers included in the survey.
>
> These recreational angler surveys (i.e. Richardson *et al.* 1984, Whiting 1986) are likely to be a more unbiased reflection of the fisheries values of the Teviot catchment, than would be gained by similar surveys, given the present plans for further hydro-electric development in the catchment.
>
> Existing information suggests that the river is not highly utilised for recreational fishing, and, on balance, the fishery is below average in importance.

Present hydro-electric structures on the Teviot River prevent upstream migration of brown trout except between the various dams on the system. The presence of trout fry indicates natural reproduction within the system. Our investigations suggest that the river's brown trout population is modest, self-contained and self-sustaining with most suitable spawning habitat in tributary streams. Availability of spawning gravels rather than food is more likely to limit trout numbers, although food and habitat availability may limit the maximum size and numbers of large trout. Trout growth rates are very slow in Teviot River tributaries, possibly due to food limitation as well as the temperature regime, with fish taking five years to exceed 200 mm in length. Faster growth rates are likely in the mainstem, where temperatures are moderated by the influence of Lake Onslow. It is probable that a better trout population is present in Lake Onslow, and that a new impoundment could also sustain more fish than does the river at present. Given the steep-sided nature of the proposed impoundment, there will not be extensive areas of food-producing littoral habitat, so the new impoundment will not be as productive as a shallow (say 6-8 m deep) lake with extensive beds of submerged aquatic macrophytes. A fish pass on the Horseshoe Bend dam or a stocking programme should not be required.

From the above conclusions, it would appear that the Teviot River in its natural state would unlikely to have produced a trout population much different to that found in the main river today, i.e. dominated by small fish, and not highly rated by anglers. The impoundments created by hydro-electric modification of the Teviot River have provided a more favourable environment for trout, so that if anything, the value of the trout fishery has been enhanced. Also, the fishery has become more accessible for anglers, thus creating more opportunity and higher use of the area by anglers, than may have been the case in its unmodified state.

4.4 Macroinvertebrate Communities

Eighty-seven different macroinvertebrate taxa are known from the Teviot River catchment (including Lake Onslow) with caddisflies (22 kinds), true flies (17), Crustacea (9), beetles (8), stoneflies (6) and mayflies (6) present in greatest variety. Greatest variety of species and densities of individuals generally was associated with tributary streams, with the least in steep bedrock sections. No species that could be considered "rare or endangered" were recorded.

5.0 CONCLUSIONS

The severe physical instream characteristics of the Teviot River limit natural distribution of fish within this system. Six species of fish have been recorded in the Teviot River, but only four of these can be considered regular residents, and of these, only one is a true migratory species. By comparison, other Clutha River tributaries nearby had nine species of fish, of which seven were true migratory species. These tributaries had more gentle lower reaches, and their higher species richness was made up mainly of migratory species.

Longfinned eels are the most aggressive of New Zealand's migratory freshwater fish. In the Teviot River, their presence as the only migratory species, their low density, and confined distribution, highlight the difficulty fish have accessing this river. The weir and dams may further exacerbate eel access, but anecdotal evidence suggests that they are occasionally able to penetrate beyond these structures. The low density of longfinned eels below these structures, and their occasional presence above, suggest that the structures are unlikely to be a significant limiting factor. Consequently, there would be little point in providing fish passes for such low numbers of eels.

The presence of roundhead *Galaxias* in the Teviot catchment is of scientific interest. Their presence only where trout are absent in the Teviot's tributaries, suggests that any artificial raising of river levels that would allow trout to access them, could endanger the continued survival of this species. However, this is not expected to occur as a result of the Horseshoe Bend hydroelectric development.

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The most abundant species in the Teviot River was the brown trout, and these were non-migratory. Spawning and recruitment of brown trout occurs in tributaries and parts of the mainstem. The same structures which prevent upstream migrants, do not prevent downstream dispersal of brown trout, so that brown trout recruitment within the Teviot is largely unaffected by these structures. If anything, the impoundments created by these structures probably enhance the trout carrying capacity of this river system by providing more habitat than would otherwise be available. Without the impoundments, the harsh conditions of the Teviot would likely result in downstream loss of many juvenile trout.

Lake Onslow is the most "important" part of the Teviot River trout fishery. By comparison, only a few fishermen regard the remaining part of the river as "important". It is therefore apparent that in the Teviot's case, hydroelectric development has created fishing opportunity in a system that might otherwise have been of limited angling value.

Greatest densities and diversity of macroinvertebrates in the Teviot catchment appear to be associated with tributary streams, although in more benign reaches of the mainstem high densities and a good variety of macroinvertebrates are present also. In these places, macroinvertebrates appear to provide an adequate or good food supply for fish. Lower densities and fewer species of macroinvertebrates are present in steeper and more turbulent reaches (mainly in the gorge below Horseshoe Bend and the lower one third of the Teviot River). In these areas macroinvertebrates may provide insufficient food for fish, although such places are generally unfavourable physical habitats for fish in any case. The moderating effect of hydroelectric schemes on flows, and the abstractions for irrigation, may effectively result in improved conditions for aquatic life in these areas compared to the "natural" situation.

The Teviot River has been regulated and abstracted from for 100 years or so. We can find no good evidence to suggest that this has had any significant negative impacts on aquatic life – quite the reverse in some cases.

6.0 LITERATURE CITED

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Appendix 1: Approximate relative abundances of macroinvertebrates at selected sites in the Teviot River catchment. BH = tributary at Bridge Huts, LC = Luncheon Creek, OHC = Old Hut Creek, PC = Pinelheugh Creek, Onslow = Lake Onslow, T0 – T13 = Teviot River (upstream – downstream). Numbers indicate bands of percentage composition (1 = <5%, 2 = 6 – 25%, 3 = 26 – 50%, 4 = >50%).

	BH	LC	OHC	Onslow	PC	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
MAYFLIES																			
1 *Ameletopsis perscitus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2 *Austroclima jollyae*	-	1	1	-	1	1	1	1	1	2	2	2	1	2	-	-	-	1	-
3 *Austroclima sepia*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
4 *Coloburiscus humeralis*	-	1	1	-	1	-	1	1	-	-	-	1	1	1	-	-	-	-	-
5 *Deleatidium* spp.	2	2	3	1	2	-	2	2	1	2	2	1	2	3	1	1	1	1	1
6 *Nesameletus* sp.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STONEFLIES																			
7 *Acroperla* n. sp.	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
8 *Austroperla cyrene*	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
9 *Megaleptoperla* sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 *Zelandobius furcillatus*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11 *Zelandoperla decorata*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
12 *Zelandoperla fenestrata*	-	-	1	-	-	-	-	-	1	-	1	1	1	-	-	-	1	-	-
DOBSONFLIES																			
13 *Archichauliodes diversus*	-	1	1	-	1	-	1	1	-	1	-	-	1	1	-	-	-	-	-
DAMSELFIES																			
14 *Xanthocnemis zealandica*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WATER BUGS																			
15 *Sigara* sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BEETLES																			
16 *Antiporus strigosulus*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 Elmidae	1	1	1	-	1	-	1	1	-	1	-	-	1	-	-	-	1	1	-
18 Hydraenidae	1	1	1	-	1	-	1	-	1	1	-	-	1	1	-	-	-	1	-
19 Hydrophilidae	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
20 *Lancetes* sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21 *Liodessus* sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
22 Scirtidae	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-
23 Staphylinidae	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-	-	-
TRUE FLIES																			
24 Anthomyiidae	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
25 *Aphrophila neozelandica*	1	1	-	-	1	-	1	1	1	1	2	-	1	1	-	1	1	1	-
26 *Austrosimulium* spp.	1	-	1	-	1	-	1	1	1	1	-	-	1	-	1	1	1	1	1
27 Ceratopogonidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
28 Chironomidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
29 *Chironomus* sp 'a'	-	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
30 *Chironomus zealandicus*	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
31 Empididae	-	-	-	1	1	-	1	1	1	1	-	-	1	-	-	1	1	1	1
32 Eriopterini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
33 *Maoridiamesa* spp.	1	1	-	1	1	1	1	2	2	-	-	1	1	-	-	1	3	1	-
34 Orthocladiinae	1	2	1	1	2	1	2	4	4	2	2	2	3	2	4	3	3	2	1

CAWTHRON

Appendix 1 (continued)

	BH	LC	OHC	Onslow	PC	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
35 *Parochlus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
36 *Polypedilum* sp.	1	-	-	1	-	-	1	1	-	-	-	-	-	-	-	1	-	1	-
37 Tanypodinae	1	-	-	1	-	-	1	1	1	1	-	-	1	1	1	1	-	1	1
38 *Tanytarsus funebris*	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
39 *Tanytarsus vespertinus*	-	1	-	1	1	1	1	1	1	-	-	-	1	2	-	1	-	1	1
40 Tipulidae	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CADDISFLIES																			
41 *Aoteapsyche* spp.	1	2	1	-	2	1	3	1	1	2	-	1	2	1	-	1	1	-	-
42 *Beraeoptera roria*	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43 *Confluens olingoides*	-	1	-	-	-	-	-	-	1	1	1	2	1	-	-	-	-	-	-
44 *Costachorema callista*	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-
45 *Costachorema xanthoptera*	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46 *Helicopsyche albescens*	1	2	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-
47 *Hudsonema aliena*	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
48 *Hudsonema amabilis*	1	-	-	-	1	1	1	1	1	1	-	-	1	-	-	1	1	1	1
49 *Hydrobiosis parumbripennis*	1	1	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1
50 *Hydrobiosis* sp.	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	1	-	-
51 *Neurochorema confusum*	-	1	-	-	1	-	1	1	1	-	-	-	1	-	-	-	-	-	-
52 *Neurochorema forsteri*	-	1	1	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-
53 *Neurochorema* sp.	-	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-
54 *Oecetis unicolor*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55 *Olinga feredayi*	-	1	1	-	2	-	1	1	1	2	1	1	1	1	-	-	1	-	1
56 *Oxyethira albiceps*	1	-	-	-	-	1	1	1	1	1	-	-	1	1	-	1	1	-	1
57 *Paroxyethira hendersoni*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58 *Polyplectropus puerilis*	-	-	-	-				1	-	-	-	-	-	-	-	-	-	-	-
59 *Psilochorema nemorale/mataura*	1	1	1	-	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-
60 *Pycnocentria evecta*	1	2	1	-	1	1	1	1	1	2	3	3	2	1	-	1	1	1	2
61 *Pycnocentrodes* sp.	1	1	1	1	1	1	-	1	-	-	-	-	1	1	-	-	-	1	1
62 *Zelolessica cheira*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63 **ANNELIDA**	1	1	1	4	1	2	2	2	2	1	2	1	2	2	1	4	1	3	3
64 **NEMATODA**	-	1	-	1	1	-	1	1	1	-	-	-	1	-	-	1	-	-	-
65 **NEMATOMORPHA**	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
66 **NEMERTEA**	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
67 **PLATYHELMINTHES**	1	1	1	-	1	2	1	-	-	-	-	-	1	-	-	-	-	-	1
68 *Temnocephala* sp.	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
69 *Lymnaea* sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70 *Physa* sp.	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
71 *Potamopyrgus antipodarum*	3	2	1	1	2	2	2	1	1	2	1	-	1	2	-	1	2	4	3
72 Sphaeriidae	1	-	-	1	1	4	1	1	-	1	-	-	1	-	1	-	-	-	1
CRUSTACEA																			
73 Amphipoda	1	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	1	1
74 *Alona* sp.	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

Appendix 1 (continued)

	BH	LC	OHC	Onslow	PC	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
75 *Daphnia carinata*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76 *Ilyocryptus sordidus*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
77 *Simocephalus* sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78 Cyclopoidea	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
79 Calanoidea	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80 Ostracoda	-	1	-	1	1	-	1	1	1	-	-	-	1	-	-	-	-	-	-
81 *Paranephrops zealandicus*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
82 MITES	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	1	-
83 *Flabellifrontipoda* sp.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
84 Oribatidae	-	1	-	1	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-
85 Pionidae	-	1	-	1	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-
COELENTERATA																			
86 Hydra sp.	-	-	-	1	-	-	-	1	1	-	-	-	1	-	-	-	-	-	-
87 COLLEMBOLA	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	1	-	-	-
NUMBER OF SAMPLES	1	2	1	19	2	1	7	6	10	3	2	2	6	3	1	4	3	4	1
Number of taxa	26	33	22	34	33	19	37	38	33	22	13	14	37	20	8	23	21	25	18