internal report **244**

Effects of suspended solids on stream biota downstream of a road crossing on Jim Jim Creek, Kakadu National Park

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Summary

The problem

Tourist vehicle traffic using an unformed stream bed crossing on the upper reaches of Jim Jim Creek in Kakadu National Park has caused increased turbidity of the water downstream for a number of years. A study of possible adverse effects of increased suspended solids on the biota of the stream was conducted following expression of concern by the management of Kakadu National Park, Parks Australia.

Study procedure

The study monitored turbidity, water chemistry, macroinvertebrate and fish community structure and condition factors of two fish species in 1996 for two months before the creek crossing was opened to tourist traffic early in the Dry season (24 June) and for 4 months afterwards. A modified BACIP experimental design was used, which included paired sites in both Jim Jim Creek (upstream and downstream of the road crossing) and Twin Falls Creek (a control stream, with analogous but undisturbed upstream and downstream sites).

Water chemistry results

Turbidity levels peaked one month after the road opened, reaching an average maximum of 60 NTU (or ~100 mg/L suspended solids) 200 m downstream of the crossing. The lag was due to initial erosion of a layer of clean sand deposited at the crossing during the Wet season and not to peak traffic levels at this time. Turbidity levels decreased with greater distance downstream reaching maximum average levels of 30 NTU (or ~8 mg/L suspended solids) 1000 m downstream of the crossing. Turbidity declined towards the end of the tourist season as discharge declined but remained well above background levels, even 1000 m downstream. The concentrations of total iron and aluminium increased markedly downstream of the Jim Jim Creek road crossing after the road opening, in association with increases in suspended solids. At the prevailing near-neutral pH of the creek water, these metals were present predominately in a particulate (non-toxic) form. There were some minor increases in levels of other chemical parameters downstream of the road crossing but all parameters were well within Australian water quality guideline values (ANZECC 1992).

Macroinvertebrate results

Macroinvertebrates were sampled in rootmat and sand-bed habitat using a standardised sweep net procedure. Two potentially impacted sites were sampled, located 200m and 1000m respectively, downstream of the Jim Jim Creek road crossing. Also sampled were three control sites, one upstream of the road crossing on Jim Jim Creek and two sites on Twin Falls Creek. The macroinvertebrate communities at all sites (both downstream and control) were characterised by a natural increase in invertebrate abundance as the Dry season progressed. Within this general trend, there was considerable variability among sampling occasions for all sites. Turbidity-related effects on macroinvertebrate communities inhabiting the rootmat substrate were strongly indicated by a general disparity of samples collected 200 m downstream of the road crossing with control sites late in the Dry season. These effects were primarily indicated by multivariate measures of overall community similarity, as well as an apparent reduction in the abundance of macroinvertebrates, particularly Chironomidae, at downstream sites in comparison to control sites. Macroinvertebrate community changes were not as distinct among samples collected 1000 m downstream, although there was some evidence

for impact-related changes this far downstream in the multivariate analysis. Impact-related changes were not detected in the samples from the sand habitat, primarily a consequence of a large amount of natural variability among samples and sampling occasions, masking any effects of the road crossing.

Fish results

Fish were sampled by gill and seine netting on a single occasion before the road opened and again 4 months later, from paired upstream and downstream sites either side of the Jim Jim Creek crossing, as well as in Twin Falls Creek.. There were consistent differences between the two streams in their fish assemblages. Community structure changed in both streams between sample times but the direction of change of the two sites differed between streams in multivariate ordination. In the control stream, both sites moved in the same direction in the ordination space whereas in the disturbed stream the sites moved in different directions indicating that the dissimilarity between sites increased much more in the disturbed Jim Jim Creek. Both turbidity and the numerically dominant fish species, *Craterocephalus marianae*, were significantly correlated with the ordination space. Numbers of *C. marianae* declined by 90% downstream of the road crossing whereas they increased at all other sites.

Condition factors of the two most abundant fish species, *C. marianae* and *Amniataba percoides*, showed no significant difference between sites in the same stream so there was no evidence that the invertebrate food supply was impaired. Spawning of *C. marianae* occurred in the period between samples. Length frequency analysis of *C. marianae* populations indicated that there was a decline in numbers of larger fish downstream of the road crossing but that the reproduction and recruitment process may not have been impaired.

Recommendations

It was considered that the annual scouring of the stream bed during the Wet season would remove fine sediments deposited downstream of the Jim Jim Creek crossing, allowing the normal assemblage of stream biota to re-establish each year. Consequently more severe and longer term effects on biota than those reported are unlikely to occur.

However, the distribution of *C. marianae* is restricted to the west Arnhemland region and much of its known range is within Kakadu National Park. Given the present adverse effects of the road crossing on this species in particular, the adverse effects on other species of fish and invertebrates, as well as the high conservation value of the area, consideration should be given to alleviating effects of the road crossing. A low level engineered structure is recommended.

The study indicated that a threshold level of turbidity for effects on invertebrates and fish would be at, or less than, 30 NTU. Management strategies should aim to achieve levels well below this value and should include a monitoring program for measurement of turbidity to evaluate the effectiveness of remedial measures.

Contents

FIGURES

TABLES

Acknowledgements

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1 Introduction

Jim Jim and adjacent Twin Falls lie at the escarpment of the Arnhemland plateau in Kakadu National Park and are managed by Parks Australia as major tourist destinations. Access to both waterfalls is available to 4WD vehicles only in the Dry season by way of an unsealed road from the Kakadu Highway. Access to Twin Falls is via a road which crosses Jim Jim Creek adjacent to the Jim Jim Falls camp-ground (Fig 1.1). There are presently no engineered road structures at the road crossing on Jim Jim Creek, a factor resulting in recent years, in erosion of the clay creek-bed and localised increases in turbidity. This contrasts markedly with the high clarity waters upstream. There is anecdotal evidence that the severity of downstream turbidity has worsened over recent tourist seasons, with turbid water being observed for several kilometres downstream of the road crossing in 1995.

Increased loads of suspended solids are a common result of human activity on aquatic ecosystems and have been studied intensively elsewhere. There are, however, no well-established principles developed which characterise the environmental effects of suspended sediment on aquatic biota (Newcombe & MacDonald, 1991). In addition to the measurable level of suspended solids, site specific factors such as sediment characteristics and duration of exposure appear to be determinants of the biological response. Previous studies have indicated that in situations where there is normally high water clarity, elevated suspended solids, even at low concentrations (eg 10-30 mg/L), can have adverse effects on aquatic biota. As these conditions appeared to be occurring in Jim Jim Creek, the management of the park was concerned to establish whether any significant, adverse ecological effects resulted from this activity and if corrective action was appropriate.

Suspended sediment is capable of affecting biota in a number of ways. For example, the sediment may directly affect animals such as invertebrates by clogging filter feeding or respiratory structures or in severe cases, by smothering organisms inhabiting the creek-bed. Turbid water may also evoke behavioural responses such as invertebrate drift or avoidance by fish. Suspended sediment may inhibit algal growth by reducing light penetration, having consequences for the wide variety of organisms which rely on algae as a food source.

Benthic macroinvertebrates are the small (visible to the naked eye) invertebrate organisms inhabiting the creek-bed. Macroinvertebrates are widely used as biological indicators in freshwater ecosystems. They have inherent properties which make them highly suitable for this role: in particular, their abundance in all freshwater environments and a generally high taxonomic diversity that ensures a comprehensive array of different levels of sensitivity to environmental stress. The sedentary nature of these organisms means localised effects of pollution can be determined at various sites. Macroinvertebrates react quickly to stress but also have sufficiently long life-cycles that, in measurement of attributes of community structure, longer-term effects may be detected (Rosenberg & Resh, 1993).

The deposition of fine sediment that accompanies increases in turbidity can also affect freshwater fishes in ways other than the general biotic effects mentioned above, eg adverse physical changes to habitat, especially of riffle species, and smothering of the eggs of demersal spawners. Unfortunately, most of the information available on effects of turbidity and siltation on fish relates to northern hemisphere species and the applicability of these effects to most

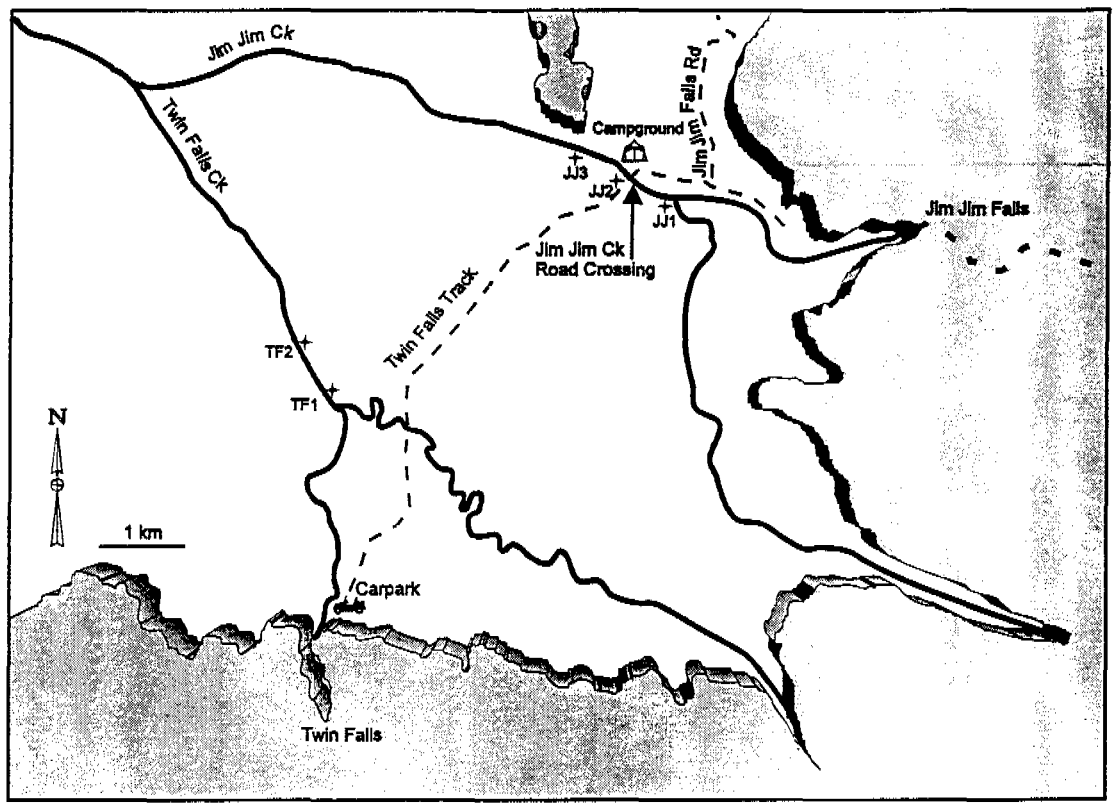


Figure 1.1. Sampling locations on Jim Jim and Twin Falls creeks, Kakadu National Park.

Australian species is unknown. As there is little information on the levels of sediment and duration of exposure that might induce these effects in Australian freshwater fish species, it was not possible to predict potential effects from simple measurements of sediment load. Consequently, in Australia any evaluation of whether an increase in turbidity is large enough to have such adverse effects requires direct examination of the fish community.

In response to the concerns of the management of Kakadu National Park about the possible turbidity problem in Jim Jim Creek, *eriss* has undertaken a study to determine the effects, and their extent, of vehicle-induced disturbance downstream of the Jim Jim Creek road crossing. Sampling of macroinvertebrate and fish communities, as well as comprehensive water chemistry analysis, were conducted at a number of sites in Jim Jim and Twin Falls creeks before and after the opening of the Jim Jim Creek crossing to the general public in the 1996 tourist season. This information would assist with future management of the Jim Jim and Twin Falls district and would be used to evaluate the need for a hard road crossing that would significantly reduce the turbidity and its effects on aquatic biota.

2 Procedures

2.1 Study design

Macroinvertebrate and fish data were collected according to a statistically rigorous BACIP (*B*efore, *A*fter, *C*ontrol, *I*mpact, *P*aired difference) design. This involves sampling of both potentially impacted and undisturbed (control) sites before and after the disturbance thereby using a form of 'temporal' control. This design makes the assumption that there would always be natural differences in measured biological parameters between any two sites. Consequently, an impact may be indicated if the size of the *difference* in biotic response between control sites and impact sites changes significantly (- as determined by a Student t-test -) after the onset of disturbance (figure 2.1). This is shown schematically using hypothetical data in figure 2.1. For the current study, control and impact sites were located upstream and downstream of the Jim Jim Creek road crossing respectively. Two significant modifications to BACIP designs include (Faith et al 1995, Humphrey et al 1995):

1. Multivariate extension of the design using dissimilarity measures as the measure of difference between 2 sites; and
2. Incorporation of control data for all phases of impact assessment ('before' and 'after') that would increase inferences made about impact. Such control data, in the case of streams, comprise 'differences' derived from similarly paired sites in (a) stream(s) adjacent to the stream of interest. Incorporation of an additional control is also displayed in figure 2.1. In this case, the design is based on a symmetrical ANOVA, using single control stream and single impact stream. A test for interaction is conducted within a 2-factor ANOVA ('before' vs 'after' impact, 'control'-stream vs 'impact'-stream).

Both modifications were employed in the current study. In the case of 2. above, measurements were made on a similar stream which was unimpacted by a road crossing, Twin Falls Creek - providing a further control situation against which to compare before and after changes in biotic parameters.

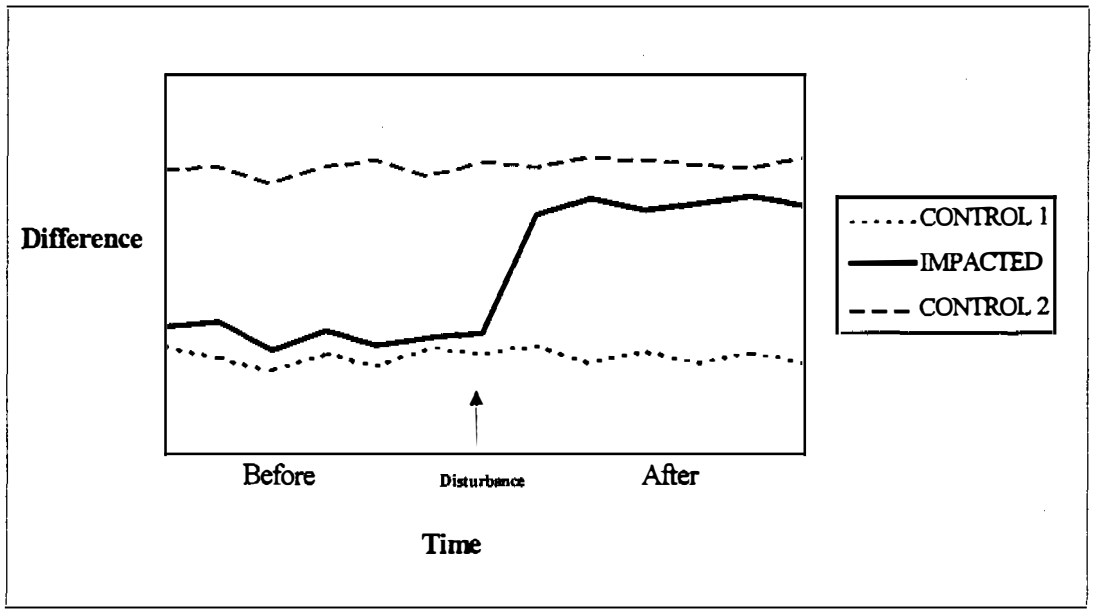


Figure 2.1 Idealised result of BACIP experiment with present design.

[Note that sites need not be identical in the undisturbed state. An impact is indicated when a significant change is observed in the *difference* between un-impacted (control sites) and impacted sites, after the onset of the disturbance.]

One of the important assumptions behind BACIP designs includes the need for independence of the temporal difference values over time. If this assumption cannot be met, modelling of the temporal variation by way of covariates may be required, the data analysis then employing trend analysis (regression) or analysis of covariance.

Measurements of physical and chemical parameters of the creek water were made at the same sampling sites at which the biota were sampled.

2.2 Macroinvertebrate studies

2.2.1 Frequency of sampling

Sampling of sites in Jim Jim and Twin Falls creeks was undertaken over a period of five and a half months, encompassing a pre-impact period of two months - between first possible access and the opening of the Jim Jim Creek crossing to the general public (June 24, 1996) - and a three-and-a-half month period of impact data. Macroinvertebrate samples were collected on a fortnightly basis prior to the crossing being opened and on a monthly basis after the opening of the road crossing. Sampling extended until mid October when the flow of Jim Jim and Twin Falls creeks had receded to near-cessation.

2.2.2 Sampling locations

Sampling was conducted at five creek sites (figure 1.1). On Jim Jim Creek, two potentially impacted sites, 200 m and 1000 m downstream of the road crossing were selected together with one control site 200 m upstream of the crossing. Two additional 'independent' control sites were selected on nearby Twin Falls Creek, the locations of which were selected to correspond with the 200 m upstream and 1000 m downstream sites of Jim Jim Creek (in terms of their creek-line distance from the escarpment), thus incorporating a similar spatial gradient as the sites on Jim Jim Creek. All sample locations contained similar habitats and were of similar depth, width and flow rate.

Table 2.1 Location and GPS coordinates (WGS 84) of sampling sites

Site code	Location	Longtitude	Latitude
JJ1	200 m upstream from road crossing	132.81603688	13.27098484
JJ2	200 m downstream from road crossing	132.80972625	13.26690914
JJ3	1000 m downstream from road crossing	132.80219371	13.26435003
TF1	3800 m downstream from Twin Falls	132.77873185	13.29604692
TF2	1200 m downstream from TF1	132.77921687	13.28533337

2.2.3 Collection of samples

Macroinvertebrates are found in abundance among the physical structures within the creek such as the sand creek-bed, leaf-litter, submerged edges, aquatic plants etc. Hereafter, such habitats colonised by macroinvertebrates are referred to as *substrates*. Invertebrates were collected from two natural substrates and from artificial substrates placed in the stream at each site. A different sampling procedure was used for each substrate type.

Natural substrates

The major natural substrates identified in Jim Jim and Twin Falls creeks were sand, root mat and aquatic plant edge. Whilst initially, sampling of all three habitats was conducted, aquatic

plant sampling was abandoned during the study as this habitat was lost with receding water levels. Consequently, methods for sampling this habitat are not described here.

Sand

The predominant substrate in the main channel of Jim Jim and Twin Falls creeks is a medium-grained sand. An organic floc, supporting a rich macroinvertebrate fauna, forms over this sand as flow recedes during the Dry season.

Sampling of the sand habitat was performed by lightly drawing a 250 μm kick net (basal width of 25 cm) across a pre-marked 5 m transect of the sand. The creek-bed surface immediately in front of the net was agitated by hand to suspend any organic matter and invertebrates, this material then being swept into the net. Only sand upon which an organic floc had formed (as opposed to clean-swept sand in areas of stronger stream flow) was sampled. Transects of suitable habitat were selected at random and sampled in a direction parallel to, and against, the direction of flow of the creek; so that any suspended matter was washed downstream into the net.

The contents of the net were transferred into a 20 L bucket half-filled with clean creek water, on the creek bank. Macroinvertebrates and organic matter were elutriated and separated by vigorous stirring by hand of the contents of the bucket, followed by pouring off of organic material into a 250 μm sieve. This process of elutriation was conducted three times with each sample. The sample retained by the sieve was preserved immediately in 70% ethanol for transport back to the laboratory.

At each of the sampling sites and on each sampling occasion, three replicate sand samples were collected. Each replicate represented a total sampling area of ~1.25 m^2 of sand habitat.

Root Mat

The root mat habitat consisted of a dense mat of fine fibrous roots usually belonging to *Pandanus aquaticus* and *Melaleuca* spp. growing at the creek edge. Replicate two-metre transects of this habitat were sampled at random in a similar manner to the sand substrate, ie by lightly drawing a 250 μm kick net along the substrate, against the flow of the creek whilst vigorously agitating the substrate by hand. Again the macroinvertebrates and organic matter were elutriated from the sample by washing three times in half-buckets of creek water, pouring off the sample into a 250μm sieve. Samples were preserved in 70% ethanol for transport back to the laboratory.

At each of the sampling sites and on each sampling occasion, three replicate rootmat samples were collected. Each replicate represented a total sampling area of ~0.5 m^2 of rootmat habitat.

Artificial substrates

Artificial substrates are a method of sampling macroinvertebrates whereby a suitable artificial habitat is placed in the creek for a predetermined period to be colonised by macroinvertebrates. Although not representative of natural substrates present in Jim Jim Creek, rock aggregate artificial substrates provide diverse and highly consistent sampling. Artificial substrates have been successfully employed in the Kakadu region previously (Faith *et al.* 1995) and were initially considered useful in this study due to the uncertainty associated with natural substrates in such a seasonal environment.

Artificial substrates consisted of cylinders of plastic mesh (approximately 200 mm x 100 mm basal diam.) filled with coarse 'blue metal' aggregate. The aggregate could be readily removed and replaced by cutting and reinserting cable ties holding the ends of the cylinder in place.

At each sampling site, ten artificial substrates were placed in a regular arrangement in shallow-flowing water on the sand creek bed, with the length perpendicular to the flow of the creek.

After a two-week exposure period in the creek, the substrates were removed successively from the creek bed by placing a 250 µm sweep net immediately downstream of the substrate and lifting the substrate whilst sliding the net in underneath. The net containing the substrate was then taken to the creek bank where the substrate and any material in the net was transferred to a 20 L bucket half filled with creek water. The aggregate was then released from the substrate cage and swirled vigorously by hand. The suspended organic material and invertebrates were collected by pouring through a 250 µm sieve. This elutriation procedure was conducted three times for each substrate.

Macroinvertebrates and associated organic matter were preserved on site in 70% ethanol and sealed in plastic containers for transport to the laboratory where they were stored until further processing.

Environmental variables recorded in association with each macroinvertebrate sample were water depth and flow, the latter measured by timing a float over a distance of 2 m.

2.2.4 Laboratory processing of samples

Subsampling

Samples that were considered too large to process in their entirety were subsampled using a 'riffler' (geological splitting device). Subsampling was achieved by suspension of the sample in a jug of water then pouring evenly through the riffler to split the sample into two equal portions Successive splitting was performed until the desired quantity of sample was obtained. The required subsample was collected onto a 250 µm sieve and placed in ethanol for subsequent 'sorting'.

Sample processing and identification

Invertebrates were sorted from the organic residues using a stereomicroscope and then identified to family level using keys developed for the Alligator Rivers Region.

2.2.5 Data analysis

Changes in the macroinvertebrate community downstream of the Jim Jim Creek road crossing, were evaluated using a number of approaches: comparison of univariate 'difference' measures, comparison of multivariate dissimilarity measures (both directly and with creek discharge as a covariate), multivariate ordination and simple comparison of the abundance of major taxa.

Univariate 'difference' measures

Univariate analysis (based on one community summary variable) was performed using site differences based on total macroinvertebrate abundance, as well as the differences based on major taxa (Chironomidae, Caenidae, Baetidae, Elmidae and Acarina). All community summaries were measured as the difference between the upstream and downstream sites for the combined total abundance of the three replicate samples.

Multivariate dissimilarity

Multivariate community dissimilarities (using abundance data of all taxa as variables) were calculated using the Bray-Curtis dissimilarity index (on a continuous scale from 0 = identical to 1 = totally dissimilar), in the statistical analysis package PATN (Belbin 1994). Separate multivariate comparisons of site data were made using raw (untransformed) data, transformed ($\log_{10}$ (x+1)) data (which emphasises the influence of rarer taxa), and rank order abundance data. Regression analysis of dissimilarity/ stream discharge data was performed using the SAS package (SAS Institute 1995).

Multivariate ordination

Ordination is a method of data analysis which separates biological samples containing an array of taxa, on the basis of overall similarity. Samples which are most similar will be represented on axes as close together, conversely, those far apart are less similar. For a given sampling occasion, control and downstream sites located relatively close to one another (and similar in every way as well as not being affected by human disturbance) would generally be expected to be represented in ordination space by points interspersed with one another (due to their similarity). Should community changes have occurred (ie an impact), the difference between control and impact samples will be indicated, in ordination space, by separation among points.

Ordinations of all samples (before and after), based on both raw (untransformed) and transformed ($\log_{10}$(x +1)) data, were performed with the statistical package PATN (Belbin 1994) using Semi-Strong-Hybrid Multi-dimensional Scaling (SSH) based on the Bray-Curtis Dissimilarity Index. Significant taxa and environmental parameters correlating with the ordinations were determined using Principle Axis Correlation (PCC) and Monte-Carlo evaluation. All ordinations were performed with 100 'random starts'. Three dimensions were required to reduce the 'stress' value for the ordination pattern below an acceptable level of 0.2 (Belbin 1994).

Additionally, ordinations and correlation analysis (as outlined above) were performed on the 'before crossing opening' and 'after crossing opening' rootmat substrate data independently.

Observed community changes

Simple comparisons were made among sites of total taxa abundance and abundances of major taxa (Chironomidae, Caenidae, Baetidae, Elmidae and Acarina) individually to indicate how and to what extent these taxa had been affected downstream of the road crossing.

2.3 Fish studies

2.3.1 Study design

The study of effects on fish involved the same spatial design of sampling sites as the BACIP design for the macroinvertebrate study with the exception of the absence of the site 1000 m downstream from the road crossing (JJ3) for fish study. The temporal design of the fish study differed from the invertebrate study by involving only a single sampling at each of the 4 sites before the opening of the Jim Jim Creek crossing and a single sampling 3 months after the opening. The sampling was undertaken in the largest and deepest pools at the sample points.

Effects on fish were evaluated using two attributes: fish community structure and fish relative condition (body weights). Changes in fish community structure could arise from a decline in

numbers of some species caused by reduced breeding success and subsequent lack of recruitment, increased mortality and/or avoidance responses, although it is possible some species could be favoured by the altered conditions and increase in numbers. Impairment of feeding could result in a loss of condition of fish. The condition of two sufficiently large-bodied and abundant fish species was examined. These species were Mariana's hardyhead (*Craterocephalus marianae*) and banded grunter (*Amniataba percoides*). *C. marianae* is a carnivorous bottom feeder preying on meio- and macroinvertebrates in the sandy stream bed (Bishop *et al.* in press, Macfarlane 1996). *A. percoides* is omnivorous, feeding on benthic macroinvertebrates and plant material. The exposure period of this study did not coincide with the main breeding period for fish in this region (late Dry-early Wet season, Bishop *et al.* in press) and so significant adverse effects on fish breeding success were not expected. Nevertheless, length measurements of the abundant *C. marianae* enabled effects on recruitment to be examined.

2.3.2 Sampling methods

Sampling sites were large pools up to 30 m wide and up to 4 m deep. The pools had a sand substrate and contained numerous logs and branches. In the pools there were extensive shallow sandy areas less than 1 m deep at all sites. Sampling was confined to a 200 m section of each pool. Because of the high turbidity of water in Jim Jim Creek, visual sampling was not possible after the road crossing was opened. Consequently, fish were captured using nets. Larger fish were sampled by gill nets and smaller-growing fish species by seine netting in shallow sandy areas of the pools.

Gill netting

Multi-panel gill nets containing 7 different mesh sizes were used (Table 2.2). The nets were 21 m long with each panel 3 m long and with a 2 m drop. The gill-nets were weighted so that the float line remained at the water surface while the weighted line remained suspended above the bottom in situations where water depth exceeded 2 m. Three gill nets were used at each site. The nets were set by attaching one end to the bank on the deepest side of the stream and stretching the net diagonally across the stream.

The nets were fished for 3 hours: 2 hours before dark and one hour after dark. They were checked at least 3 times in this period to enable the removal alive of as many fish as possible. Fish were held in water-filled containers until measured and weighed as soon as possible after capture. To avoid re-catching the fish, processed fish were enclosed in a 'corral' made of 12 mm mesh, until the gill nets were removed from the pool.

All fish were identified and their length (LCF = length to caudal fork) measured. When possible, fish were also weighed alive on spring balances. All *A. percoides* captured in gill nets were retained for re-weighing and measuring in the laboratory. Specimens were preserved in 70% alcohol.

Seine netting

A seine net was used to capture small fish inhabiting shallow sandy areas of the pools. The net was 16 m long, 2 m deep and made of 12 mm stretched mesh. Three hauls of the net were carried out at each site. The net was tethered by one end on the shallow bank and then run out to half its length. It was then moved upstream parallel to the bank until fully extended and then dragged to the shallow bank to enclose a semi-circle. Both ends were then hauled in together to

the shore. All fish were collected from the net and placed in buckets of water. All fish except *C. martianae* and *A. percoides* were measured, weighed alive and returned to the stream. All *A. percoides* and either a subsample or the entire sample of *C. martianae* were retained as preserved specimens for measurement in the laboratory.

Table 2.2 Specifications of nets used for sampling fish at Jim Jim and Twin Falls Creeks

Net type		Length (m)	Depth (m)	Mesh type	Mesh ϕ (mm)	Mesh size (mm)
Seine-net		16	2	nylon multifilament	0.65	12.6
Multipanel gill-net[1]:	panel 1	3	2	monofilament	0.2	26
	panel 2	3	2	monofilament	0.2	44
	panel 3	3	2	monofilament	0.3	58
	panel 4	3	2	monofilament	0.4	76
	panel 5	3	2	monofilament	0.4	100
	panel 6	3	2	monofilament	0.5	132
	panel 7	3	2	nylon multifilament	0.7	150
Total length & depth (m):		21	2			

[1]The gill-net was weighted so that the float line remained at the waters surface while the weighted line remained suspended above the bottom in situations where water depth > 2m

Visual sampling

Prior to the opening of the road crossing, fish at each site were counted by observation from a canoe aided by polarised sunglasses. These data were used to assess the selectivity of the netting procedures.

2.3.3 Data analysis

Community structure

Changes in community structure were examined using measures of species richness (number of species present at a site on each sample occasion), changes in numerical abundance of each species and a multivariate measure of the dissimilarity of the community between paired sites (based on number of individuals of each species present in each sample). The multivariate dissimilarity measure used was the Bray-Curtis index.

The Bray-Curtis index and other multivariate procedures were calculated using the statistical package, *PATN* (Belbin 1994). The calculation was conducted using the total number of each fish species combined from both standard gill- and seine-net samples. Data for species recorded only once over all sampling occasions and sites were excluded (only one species, *Arius midgleyi*). Calculations were made for both raw data and $\log_{10}$ (x+1) transformed data. Ordination analysis using the Semi-Strong-Hybrid Multidimensional Scaling (SSH MDS) procedure was then carried out using 2 dimensions (vectors) and 999 random starts. Only two dimensions were required to reduce the 'stress' value for the ordination pattern below an acceptable level of 0.2. Correlation analysis of individual fish species and water physico-chemical variables with the fish ordination pattern was conducted using the PCC and Monte-Carlo evaluation methods to determine species and water quality variables contributing significantly to the ordination pattern.

Condition factor

The condition of each fish was calculated as the ratio of observed weight of fish divided by the predicted weight of the fish, the latter derived from a predictive relationship between length and weight (data from all sites and occasions combined). The relationship was based on measurements of specimens preserved in alcohol and was calculated by least squares regression using log transformation of both variables. Calculations were made using the statistical package *Statistica* (StatSoft 1995).

Length frequency analysis

Length frequency analysis of samples of the most abundant species, *C. marianae*, was undertaken by grouping the fish into 5 mm size classes. The number of fish in each size class was then plotted as a percentage of the total number of fish in the sample. Evaluation of differences in population structure were made by visual examination of these plots.

2.4 Environmental variables

2.4.1 Turbidity

Laboratory and field measurements of turbidity were made from samples collected fortnightly at each of the five sampling sites on Jim Jim/ Twin Falls Creeks. In addition, a Hydrolab Datasonde 3 data logger was permanently secured in Jim Jim Creek 200 m downstream of the road crossing. Turbidity measurements were made at hourly intervals, 24 hours a day by the data logger, for the duration of the study. An additional Hydrolab data logger was available periodically and was placed for a two week period at each of the other sites at least once during the study to indicate the short term variability of the baseline condition.

2.4.2 Suspended solids

Samples for gravimetric determination of suspended solids were collected monthly. Additional samples were collected downstream of the road crossing at random for determination of the correlation between turbidity and suspended solids in Jim Jim Creek (thus enabling inference of suspended solid levels from the continuous turbidity measurements).

2.4.3 Chemical variables

Water samples were collected at regular intervals at each of the five Jim Jim/ Twin Falls Creek sites. The basic parameters of turbidity, pH and conductivity were measured fortnightly. Samples were collected monthly for comprehensive water chemistry analysis including suspended solids, turbidity, pH, alkalinity, conductivity, total and dissolved organic carbon, orthophosphate, total phosphate, alkali metals (Na, K, Ca, Mg), heavy metals (Cu, Pb, Cd, U, Zn, Mn, Fe, Cr, Ni, Al - total unfiltered) and other major ions (Cl, NO_3, SO_4, NH_4). All samples were analysed by the *eriss* analytical chemistry laboratory.

2.4.4 Chlorophyll analysis

Water samples were collected at each sampling site on a monthly basis for determination of chlorophyll a, b and c. Samples of 500 mL of creek water were filtered on site and the retained sample stored on ice then frozen until processed. Samples were emulsified in 10 mL of 90 percent acetone and their optical densities measured at 750 nm, 664 nm and 645 nm and 630 nm with a spectrophotometer, the measurement at 750 nm being a correction for turbidity. Calculations of chlorophyll a, b and c levels were performed using a computer spreadsheet template developed by the *eriss* Environmental Chemistry section for this purpose.

2.4.5 Vehicle movements

Vehicle counters were installed in two locations: one on Jim Jim road before the crossing and another on Twin Falls road, the latter recording the number of vehicles crossing the creek.

2.4.6 Stream discharge

Accompanying the monthly sampling of invertebrates at each site, measurements were made for calculation of instantaneous stream discharge. For this, a transect was placed across the creek and water velocity measured at 1.0 m intervals on the cross-section; each measurement was made at a depth of 0.6 x total water depth. Water velocity was measured using a miniature current meter (Hydrological Services, Model OSS PC1). At the laboratory, cross-sectional area was determined graphically using water depth measurements made at the same (0.5 m) intervals across the section. Discharge values were derived from the product of average water velocity along the transect and the cross-sectional area of the river.

3 Results

3.1 Environmental variables

3.1.1 Vehicle counts

Traffic counter data for the Jim Jim Falls Road (adjacent to the 'Jump Up') and the Twin Falls Track are presented in figure 3.1. The absence of data for some periods is a result of the traffic counters being non-operational. The Twin Falls counter was damaged by fire, resulting in loss of much of the data.

In the 7 weeks for which data were collected on the Twin Falls track, there were 200-300 vehicles per week crossing the creek. In the 4 weeks for which there were vehicle counts on both roads the number of vehicles visiting Twin Falls was less than that visiting Jim Jim Falls. The present crossing, by way of its depth and substrate is a limitation to the accessibility of Twin Falls.

3.1.2 Turbidity

The natural Dry season levels of turbidity in the Jim Jim / Twin Falls Creek system are very low, averaging less than 3 NTU. Elevated levels of turbidity were experienced downstream of the road crossing subsequent to its opening to the public on June 24th 1996. A delay in the rise and subsequent peak of turbidity was evident, with the levels measured 200 m downstream of the crossing (site JJ2) peaking at an average of 60 NTU in late August (figure 3.2).

Turbidity measurements made 1000 m downstream of the crossing (site JJ3) were consistently lower than those immediately downstream of the crossing. Nevertheless, the turbidity recorded this distance downstream was well above the natural levels for this creek system, reaching 27 NTU (figure 3.2).

Turbidity downstream of the Jim Jim Creek crossing began to decline in early September, with receding creek flow, but remained elevated for the duration of the tourist season. The discolouration of creek water downstream of the road crossing was visually apparent for at least 1000 m downstream, from July until the end of the study period in mid October when creek flow this far downstream (1 km) had ceased.

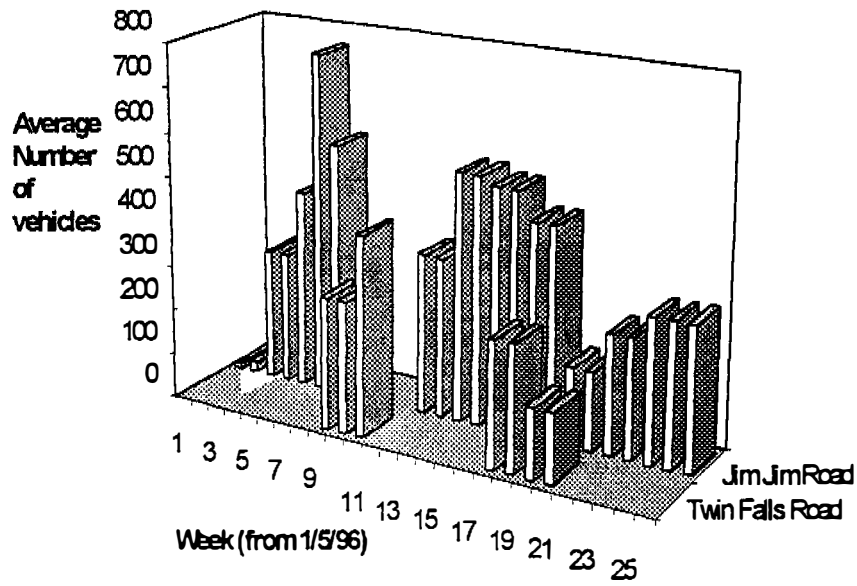


Figure 3.1. Weekly traffic counts for Jim Jim and Twin Falls Roads throughout the tourist season.

Twin Falls Road was opened to the general public on 24th June 1996 (from week 8).
Periods without values were due to traffic counters being out of service.

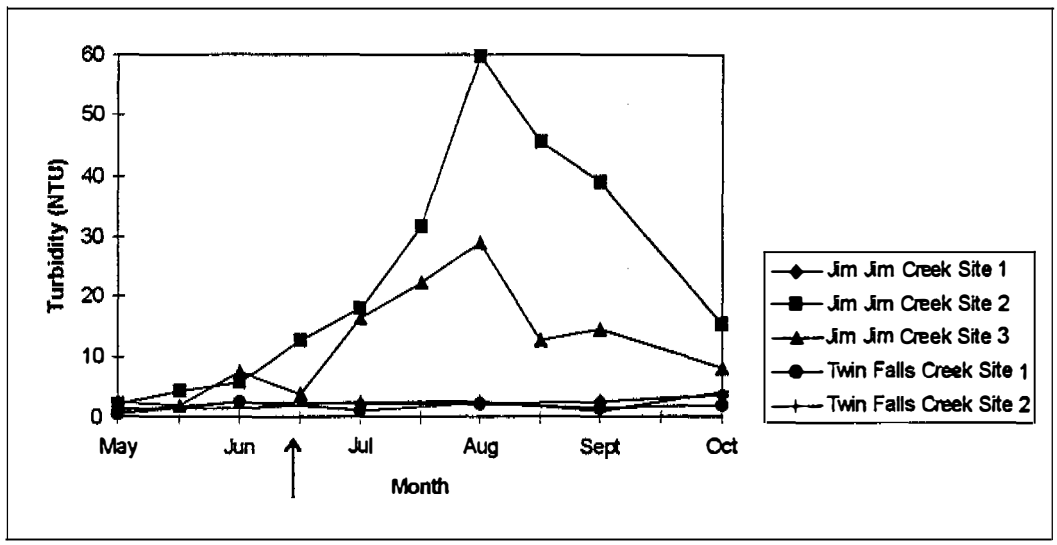


Figure 3.2. Mean turbidity levels at different study sites throughout the study period.

Values for Jim Jim site 2 are the means of continuous datalogger measurements for the preceding period.
Other values are derived from water samples collected on the indicated date.
Arrow indicates opening of the Jim Jim road crossing to the general public.

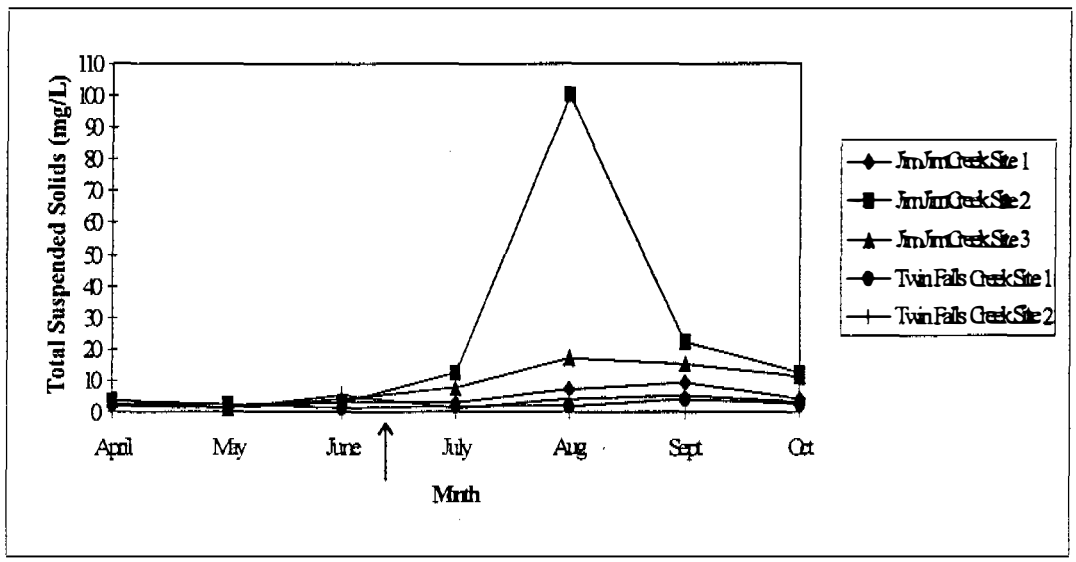


Figure 3.3. Total suspended solids measurements at different study sites throughout the study period.

Arrow indicates opening of the Jim Jim road crossing to the general public.

3.1.3 Suspended solids

Suspended solids measured in Jim Jim Creek (figure 3.3) followed a similar pattern to turbidity. In late August, levels of total suspended solids immediately downstream of the Jim Jim Road Crossing (site JJ2) reached 100 mg/L. As was also indicated by turbidity levels, suspended solids concentrations declined after late August but remained substantially elevated above background levels for the duration of the study (until mid October). Levels of suspended solids 1000 m downstream of the road crossing (at site JJ3) had a considerably lower peak (17 mg/L) than at JJ2 upstream, however, the measurements still represented a level markedly higher than background concentrations upstream of the crossing (figure 3.3).

An approximately linear relationship was determined between total suspended solids and nephelometric turbidity in Jim Jim Creek (figure 3.4). Consequently, the temporal pattern for changes in suspended solids should closely resemble that for the turbidity measurements which were made continuously (hourly readings) rather than monthly. However, the different units of measurement should be borne in mind.

3.1.4 General water quality variables

Water quality in the two streams was shown to be typical of waters draining the sandstone portions of the Arnhemland plateau by being very low in dissolved solids (as shown by electrical conductivity), poorly buffered (low alkalinity) and with very low levels of nutrients commonly associated with human activities (nitrogen and phosphorus compounds and organic carbon) (table 3.1a). A small degree of natural temporal change was observed throughout the study period in some parameters (eg. conductivity, bicarbonate and alkalinity), as may be expected with receding creek discharge with its associated reduction in dilution. The general water chemistry parameters, exclusive of turbidity and suspended solids, lie well within ANZECC water quality guidelines.

The levels of most general water quality variables in table 3.1a, other than turbidity and suspended solids, were very low and their pattern of variation did not indicate any effect of the road crossing. An exception to this was chlorophyll which showed an increase downstream of the road crossing. The measurement of chlorophyll a, b and c quantifies phytoplanktonic productivity in the creek system. Levels observed for Jim Jim and Twin Falls creeks were extremely low (table 3.1a) and below detection limits in most cases. Measurements made downstream of the road crossing (specifically at site JJ2, 200 m downstream) were lower than at JJ1 before the road opened, but after its opening they were slightly higher than those observed at other sites. These values, however, were not elevated to a level to warrant concern, and may in fact be a consequence of the turbidity of the samples (despite a correction factor being used in the determination). In higher algal productivity systems elsewhere, turbidity may be expected to cause a decrease in productivity (due to reduction in light penetration), but this was clearly not a limiting factor to productivity in the Jim Jim Creek system.

3.1.5 Major ions and other elements

In accordance with the low levels of dissolved solids characteristic of these waters, the concentrations of most other ions were very low and well within established water quality guidelines (tables 3.1b & 3.1c). However, the pattern of variation in some of these variables resulted in the appearance of these as significant correlates with changes in community structure in the multivariate analyses on the biota. Calcium showed a slight decline in

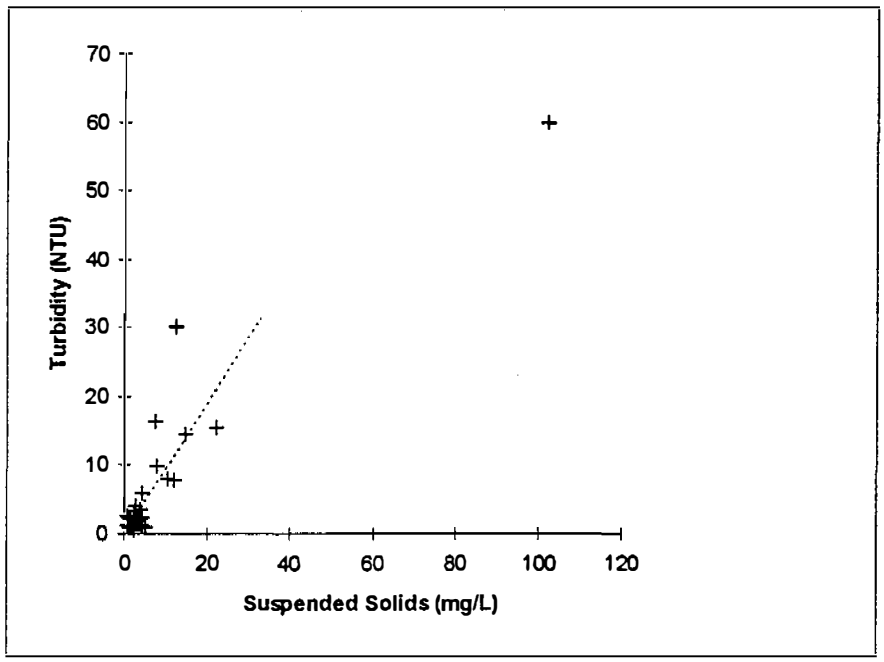


Figure 3.4. Correlation of turbidity and total suspended solids for Jim Jim Creek samples.

(R^2=0.839, p<0.0001; regression line excludes the extreme value).

concentration downstream of the crossing while levels of some other parameters increased. The concentrations of potassium, chloride and manganese had a tendency to increase throughout the study period, across all sites (table 3.1b&c). This observation is most likely a natural consequence of declining creek discharge throughout the study period and the associated reduction in dilution, as discussed above for other water quality variables. Copper, lead, uranium and zinc increased slightly downstream in Jim Jim Creek and levels of aluminium and iron increased considerably by the late Dry season (table 3.1c). The increase in these constituents is probably a result of their mobilisation by the disturbance to the sediments at the road crossing rather than contamination by vehicles.

There was a large amount of variability in the measured levels of iron and aluminium between sites and sampling occasions, even in the undisturbed condition. For example the range of measurements throughout the study period among undisturbed sites (JJ1, TF1, TF2) was 10-810 µg/L for iron and 11-49 µg/L for aluminium. Against these background levels, there was a marked elevation in the levels of iron and aluminium downstream of the road crossing on Jim Jim Creek. With the near-neutral pH of Jim Jim Creek water (table 3.1a), these metals would be present predominately as a colloidal suspension or as insoluble fine particles - ie in a non-toxic form. These metals were almost certainly associated with the increased suspended solids load emanating from the road crossing; their concentrations began to rise, to a small extent, even before the opening of the road crossing to the general public, when use was limited to occasional crossings by park management vehicles and ***eriss*** workers.

Table 3.1a Water quality variables, including some major ions, measured in water from Jim Jim and Twin Falls creeks, 1996. Site codes are given in table 2.2.

Variable[1]	Site	Month							ANZECC guidelines
		Apr	May	Jun	Jul	Aug	Sep	Oct	
EC (µS/cm)	JJ1	8.1	10	12	14	15	16	17	-
	JJ2	9	12	13	12	12	12	24	
	JJ3	9.1	12	13	12	12	12	24	
	TF1	9.9	12	12	12	12	14	14	
	TF2	9.9	12	12	12	12	14	14	
pH	JJ1	5.7	6.0	6.1	6.1	6.2	6.3	6.2	6.5 - 9.0
	JJ2	6.0	6.1	6.3	6.2	6.2	6.4	6.3	
	JJ3	6.1	6.2	6.4	6.3	6.4	6.4	6.3	
	TF1	6.3	6.3	6.4	6.2	6.4	6.4	6.4	
	TF2	6.3	6.3	6.1	6.2	6.5	6.5	6.3	
Tot SS (µg/L)	JJ1	2200	1300	3100	2800	6900	9300	3900	<10% change in seasonal mean
	JJ2	3500	2500	3100	12000	100000	22000	12000	
	JJ3	3500	1000	4300	7500	7900	15000	11000	
	TF1	2500	2300	1000	1900	1700	4200	2500	
	TF2	1700	1000	5300	1000	4100	5000	2800	
Turb (NTU)	JJ1	0.97	0.95	2.35	2.05	2.13	2.37	3.49	<10% change in seasonal mean
	JJ2	1.25	2.04	5.67	18.06	59.8	38.92	15.28	
	JJ3	1.89	2.54	7.58	16.45	28.97	14.56	8.03	
	TF1	1.96	0.64	2.45	1.13	2.18	1.26	1.76	
	TF2	0.87	1.24	1.26	2.38	2.46	0.93	4.01	
Chl a (mg/L)	JJ1	0.01	0.01	0	0.1	0	0.03	0.02	-
	JJ2	0	0	0	0.02	0.01	0.02	0.03	
	JJ3	0	0	0	0.02	0	0.02	0.02	
	TF1	0.01	0	0.01	0.01	0	0	0.02	
	TF2	0.04	0	0	0	0	0.01	0.07	
Chl b (mg/L)	JJ1	0.01	0.02	0.1	0.1	0	0.02	0	-
	JJ2	0	0	0	0.04	0.02	0.02	0.04	
	JJ3	0	0	0	0.02	0	0.02	0.02	
	TF1	0.02	0	0	0	0	0	0.01	
	TF2	0.01	0	0	0	0	0	0.09	
Chl c (mg/L)	JJ1	0	0.03	0	0	0	0.03	0	-
	JJ2	0	0	0	0.05	0.02	0.03	0.06	
	JJ3	0	0	0.1	0.03	0	0.03	0.03	
	TF1	0.03	0	0	0.01	0	0	0.01	
	TF2	0.01	0	0	0	0	0	0.11	
DOC (mg/L)	JJ1	1.1	0.9	0.9	1.9	0.3	1.0	2.3	-
	JJ2	1.0	1.1	0.9	0.3	0.1	0.3	1.7	
	JJ3	1.0	1.1	1.0	0.1	0.2	0.2	1.5	
	TF1	1.1	1.2	0.9	1.6	<0.1	0.1	<0.1	
	TF2	1.2	1.0	0.9	0.1	<0.1	1.0	<0.1	
TOC (mg/L)	JJ1	1.2	1.0	1.9	0.1	0.2	2.0	3.1	-
	JJ2	1.3	1.2	2.0	0.1	0.2	0.1	2.0	
	JJ3	1.2	1.2	2.0	<0.1	<0.1	0.1	1.6	
	TF1	1.2	1.0	1.4	1.0	<0.1	0.1	0.1	
	TF2	1.2	1.1	1.4	<0.1	<0.1	0.5	0.1	
Alk (mg/L)	JJ1	0.5	0.9	1.8	2.7	3.2	3.3	8.4	-
	JJ2	1.0	1.8	2.6	2.5	2.7	2.8	8.2	
	JJ3	1.1	1.7	2.6	2.9	2.7	2.5	7.7	
	TF1	1.4	1.7	2.4	2.0	1.7	2.6	3.4	
	TF2	1.3	2.0	2.1	1.6	1.8	2.3	1.5	
Bicarb (mg/L)	JJ1	0.6	1.1	2.2	3.3	3.9	4.0	10	-
	JJ2	1.2	2.2	3.2	3.1	3.3	3.4	10	
	JJ3	1.3	2.0	3.2	3.6	3.2	3.1	9.5	
	TF1	1.7	2.1	2.9	2.4	2.1	3.1	4.2	
	TF2	1.6	2.5	2.6	2.0	2.2	2.8	1.9	

[1] EC = electrical conductivity; Tot SS = total suspended solids; Turb = turbidity Chl a, b, c = chlorophyll a, b, c resp.; DOC & TOC= dissolved and total organic carbon resp.; Alk = alkalinity ($CaCO_3$); Bicarb = bicarbonate (HCO_3).

Table 3.1b Nutrients and other major ions in water from Jim Jim and Twin Falls creeks, 1996. All units in µg/L. Site codes are given in table 2.2.

Variable[1]	Site	Month							ANZECC guidelines
		Apr	May	Jun	Jul	Aug	Sep	Oct	
Ortho-P	JJ1	8	<2	<2	<2	5	<2	<2	-
	JJ2	9	<2	<2	<2	7	5	5	
	JJ3	2	<2	<2	3	9	4	3	
	TF1	3	<2	<2	<2	7	2	<2	
	TF2	<2	<2	<2	3	3	5	<2	
Total P	JJ1	9	<5	12	<5	<5	20	15	<10
	JJ2	9	<5	10	<5	22	19	27	
	JJ3	39	<5	47	11	45	16	<5	
	TF1	NR	<5	72	<5	<5	<5	NR	
	TF2	13	<5	19	18	24	10	20	
NH_4^+-N	JJ1	NR	30	30	30	30	30	30	20 - 30
	JJ2	30	30	30	30	30	30	30	
	JJ3	30	30	30	30	30	30	30	
	TF1	30	30	30	30	30	30	30	
	TF2	30	30	30	30	30	30	30	
NO_3-N	JJ1	NR	10	10	10	10	10	10	<100
	JJ2	10	10	10	10	10	10	10	
	JJ3	10	10	10	10	10	10	10	
	TF1	10	10	10	10	10	10	10	
	TF2	10	10	10	10	10	10	10	
Calcium	JJ1	NR	120	290	440	380	350	460	-
	JJ2	120	150	100	160	120	100	310	
	JJ3	120	120	150	130	150	130	320	
	TF1	130	130	140	170	140	190	190	
	TF2	90	170	NR	180	110	130	180	
Potassium	JJ1	NR	50	90	50	60	70	230	-
	JJ2	50	50	60	60	70	70	880	
	JJ3	50	50	50	70	60	80	730	
	TF1	50	50	50	130	100	140	140	
	TF2	50	50	80	50	110	180	180	
Sodium	JJ1	NR	1200	1300	1400	1300	1200	1400	5000 *
	JJ2	1000	1300	1100	1100	1000	1000	1600	
	JJ3	1100	1100	1200	1400	900	1000	1700	
	TF1	1100	1200	1200	2000	1200	1300	1500	
	TF2	1200	1400	1200	1600	1200	1500	1400	
Magnesium	JJ1	NR	250	460	510	620	660	660	-
	JJ2	300	430	650	560	590	580	1100	
	JJ3	320	430	550	560	570	560	1200	
	TF1	340	390	430	440	400	470	440	
	TF2	350	410	440	490	420	470	460	
Chloride	JJ1	NR	1900	2400	2100	2100	1900	2900	-
	JJ2	1700	1900	1800	1600	1600	1300	4400	
	JJ3	1700	1800	1800	1500	1500	1200	4500	
	TF1	1800	1900	1700	1900	1900	1900	2500	
	TF2	1800	1900	1900	2000	2000	2100	2400	
Sulphate	JJ1	NR	240	200	200	30	30	200	-
	JJ2	550	280	30	200	30	30	200	
	JJ3	270	140	200	400	30	30	30	
	TF1	350	170	30	400	200	200	400	
	TF2	140	500	30	600	200	30	300	

Ortho-P = Orthophosphate; Total P = Total phosphorous; NH_4^+-N = Ammonium-N; NO_3-N = Nitrate-N.

* Interim guide only.

Table 3.1c Heavy metals in water from Jim Jim and Twin Falls creeks in 1996. All units in µg/L. Site codes are given in table 2.2.

Variable[1]	Site	Month							ANZECC guidelines
		Apr	May	Jun	Jul	Aug	Sep	Oct	
Manganese	JJ1	3	5	5	5	4	10	NR	-
	JJ2	4	5	3	7	5	12	NR	
	JJ3	5	5	2	5	7	11	NR	
	TF1	4	5	4	10	12	6	NR	
	TF2	4	4	5	9	6	6	NR	
Iron	JJ1	10	190	410	400	420	490	NR	<1000
	JJ2	370	530	670	110	980	1300	NR	
	JJ3	360	540	660	760	1100	1400	NR	
	TF1	200	220	280	360	810	230	NR	
	TF2	240	180	390	390	290	210	NR	
Aluminium	JJ1	17	22	49	38	24	42	NR	<5
	JJ2	33	48	23	40	760	270	NR	
	JJ3	32	42	86	14	980	420	NR	
	TF1	16	12	12	24	25	12	NR	
	TF2	16	12	21	23	49	11	NR	
Chromium	JJ1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
	JJ2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	JJ3	NR	<0.5	<0.5	<0.5	<0.5	1.4	<0.5	
	TF1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Copper	JJ1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2 - 5
	JJ2	NR	<0.5	<0.5	1	1.2	0.7	0.6	
	JJ3	NR	<0.5	<0.5	<0.5	0.6	1	0.5	
	TF1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Nickel	JJ1	NR	<1	<1	<1	<1	<1	<1	15 - 150
	JJ2	NR	<1	<1	<1	<1	<1	<1	
	JJ3	NR	<1	<1	<1	<1	<1	<1	
	TF1	NR	<1	<1	<1	<1	<1	<1	
	TF2	NR	<1	<1	<1	<1	<1	<1	
Lead	JJ1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1 - 5
	JJ2	NR	<0.5	<0.5	0.6	0.8	<0.5	<0.5	
	JJ3	NR	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	
	TF1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Uranium	JJ1	NR	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<5
	JJ2	NR	<0.02	0.03	0.07	0.09	0.08	0.04	
	JJ3	NR	<0.02	<0.02	0.05	0.03	0.08	0.05	
	TF1	NR	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	
	TF2	NR	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	
Zinc	JJ1	NR	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	5 - 50
	JJ2	NR	<0.5	<0.5	0.7	1.4	<0.5	<0.5	
	JJ3	NR	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	
	TF1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Cadmium	JJ1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.2 - 2
	JJ2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	JJ3	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF1	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
	TF2	NR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	

3.2 Macroinvertebrates

3.2.1 BACIP site dissimilarities

Observation of site dissimilarities throughout the study period was made for both sand and rootmat habitats. Preliminary results (Stowar *et al.*, 1996) indicated that the fauna colonising the artificial substrates was less sensitive to any impacts than that in the natural substrates of sand and rootmat, and hence further analysis was based only on the natural substrates.

In studying site dissimilarities, particular attention was paid to observed changes occurring in site differences present before the opening of the crossing when compared to after, noting the trends in potentially impacted sites in relation to those of unimpacted (control) sites.

Various measures of site difference, both univariate and multivariate, were examined in the assessment of impact-related community change on the basis of paired site differences or (multivariate) dissimilarity. Both rootmat and sand samples displayed very high variability with regard to all measures of difference/dissimilarity. This variability was reduced to some extent by log-transforming the data. A temporal trend, however, persisted in the dissimilarity values throughout the study period, preventing the conventional statistical testing of 'before' versus 'after' in the BACIP design using t-tests which assumes no temporal trend. There were, however, some discernible trends and analyses of these trends that enabled conclusions to be drawn about impacts at the downstream sites. Complimenting these observations are previous studies on other streams which have indicated that macroinvertebrate communities at adjacent sites in Alligator Rivers Region streams tend to become more similar as flow recedes (Humphrey, unpublished data; figure 3.9).

3.2.2 Univariate measures of site 'differences'

The univariate measures examined for both sand and rootmat included total macroinvertebrate abundances, as well as the abundances of all major taxa individually (Chironomidae, Caenidae, Baetidae, Elmidae and Acarina). The total macroinvertebrate abundance site 'differences' revealed a high degree of variability among all sample sites (including control sites) throughout the study period, in both the sand and rootmat habitat.

The rootmat habitat, although variable (- particularly early in the season), showed a divergence in the difference between JJ1 and JJ2 (potentially impacted) when compared to Twin Falls control sites or JJ1 and JJ3, in the latter part of the study (figure 3.5). Although in itself not conclusive evidence for an impact, it compliments similar observations made in the multivariate comparisons described below.

The total macroinvertebrate abundance of the sand habitat is particularly 'noisy', indicative of high patch variability and preventing any observation of possible impact-related changes with regard to total taxa abundance (figure 3.6).

In both sand and rootmat habitats, the univariate site differences based on individual taxa are similarly noisy, with no distinct differences among downstream sites evident. Thus no BACIP analysis on these data was conducted and hence results are not presented here.

3.2.3 Multivariate measures of dissimilarity

Multivariate analysis of site dissimilarity provides an overall comparison of macroinvertebrate samples between upstream-downstream sites, in terms of both taxa present and the abundances

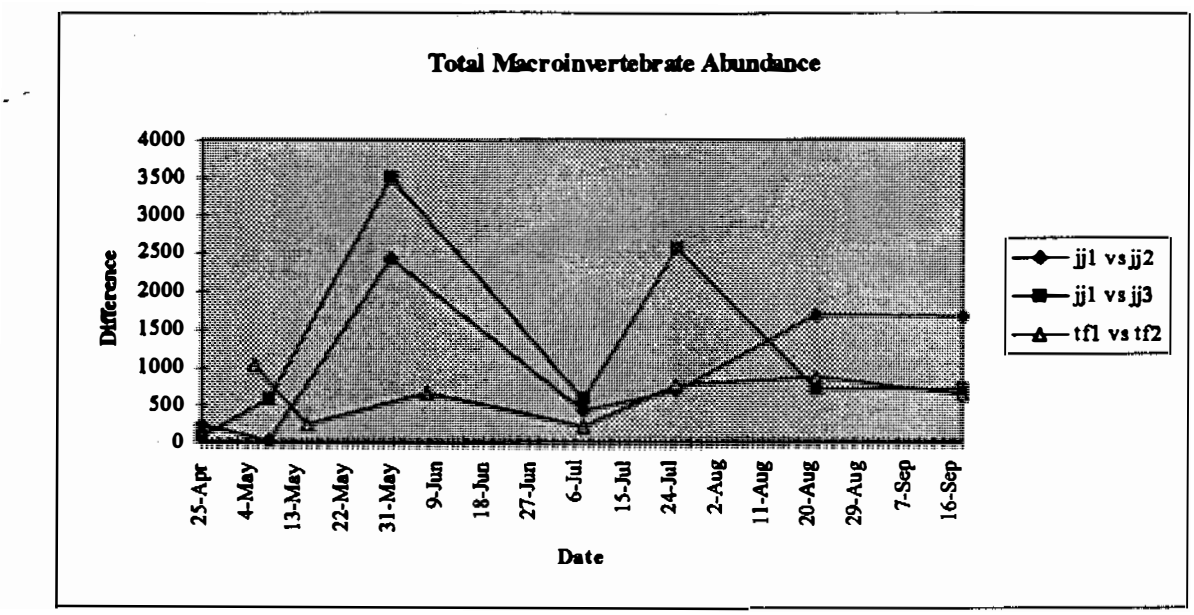


Figure 3.5. Temporal change in site dissimilarities as measured by the difference in total invertebrate abundance (all taxa combined) for the *rootmat* habitat.

Three replicate samples were collected at each site and time.

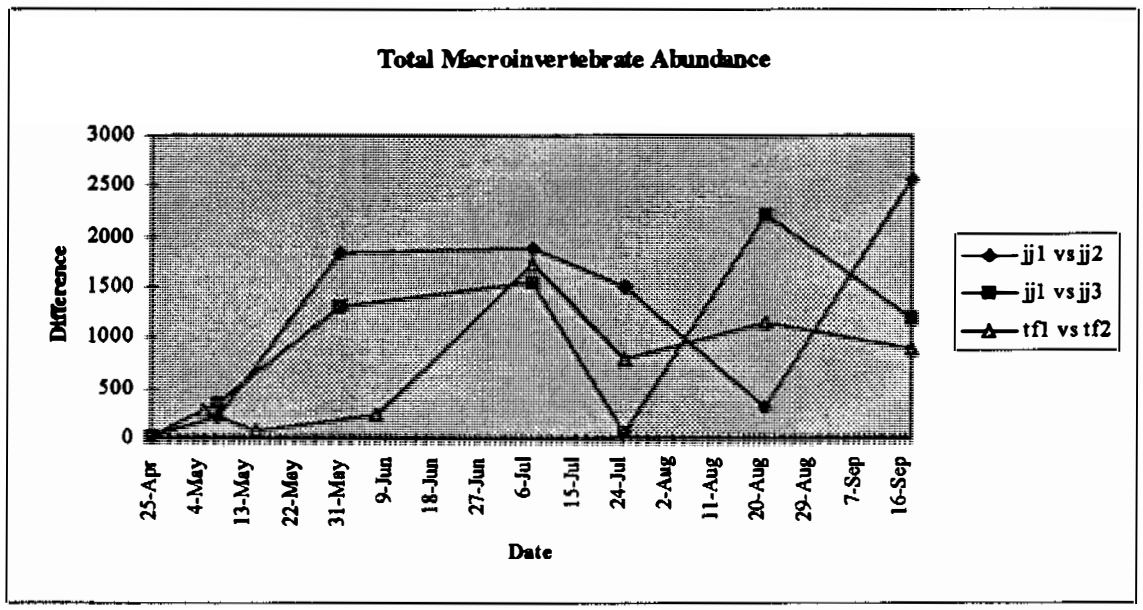


Figure 3.6 Temporal change in site dissimilarities as measured by the difference in total invertebrate abundance (all taxa combined) for the *sand* habitat.

Three replicate samples were collected at each site and time.

of these taxa. Multivariate analyses have been presented using both transformed and untransformed data. The effect of transforming the data is to lessen the 'weight' of the most common taxa and thus increase sensitivity to impacts where such changes occur among the less common taxa. As with univariate analysis, multivariate comparison revealed a large amount of natural variability associated with the inter-site comparisons, as indicated by the variation observed among sites before the opening of the road crossing, and also in the Twin Falls Creek sites throughout the season.

Rootmat

The site dissimilarities based on untransformed rootmat data show a marked departure of the JJ1/JJ2 data for the August and September sampling occasions in relation to the independent control, TF1/TF2, and JJ1/JJ3 data comparison. This increase in dissimilarity, although within a background of high variability, is at a time when undisturbed sites would be expected to be become more similar (as is the general trend throughout the season for the Twin Falls sites) (figure 3.7).

Site dissimilarities based on log transformed rootmat data show less variability than those based on untransformed data. The departure of the JJ1/JJ2 comparison, relative to the Twin Falls control stream is clearly evident in the last two sampling ocasions. There also a slight divergence of the JJ1/JJ3 comparison late in the season - contrasting with the TF1/TF2 comparison which follows the expected trend of increasing similarity (figure 3.8).

The observed departures in dissimilarity of potentially impacted sites late in the tourist season, particularly involving the 200 m downstream site (JJ2), indicates impact-related changes to macroinvertebrate communities in the latter part of the study downstream of the road crossing. No formal statistical ANOVA test for interaction of data 'before' and 'after' impact, and between 'control' and 'impact' stream, was possible using the results of the present study because of lack of independence (= serial correlation) of the temporal dissimilarity values. Modelling of the temporal variation by way of covariates, using regression analysis, was used to draw statistical inference. These results are described below.

The observation of decreasing dissimilarity in community structure between adjacent stream sites was used to corroborate the inferences drawn from the dissimilarity-time relationships described above. Thus, regression relationships describing the (positive) association between dissimilarity and stream discharge for paired sites in the upper South Alligator River River (as an example from a previous study; Humphrey, unpublished data) and Twin Falls and Jim Jim creeks (this study) are presented in figure 3.9a & b, respectively. Only the dissimilarity data for the unimpacted condition (JJ1/JJ2 and JJ1/JJ3 paired site dissimilarity data prior to opening of the Jim Jim road crossing and all TF1/TF2 data) were incorporated in regression analysis. The creek discharge value used in he regression was the average instantaneous (Twin Falls/ Jim Jim) or daily discharge over the preceding 20 days (South Alligator River) value for the two sites. Dissimilarity values were calculated on log transformed macroinvertebrate data in both cases.

Figure 3.9 a & b clearly show strong relationships between macroinvertebrate community dissimilarity and discharge from paired undisturbed sites of ARR streams. When paired site dissimilarity values for JJ1/JJ2 and JJ1/JJ3 *after* vehicle access to the crossing are superimposed upon the Twin Falls/ Jim Jim undisturbed regression, it is clearly apparent that

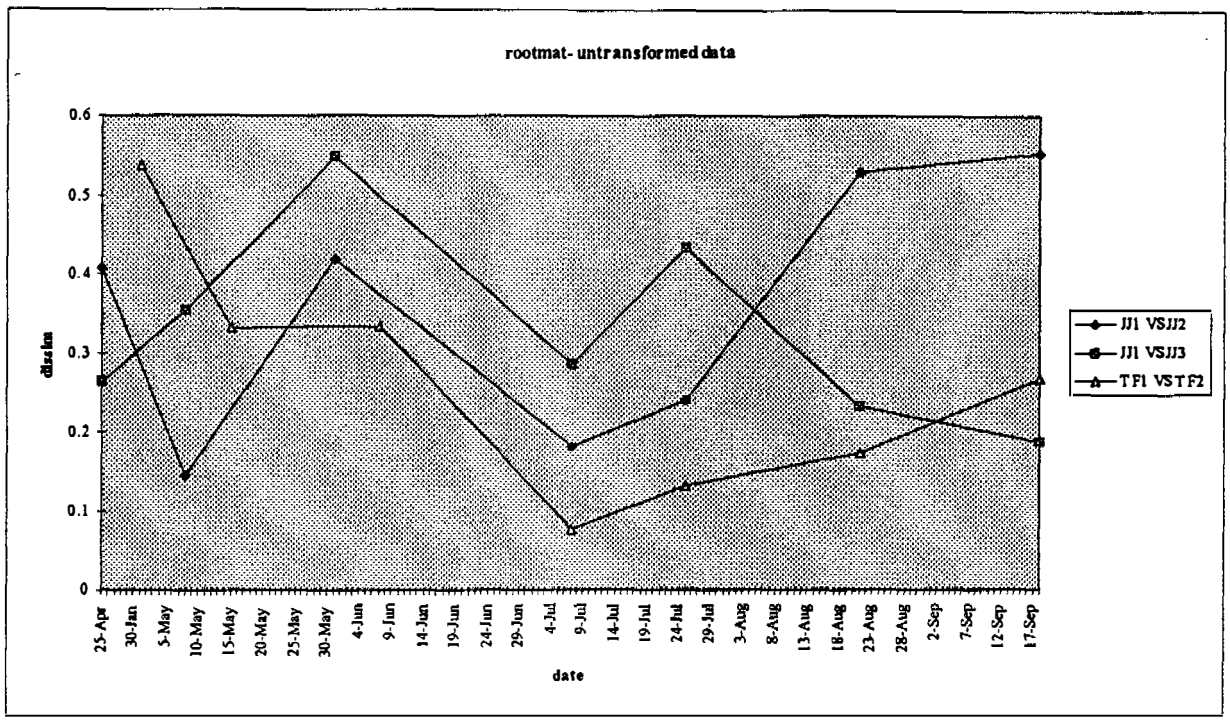


Figure 3.7 Temporal change in Bray-Curtis multivariate dissimilarities for the *rootmat* habitat calculated using *untransformed* data.

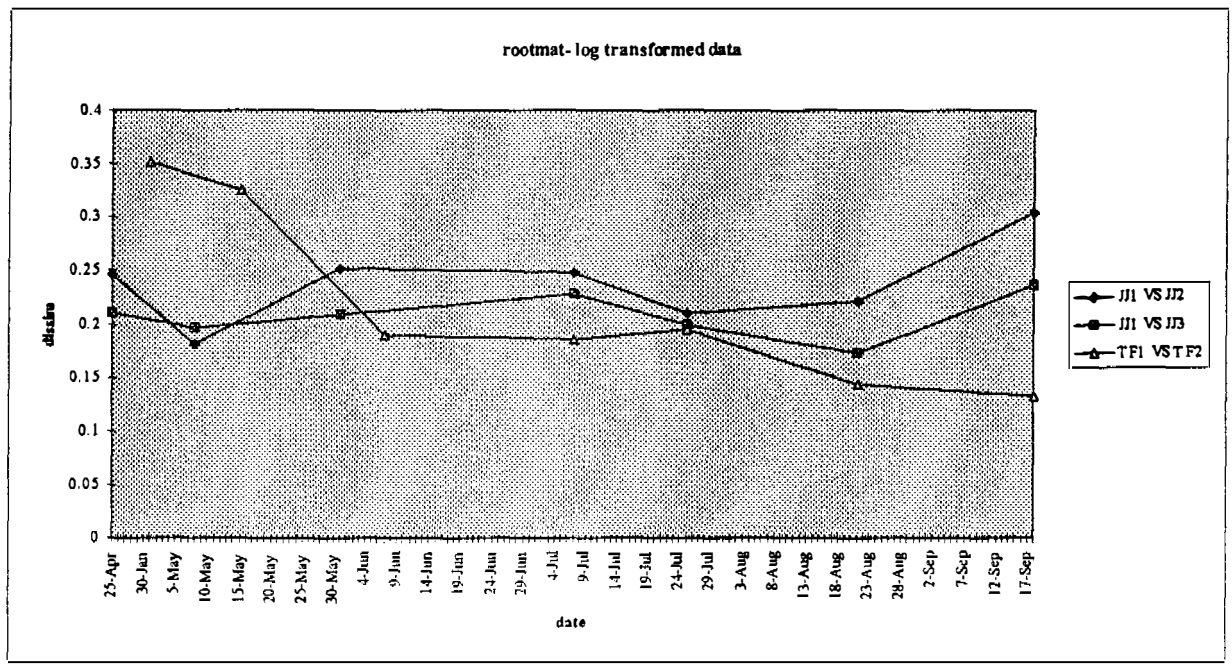


Figure 3.8. Temporal change in Bray-Curtis multivariate dissimilarities for the *rootmat* habitat calculated using $\log_{10}(x+1)$ *transformed* data.

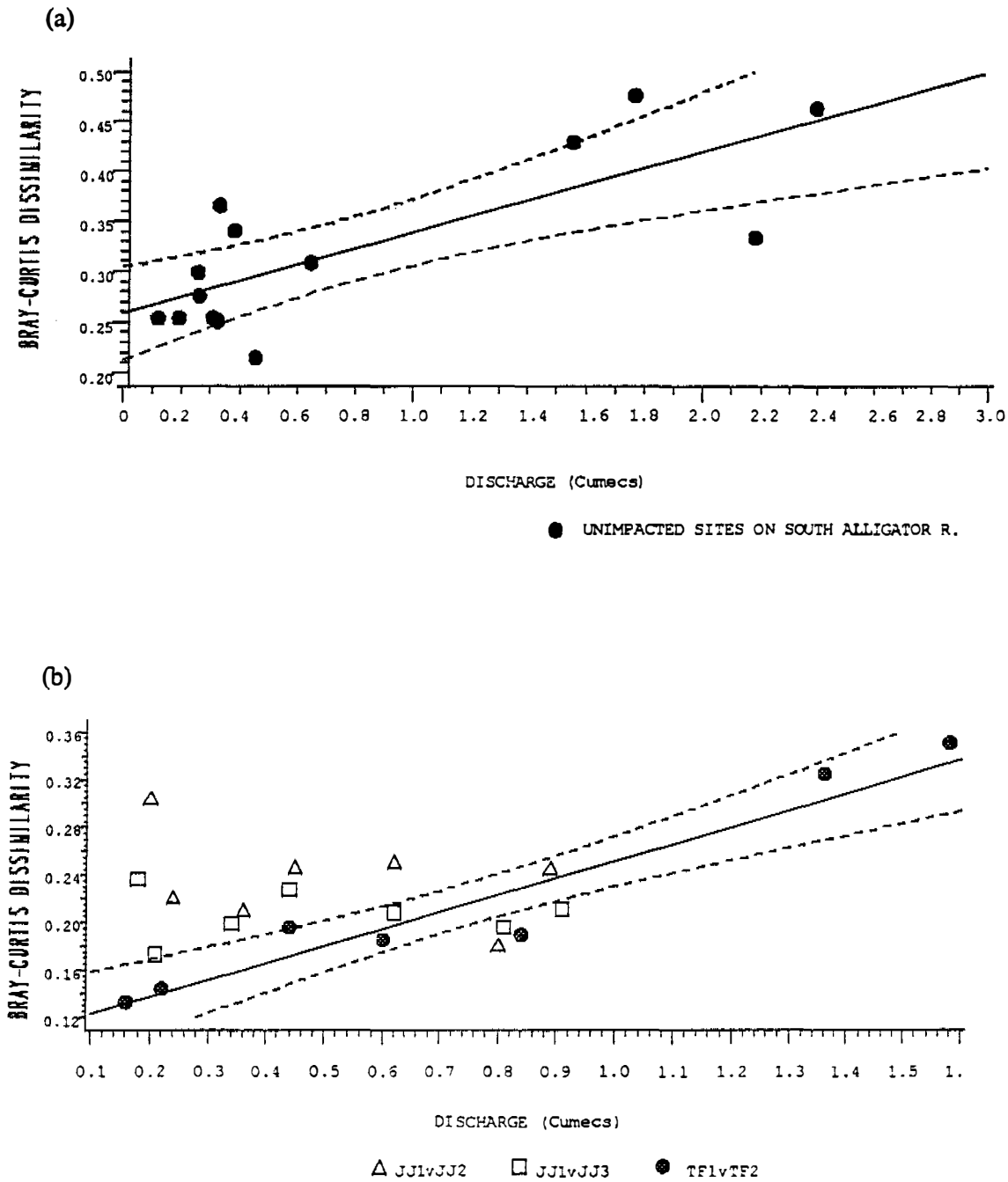


Figure 3.9. Relationship between discharge and Bray-Curtis dissimilarity of macroinvertebrate community structure between upstream and downstream sites for (a) the upper reaches of the South Alligator River using species level data and (b) Jim Jim and Twin Falls Creeks using family level data.

Shaded symbols indicate the unimpacted sites (ie all South Alligator River and Twin Falls Creek sites and all Jim Jim creek sites BEFORE the opening of the Jim Jim Creek road crossing to the public).

Open symbols indicate potentially impacted sites (ie Jim Jim Creek sites AFTER after the opening of the Jim Jim Creek road crossing to the public).

The regression line and 95 percent confidence interval relates to all 'unimpacted' (shaded) samples and creek discharge at the time of sampling. R^2 values for regressions (a) and (b) are respectively 0.600 and 0.804.

this Jim Jim Ck data falls increasingly outside of the 95% confidence limits of the regression relationship with decreasing creek flow (= increasing time after crossing opening). These observations indicate disturbance to macroinvertebrate communities downstream of the Jim Jim road crossing following vehicle access.

Sand

In contrast to the rootmat communities, the trends in dissimilarity values for sand communities, based on untransformed data, indicate there are no exceptional differences observed in downstream sites compared with control sites (including Twin Falls Creek), in the 'after' period (figure 3.10). Again, as expected of undisturbed sites, there is a general downward trend with time in all site comparisons (indicating increasing paired-site similarity). The slight increase in the JJ1/JJ2 comparison for the last sampling occasion does not provide strong inference for an impact-related community change, particularly considering the variability observed amongst comparisons in the previous sampling occasion.

Using transformed data, the JJ1/JJ2 comparison shows a slight departure for the last two sampling occasions (figure 3.11). However, this still represents a general trend of increasing site similarity over time, combined with natural site variation.

Unlike rootmat macroinvertebrate data, no significant relationship was observed for paired site dissimilarity and discharge data for undisturbed sites in Twin Falls and Jim Jim creeks.

3.2.4 Multivariate ordination

Ordination of both sand and rootmat macroinvertebrate data indicates there is a strong temporal trend among *all* sites - as might be expected with changing characteristics of the habitat with receding flow etc. To draw stronger inferences about turbidity-related changes, without the influence of natural temporal changes, ordinations were performed separately on data gathered prior to, and after, the crossing opening to traffic.

Rootmat

The rootmat samples in the 'before' period show the similarity of samples among sites by the interspersion of represented data points in ordination space (figure 3.12). Significant environmental correlates included conductivity, alkalinity, bicarbonate, turbidity and orthophosphate (figure 3.13a) and are most likely a reflection of natural temporal changes associated with similar temporal change in the macroinvertebrate communities. Notably, one such significant environmental correlate is turbidity. However, all measurements for this period are in the 'low' range (<5NTU) and the correlation of this parameter for the before period is most likely, again, a consequence of temporal differences among samples (water clarity decreased slightly in undisturbed sites with receding creek flow). Most major taxa, namely Chironomidae, Baetidae, Caenidae, Ceratopogonidae and Acarina, are also seen to be correlated with the ordination (figure 3.13b), again a consequence of overall changes through time rather than site specific differences. No separation of particular sites is seen to follow these taxa correlations. Importantly, there is no overall separation of sites in the before period, indicating a general similarity of all the sites in the undisturbed state.

Rootmat sample ordination in the 'after' period shows a clear separation of the JJ2 samples (200 m downstream) from the samples from other sites, particularly the six points which represent the last two (August and September) sampling occasions (figure 3.14). To a lesser

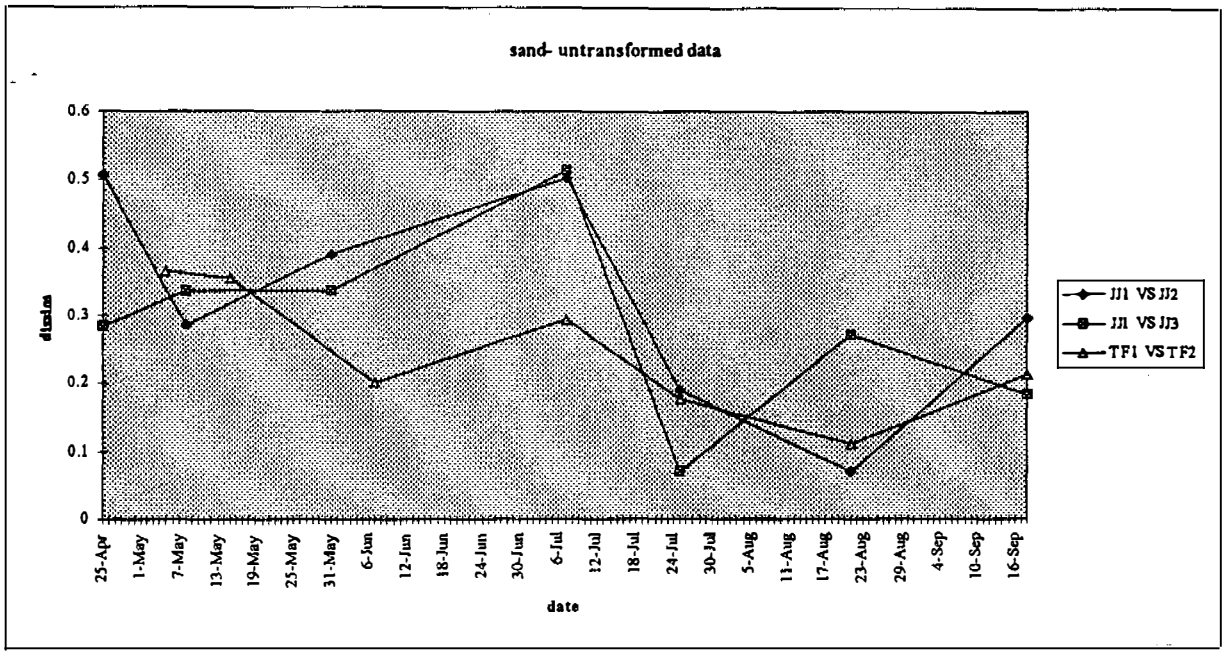


Figure 3.10. Temporal change in Bray-Curtis multivariate dissimilarities for the *sand* habitat calculated using *untransformed* data.

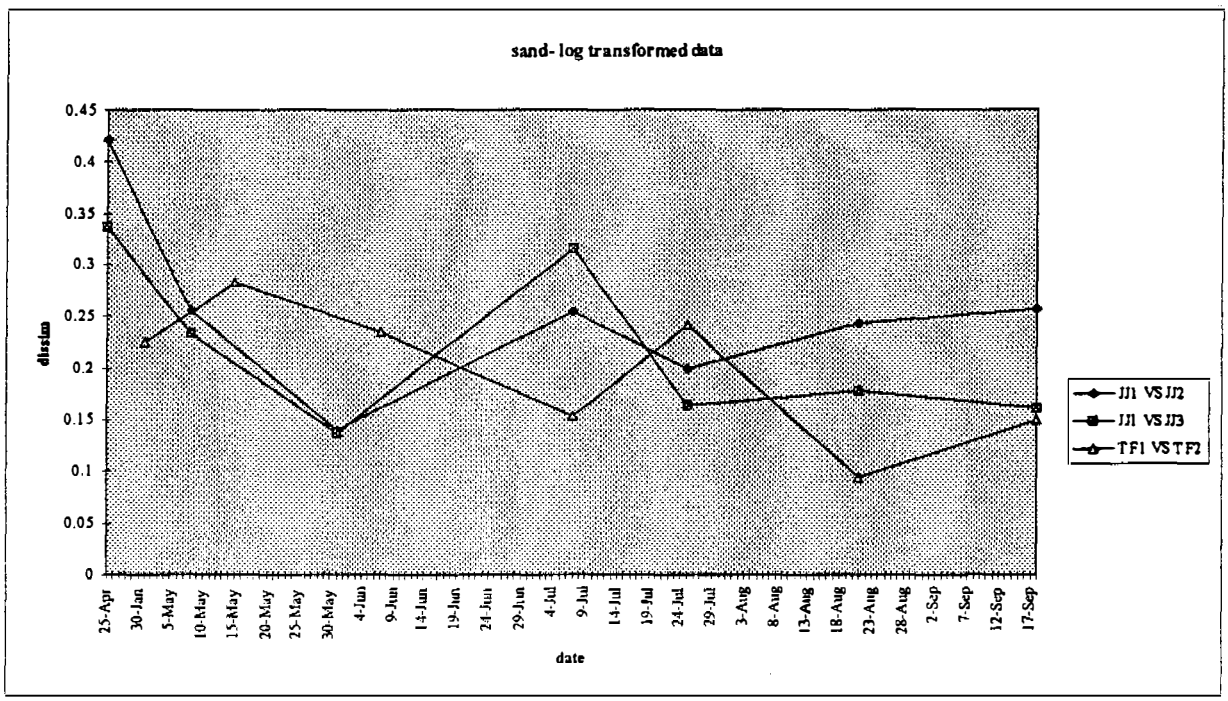


Figure 3.11. Temporal change in Bray-Curtis multivariate dissimilarities for the *sand* habitat calculated using $\log_{10}(x+1)$ *transformed* data.

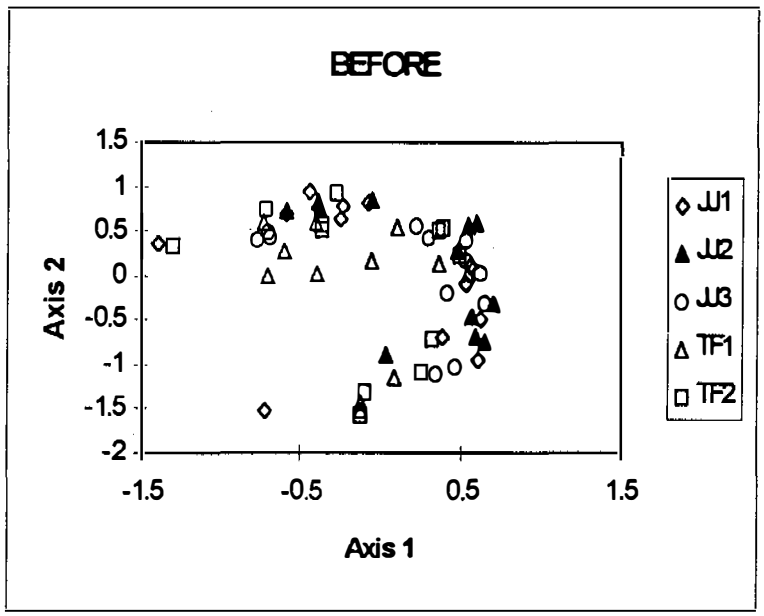
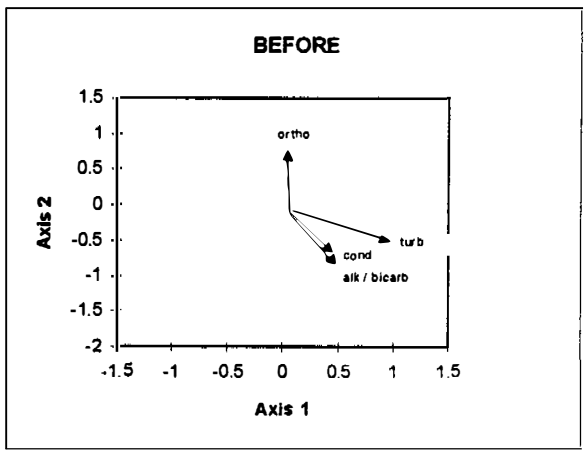


Figure 3.12 HMDS ordination of macroinvertbrate community stucture in the rootmat samples from the 'before' period (prior to the opening of the road crossing) using $log_{10}(x+1)$ transformed data.

3 dimensions; stress= 0.11.

(a)



(b)

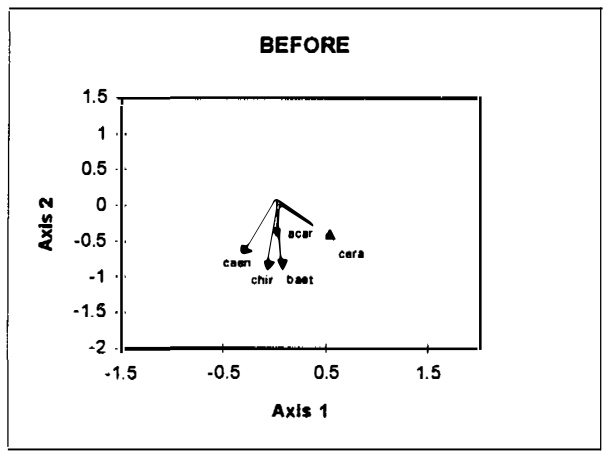


Figure 3.13. Principle axis correlation of (a) environmental variables and (b) taxa for the 'before' period ordination of rootmat samples appearing in figure 3.12.

Only significant ($P<0.01$) variables are shown.

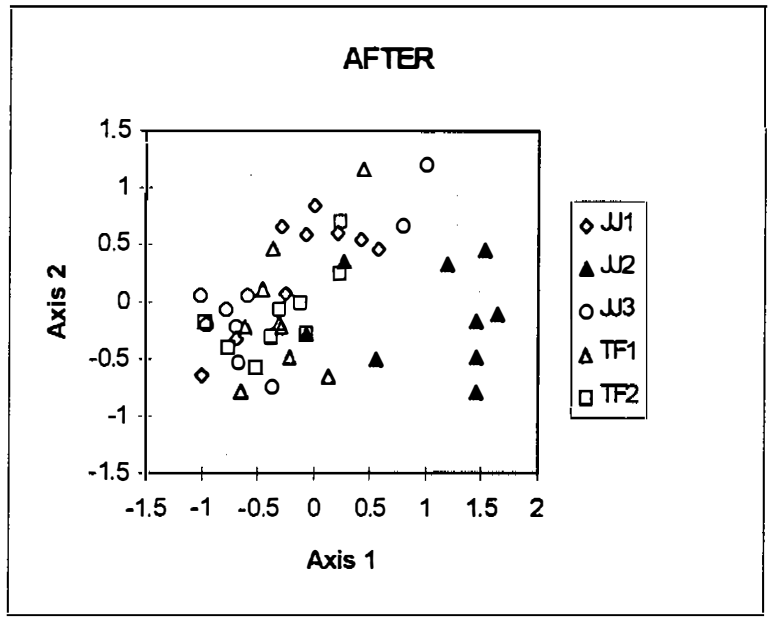


Figure 3.14. HMDS ordination of macroinvertebrate community structure in rootmat samples from the 'after' period (subsequent to the opening of the road crossing) based on $log_{10}(x+1)$ transformed data.

3 dimensions; stress= 0.12.

(a) (b)

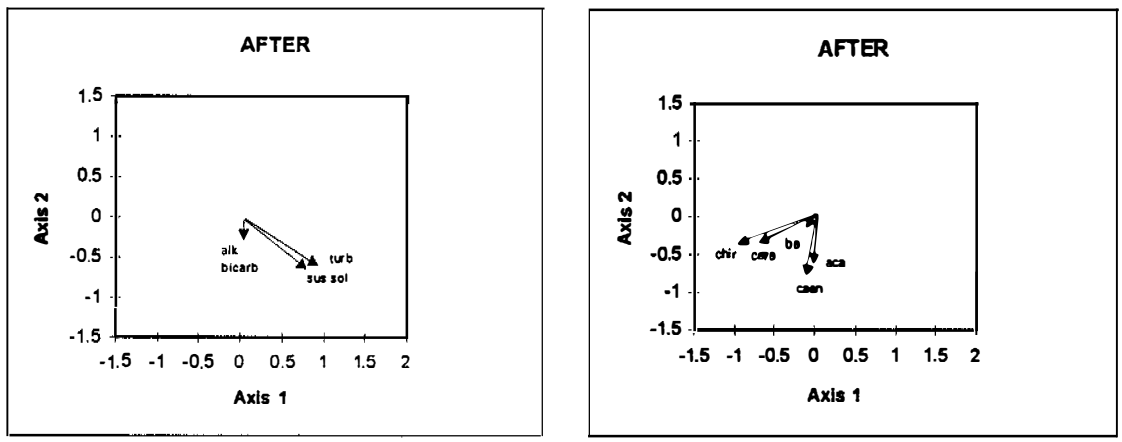


Figure 3.15. Principle axis correlation of (a) environmental variables and (b) taxa for the 'ordination of after' period rootmat samples appearing in figure 3.14.

Only significant ($P<0.01$) variables are shown.

extent, two or the three JJ3 replicates from the last sampling occasion also fall in the vicinity of the separated JJ2 samples referred to above. All other samples, including most of those from the disturbed site 1000 m downstream, constitute a separate cluster and are interspersed in ordination space. Additionally in the after period, there are significant correlations of turbidity and suspended solids in the same direction as the JJ2 site samples, indicating the macroinvertebrate separation of these sites is along a gradient in these parameters (figure 3.15a). Alkalinity and bicarbonate were also significantly correlated with the ordination in the after period, but ran in a direction distinct from the JJ2 site separation. The taxa correlated in the ordination space of 'after samples' included Chironomidae, Ceratopogonidae, Baetidae, Caenidae and Acarina. Of these, Chironomidae and Ceratopogonidae are correlated in a similar but *opposite* direction to the JJ2 site separation (figure 3.15b), with Chironomidae having a particularly strong correlation coefficient value of 0.89. Thus, these taxa were reduced in abundance at the JJ2 site and also the JJ3 site on the last sampling occasion.

Sand

The ordinations based on the *sand* samples, collected in the 'before' period show a general interspersion of points corresponding with different sites, again indicating their similarity in the 'pre-impact' (undisturbed) state (figure 3.16). As with rootmat, a number of environmental variables (pH, conductivity, alkalinity, bicarbonate and orthophosphate; figure 3.17a) and taxa (Baetidae, Chironomidae, Caenidae, Ceratopogonidae, Elmidae, Leptoceridae, Acarina and Ecnomidae; figure 3.17b) are significantly correlated with the ordination in the before period, with the temporal influence and the corresponding changes to these parameters and macroinvertebrate communities a likely cause for these correlations. No individual sites are separated out along these correlation gradients in the before period.

There is a similar interspersion of samples from all sites observed in the after period, indicating an overall similarity among sites, even after elevated suspended solids were experienced downstream. In contrast to the results for rootmat samples, the JJ2 samples fall within, and are interspersed throughout, the space occupied by the unimpacted sites (figure 3.18). Thus there is no evidence for community changes during the after period in samples from this substrate. Two environmental correlates, orthophosphate and pH, are significantly correlated with the after period sand ordination (figure 3.19a), again a likely consequence of the natural temporal changes. Taxa significantly correlated with the ordination include Chironomidae larvae, Dytiscidae and Ecnomidae (figure 3.19b). No site separation is seen with these environmental and taxonomic correlates.

3.2.5 Artificial substrates

Ordination was performed on a limited number (two sampling occasions in each period) of 'before' and 'after' artificial substrate samples to give a preliminary indication of the sensitivity of these substrates to any downstream effects. The ordination revealed interspersion of downstream sites in both the 'before' and 'after' periods (figure 3.20), suggesting no disturbance effect on these assemblages of macroinvertebrates. This was in contrast to a similar preliminary analysis of natural substrate samples (see Stowar *et al* 1996). In view of this, a decision was made to focus the sample processing effort on the more sensitive natural substrates and to discontinue further processing of artificial substrate samples.

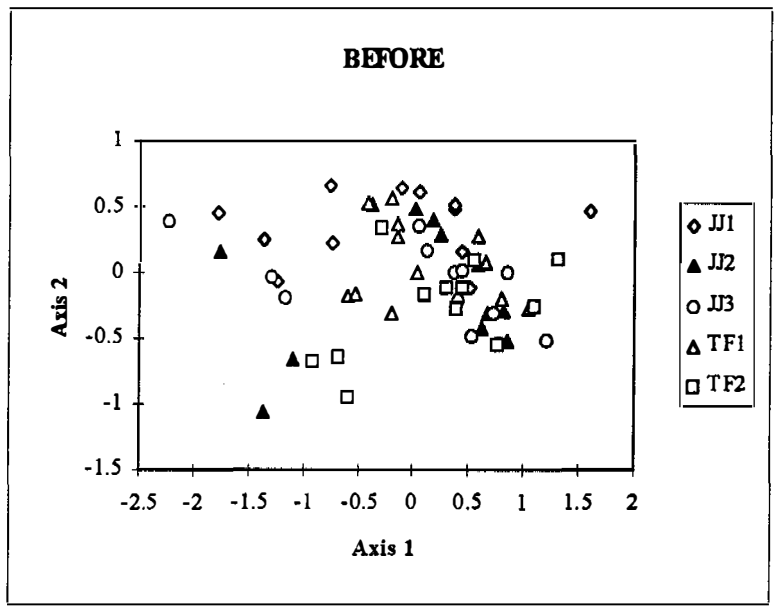


Figure 3.16. HMDS ordination of macroinvertebrate community structure in sand samples from the 'before' period (prior to the opening of the road crossing) based on $log_{10}(x+1)$ transformed data.

3 dimensions, stress= 0.11.

(a) (b)

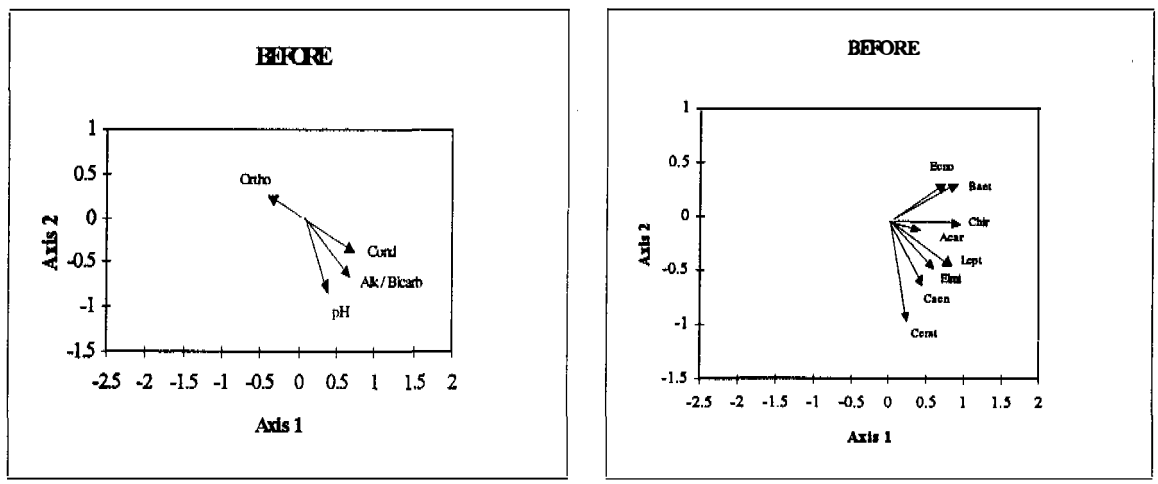


Figure 3.17. Principle axis correlation of (a) environmental variables and (b) taxa for the 'before' period ordination of sand samples appearing in figure 3.16.

Only significant ($P<0.01$) variables are shown.

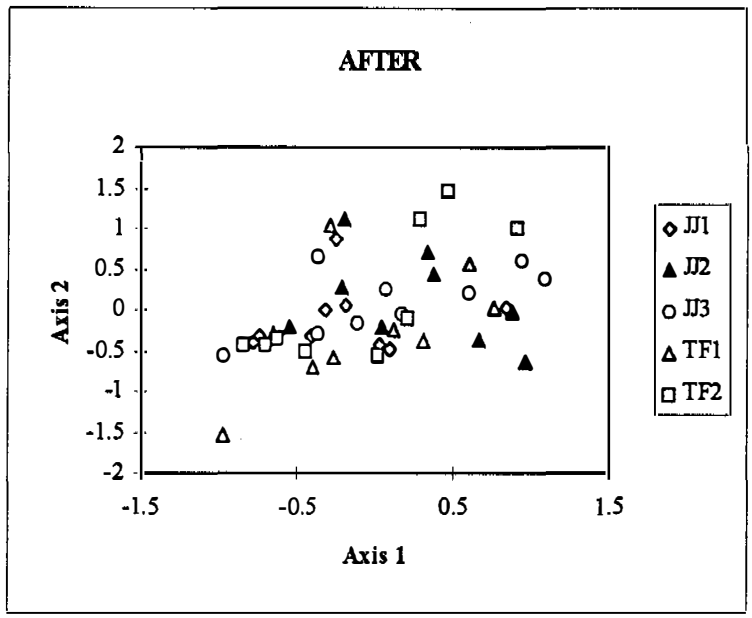


Figure 3.18. HMDS ordination of macroinvertebrate community structure in sand samples from the 'after' period (subsequent to the opening of the road crossing) based on $log_{10}(x+1)$ transformed data.

3 dimensions, stress= 0.096.

(a) (b)

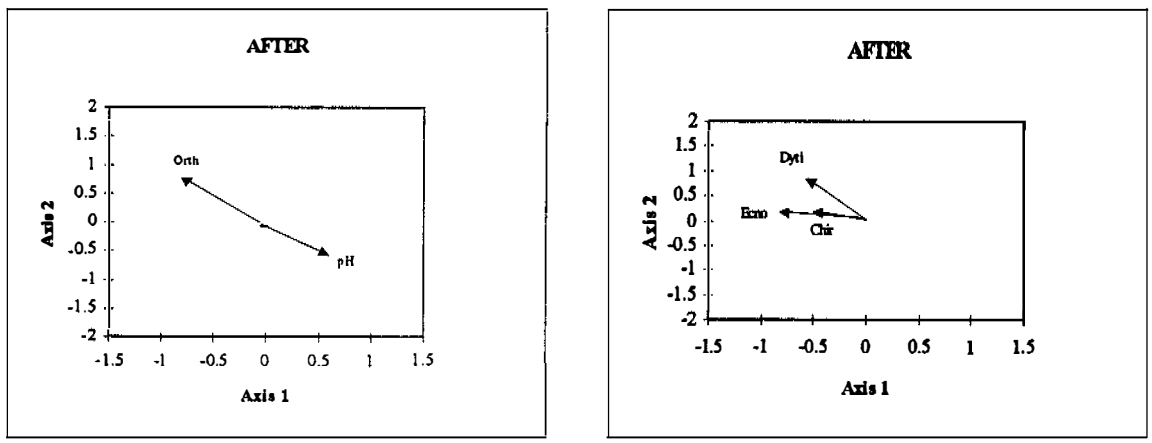
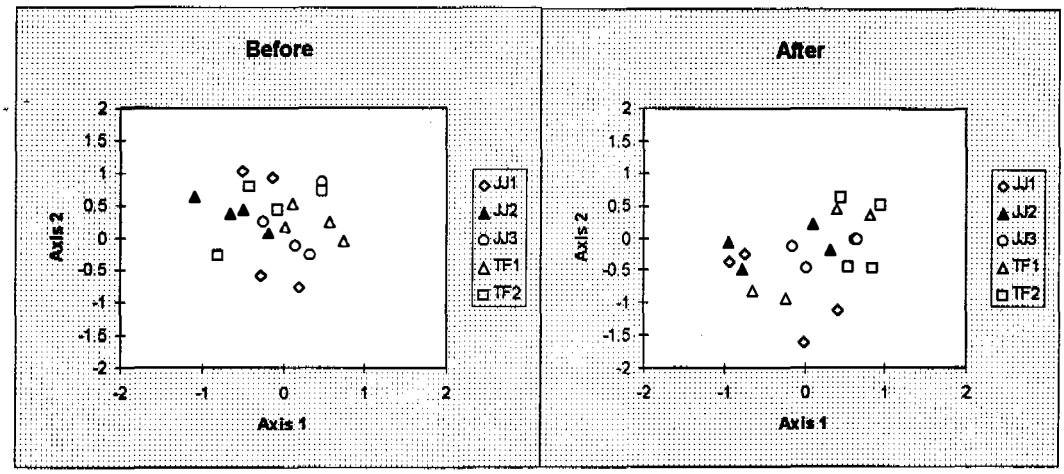


Figure 3.19. Principle axis correlation of (a) environmental variables and (b) taxa for the 'after' period ordination of sand samples appearing in figure 3.18.

Only significant ($P<0.01$) variables are shown.



(a) (b)

Figure 3.20 Ordination of artificial substrate samples (a) in the 'before' period **(prior to the opening of the road crossing)** and (b) 'after' period (subsequent to the opening of the road crossing).

Ordination performed using 3 dimensions, stress = 0.19 for both (a) and (b).

3.2.6 Observed macroinvertebrate changes

Having established community differences in rootmat samples collected 200 m downstream of the road crossing in the late Dry season, the actual changes to macroinvertebrate community structure were examined. There were no apparent changes in the presence /absence of taxa observed at any of the sites, with all major taxa being observed both prior to and after the opening of the road crossing at all sites. Changes in macroinvertebrate abundance were, therefore, responsible for the observed community changes.

Observation of total macroinvertebrate abundance in rootmat samples, for each site individually (as opposed to paired-site *differences* in total abundance which were discussed previously) shows quite clearly that the total abundance of macroinvertebrates (all taxa combined) is distinctly less in the rootmat samples from Jim Jim Creek site 2 than in samples from other sites collected in August and September (figure 3.21). This corresponds with the latter part of the period when elevated levels of turbidity and suspended solids were present. When a similar comparison is made using each of the most common taxa individually, it is apparent that chironomid (non-biting midge) larvae, consistently the most common macroinvertebrate in all samples, showed a marked decline in JJ2 samples in the latter part of the study period (figure 3.22). Similar site comparisons were made with regard to the abundance of Elmidae larvae (an aquatic beetle), Acarina (aquatic mites), Caenidae nymphs (a family of mayfly) and Baetidae nymphs (another family of mayfly), all of which constituted the most frequently-observed taxa in the rootmat samples. None of these other taxa displayed site specific trends in potentially impacted sites that are outside the variability observed among control sites (figures 3.23, 3.24, 3.25 & 3.26). Thus, chironomid larvae appear to be the major contributor to community changes, in the form of a decline in abundance at site JJ2. No such decline in either total macroinvertebrate abundance nor chironomid abundance was apparent 1000 m downstream of the road crossing (site JJ3).

The sand habitat, which by all indications did not experience discordant community changes downstream of the road crossing relative to other sites, did not display any conclusive trend in the 'after' period of a decline in total macroinvertebrate (figure 3.27) or chironomid abundance figure 3.28). Similarly, other major taxa appear not to have been affected in the sand habitat.

3.2.7 Summary of macroinvertebrate results

There is a large amount of variability among all samples collected, which to some degree masks the ability to detect disturbance related impacts on macroinvertebrate communities. However, the results indicate community changes immediately (200 m) downstream of the Jim Jim road crossing, with some evidence for less distinct changes 1000 m downstream of the road crossing, in the rootmat substrate samples collected late in the Dry season (August and September). These changes are associated with elevated turbidity and suspended solids. The changes observed in communities inhabiting the rootmat were most strongly associated with changes to overall community structure (ie involving overall taxa composition and abundance), though reductions in downstream abundances of chironomid (non-biting midge) larvae were particularly influential in the multivariate response. No community changes were detected downstream in samples collected at the same time and sites from the sand habitat.

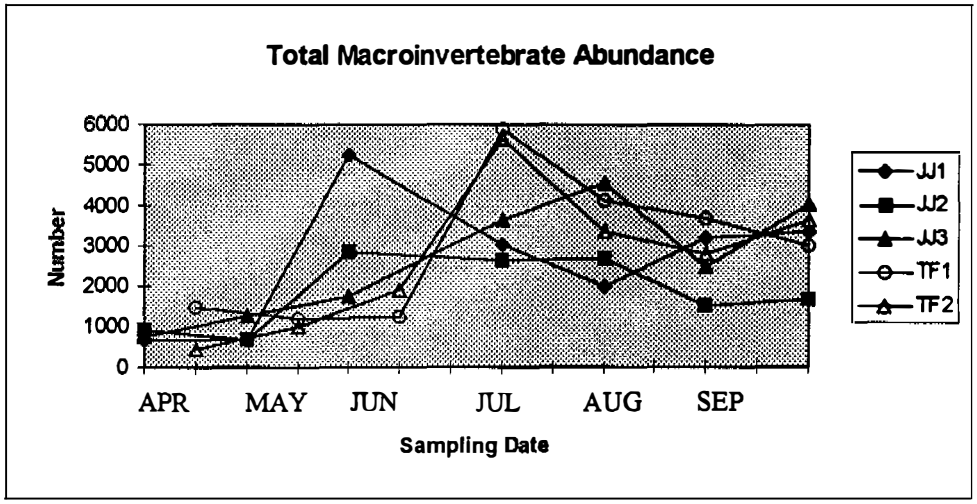


Figure 3.21. Temporal change in total macroinvertebrate abundance (all taxa) in *rootmat* samples

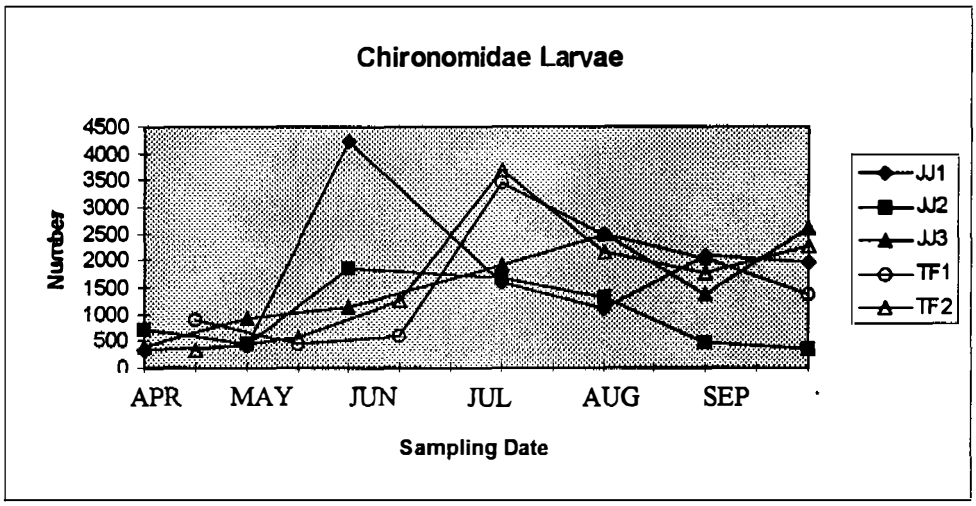


Figure 3.22. Temporal change in Chironomid (non-biting midge) larvae abundance in *rootmat* samples.

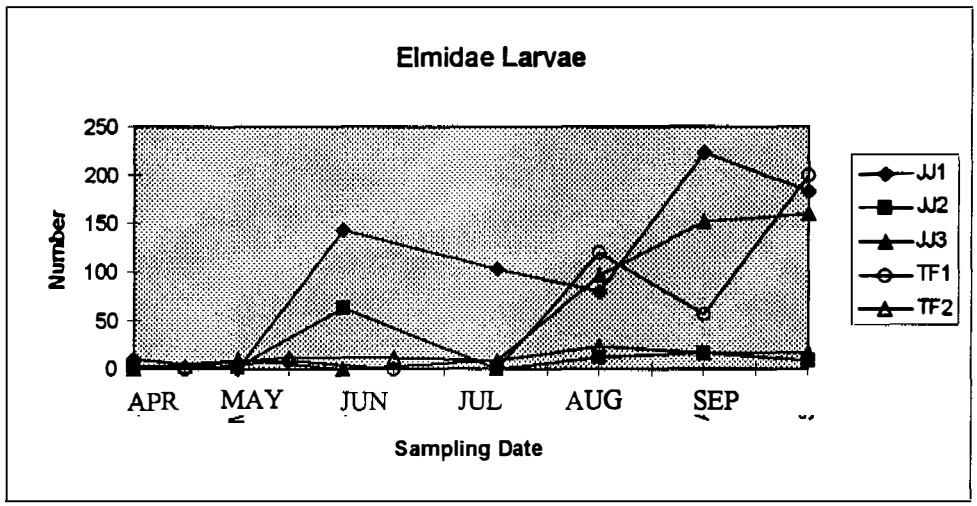


Figure 3.23. Temporal change in Elmid beetle larvae abundance in *rootmat* samples

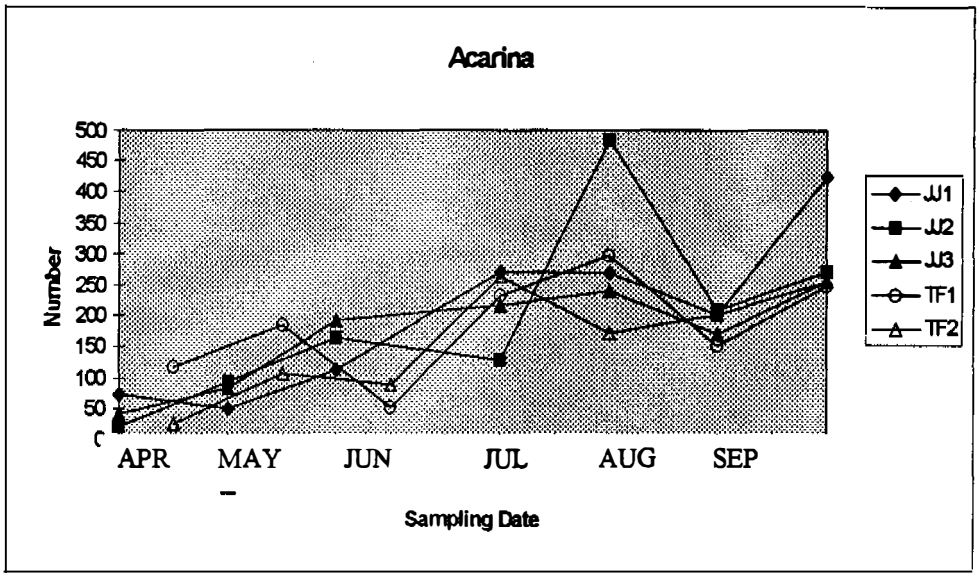


Figure 3.24. Temporal change in Acarina (aquatic mite) abundance in *rootmat* samples.

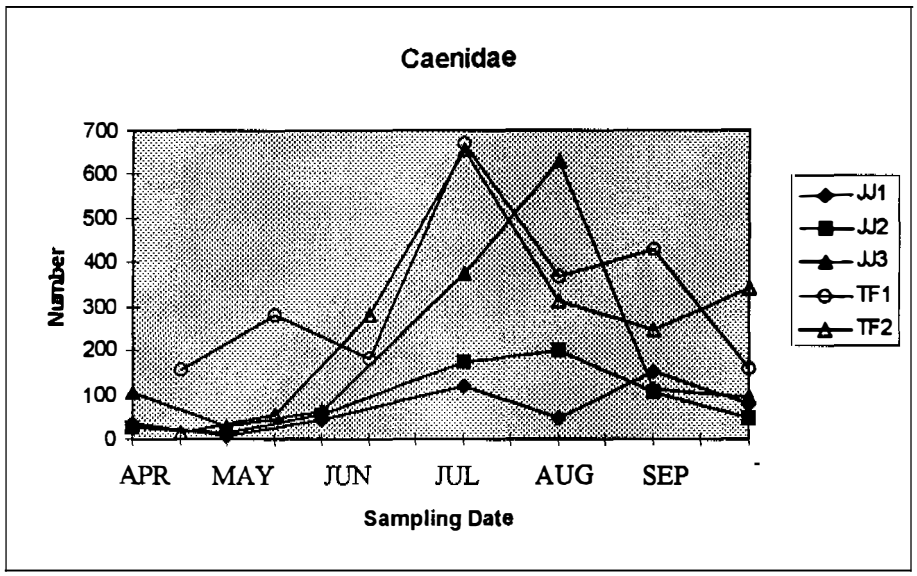


Figure 3.25. Temporal change in Caenid mayfly abundance in *rootmat* samples.

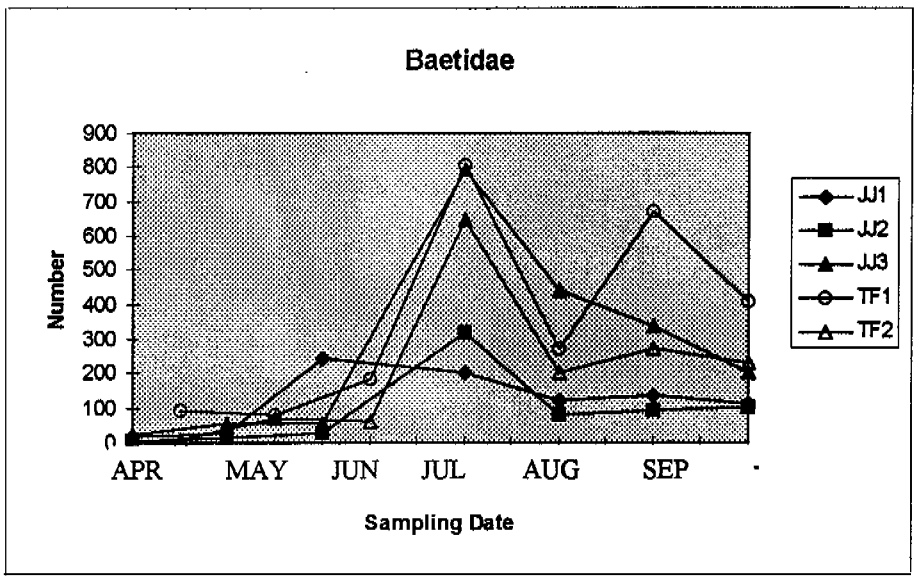


Figure 3.26. Temporal change in Baetid mayfly abundance in *rootmat* samples.

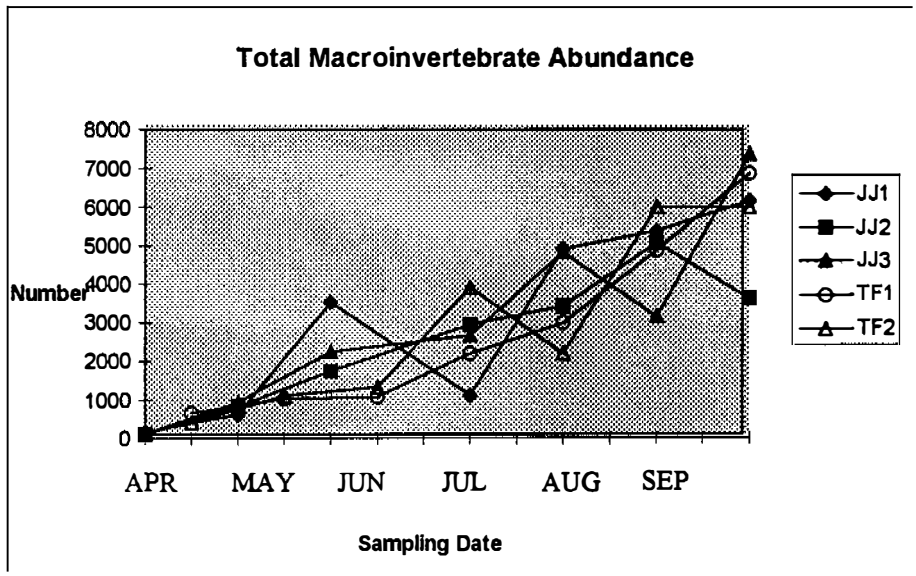


Figure 3.27. Temporal change in total macroinvertebrate abundance (all taxa) in *sand* samples.

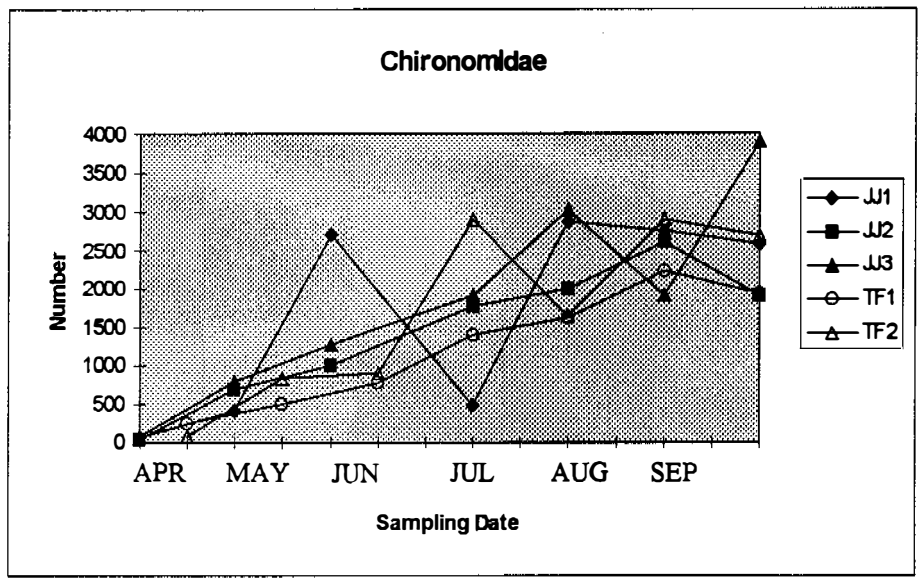


Figure 3.28. Temporal change in Chironomid (non-biting midge) larvae abundance in *sand* samples.

3.3 Fish

3.3.1 Comparison of sampling methods

The number of fish detected by different sampling methods is shown on table 3.2. The gill net and seine net procedures caught very different assemblages of fish. Gill nets caught both larger-growing fish species and more species (19 species) than the seine nets (14 species). Further, there were only 7 species in common that were captured by the two procedures. Of the 7 species captured by seine nets that were not captured in the gill nets, 3 were probably the most abundant species in the two streams, Jim Jim and Twin Falls creeks.

The visual count carried out before the road crossing opened revealed only one extra species not captured by the other methods, the penny fish (*Denariusa bandata*) (table 3.2). On the other hand, the visual procedure did detect most of the more common species captured by the two netting procedures. A number of the species not detected in the visual counts listed here were, however, observed at other times during the study: fork-tailed catfish (*Arius* spp.) saratoga (*Scleropages jardini*) and boney bream (*Nematalosa erebi*). Thus, when they can be conducted, visual census techniques for fish are probably more effective than other sampling methods. As noted earlier, this was not possible for a study in which poor visibility from increased turbidity was certain to occur.

As well as the biases of different sampling procedures, the different sampling efforts and the different units of measurement of each method present a potential problem when combining data from different procedures to represent community structure as a whole. The different units of measure were as follows:

gill-netting data — refers to number of fish per unit effort (duration and length of net set);

seine netting data — refer to either numbers per unit effort (i.e. No. per 3 hauls which is a different *effort* to the gill nets), or
number per unit area (from the total area enclosed by 3 net hauls);

visual counts — can refer to number per unit area (from the total area surveyed), or number per unit effort (again different effort to the other procedures).

Whilst it would be possible to adjust and convert number-per-unit-area data to common units (and therefore combine them in an ecologically meaningful way), this is not possible for catch per unit effort data using different procedures. Consequently, it has been common practice to accept this limitation in fish biodiversity studies and simply combine the different forms of data for the analysis of community structure indices. This procedure was followed for the calculation of multivariate community measures.

3.3.2 Species richness

The different fish species recorded at the different sites, a total of 27 species, are presented in table 3.3. Twenty species were common to both Jim Jim and Twin Falls creeks while 7 species occurred in only one or other of the streams. Before the road crossing opened, the number of species was similar in both streams (21 species in Jim Jim Creek and 19 species in Twin Falls Creek) and there was little difference in species composition between the upstream and downstream sites. Four months after the road opened there was almost no change in the number

of species present in Jim Jim Creek and only a small change in the species composition. In contrast, in Twin Falls Creek there was a considerable decline in the number of species present and the downstream site had fewer species (12) than the upstream site (15). Note that these data refer to the presence or absense of species and do not take the abundances recorded into account.

Table 3.2. Comparison of fish numbers detected by gill-netting, seine-netting, and visual count methods.

Scientific Name	Gill-netting	Seine-netting	Visual count*
Neosilurus ater	92	0	25
Nematalosa erebi	76	0	6
Syncomistes butleri	24	0	35
Megalops cyprinoides	29	0	0
Scleropages jardini	27	0	0
Anodontiglanis dahli	25	0	44
Neosiluris hyrtlii	22	0	5
Hephaestus fuliginosus	5	0	38
Arius leptaspis	4	0	0
Lates calcarifer	3	0	11
Toxotes chatareus	4	0	0
Arius midgleyi	1	0	0
Pingalla midgleyi	64	2	45
Leiopotherapon unicolor	45	5	28
Amniataba percoides	122	17	45
Strongylura krefftl	23	1	2
Ambassis macleayi	8	5	0
Glossamia aprion	5	1	1
Melanotaenia splendida inornata	62	375	289
Craterocephalus marianae	0	2367	439
Melanotaenia nigrans	0	343	106
Craterocephalus stercusmuscarum	0	253	267
Ambassis agrammus	0	34	24
Glossogobius giuris	0	18	0
Mogurnda mogurnda	0	3	1
Pseudomugil gertrudae	0	3	7
Denariusa bandata	0	0	1
Total No. of Species	**19**	**14**	**20**

*only made before road opened

Table 3.3. Fish species observed in Jim Jim Creek and Twin Falls Creek before and after the opening of Jim Jim Creek Crossing. (+ indicates species present.)

Scientific Name	Gundjeihmi Name	Common Name	Jim Jim Upstream		Jim Jim Downstream		Twin Falls Upstream		Twin Falls Downstream	
			Before	After	Before	After	Before	After	Before	After
Nematalosa erebi	Na-bardebarde or Garlalba	Boney bream	+	+	+	+				
Ambassis macleayi	Na-rranggi	Sail-fin perchlet	+	+		+				
Toxotes chatareus	Njarigan	Common archerfish		+		+				
Arius midgleyi	Almakkawarri?	Shovel-head catfish			+					
Anodontiglanis dahli	Ganbakdjdja (J), Barrabarra or Na-gurl (A)	Toothless Catfish	+	+	+	+	+			
Arius leptaspis	Almakkawarri	Salmon catfish	+		+	+		+		
Ambassis agrammus	Na-rranggi	Reticulated perchlet	+	+	+	+	+		+	
Amniataba percoides	Mandidi	Banded grunter	+	+	+	+	+	+	+	+
Craterocephalus marianae	Dilebang or Dolbo	Mariana's hardyhead	+	+	+	+	+	+	+	+
Craterocephalus stercusmuscarum	Dilebang or Dolbo	Fly-Specked hardyhead	+	+	+	+	+	+	+	+
Glossamia aprion	Na-rranggi or Djabelh	Mouth-almighty				+		+	+	+
Glossogobius giuris	?	Flathead goby	+	+	+	+	+		+	
Hephaestus fuliginosus	Na-gerdmi or Dumbuhmarj	Sooty grunter	+	+	+	+		+	+	
Lates calcarifer	Malarlalk(J), Na-rramgorl (A)	Barramundi	+				+	+	+	
Leiopotherapon unicolor	Burd	Spangled grunter	+	+	+	+	+	+	+	+
Megalops cyprinoides	Garlalba	Ox-eye herring or Tarpon	+	+	+	+	+	+	+	
Melanotaenia splendida inornata	Dilebang or Dolbo	Chequered rainbowfish	+	+	+	+	+	+	+	+
Melanotaenia nigrans	Dilebang or Dolbo	Black-Striped rainbowfish	+	+	+	+	+	+	+	+
Neosiluris hyrtlii	Binjdjarrang	Hyrtl's catfish			+	+	+		+	+
Pingalla midgleyi	Dumbuhmarj ??	Black-anal-fin grunter	+	+	+	+	+	+	+	+
Syncomistes butleri	Na-gerdmi or Dumbuhmarj	Sharp-nosed grunter	+	+	+	+		+		
Scleropages jardini	Yinmamarra (j), Guluiblrr (A)	Saratoga	+	+	+		+	+	+	+
Neosilurus ater	Binjdjarrang or Ganbakdjdja	Black catfish	+	+	+	+	+	+	+	+
Strongylura kreffti	Burrugulung	Longtom	+	+	+		+		+	+
Pseudomugil gertrudae	Dilebang or Dolbo	Spotted blue-eye					+		+	
Denariusa bandata	Na -rranggi	Penny Fish					+			
Mogurnda mogurnda	Djagok or Gomboh	Purple-spotted gudgeon					+		+	
Total No. Species			**21**	**19**	**20**	**20**	**19**	**15**	**19**	**12**

3.3.3 Fish abundance

The abundance of the different species captured by the two sampling methods is shown separately in table 3.4 (gill netting) and table 3.5 (seine netting).

Gill net samples

In Jim Jim Creek, the total number of fish captured at the upstream and downstream sites (table 3.4) was very similar prior to the opening of the road crossing (104 and 92 fish respectively). Three months after the road was opened the number of fish captured at the upstream site increased by 18% to 123 while at the downstream site there was a considerable decline in the catch by 62% to 35 fish. The two species that declined the most at the downstream site were the banded grunter (*Amniataba percoides*) and boney bream (*Nematalosa erebi*). Numbers of the black catfish (*Neosiluris ater*), one of the more abundant species before the road opened, had declined during the sample interval at all sites.

In Twin Falls Creek prior to the road opening, the total number of fish caught at the upstream site (69) was less than that caught at the downstream site (106). After the road opening, the catch at the upstream site changed very little whereas at the downstream site the catch declined by 39% to 64 fish. The main species that declined here was the chequered rainbowfish (*Melanotaenia splendida inornata*). However, this species actually increased in the seine net samples (see below) suggesting that the decline was only in the larger individuals of this species that were susceptible to the gill nets and not in the total population size of that species.

Seine net samples

As with the gill netting, in Jim Jim Creek prior to the opening of the road crossing the total number of fish captured by seine nets (table 3.5) at the upstream and downstream sites was very similar (367 and 301 fish respectively). Four months after the road was opened, the number of fish captured at the upstream site changed very little (+ 8%) while at the downstream site there was a considerable decline in the catch by 47% to 159 fish. The two species that declined the most at the downstream site, Mariana's hardyhead (*Craterocephalus marianae*) and black-striped rainbowfish (*Melanotaenia nigrans*) were reduced to only 10% of their numbers prior to the opening. Prior to the road opening, these species comprised 76% of the total seine net catch but only 16% afterwards. Conversely at the upstream site, the numbers of *C. marianae* increased after the road opened whilst abundances of *M. nigrans* had declined only slightly (table 3.5).

In Twin Falls Creek prior to the road opening, the number of fish caught by seine net at the upstream site (379) was greater than that caught at the downstream site (202). After the road opening the opposite was the case. The catch at the upstream site increased by 14% to 432 in spite of a reduction in species richness, largely due to an increase in the number of *C. marianae*. However, at the downstream site there was an even larger recruitment of young *C. marianae* so that the seine net catch increased dramatically, by 457%, to 1125 fish. Although three other species also increased in numbers here, this large change was mostly a result of *C. marianae* recruitment.

Table 3.4. Numbers of fish sampled by gill-netting at sites before and after the opening of the road crossing on Jim Jim Creek

	Jim Jim Creek				Twin Falls Creek			
	upstream		downstream		upstream		downstream	
Scientific Name	Before	After	Before	After	Before	After	Before	After
Neosilurus ater	33	9	16	2	13	9	6	4
Amniataba percoides	25	27	23	3	11	11	15	7
Nematalosa erebi	10	46	15	5	0	0	0	0
Anodontiglanis dahli	7	6	7	3	2	0	0	0
Syncomistes butleri	7	8	4	4	0	1	0	0
Ambassis macleayi	7	1	2	0	0	0	0	0
Strongylura kreffti	5	3	2	0	5	0	7	1
Pingalla midgleyi	4	6	6	2	1	4	19	22
Megalops cyprinoides	2	9	1	2	8	5	2	0
Melanotaenia splendida inornata	1	0	4	3	5	4	38	7
Leiopotherapon unicolor	1	3	5	4	15	5	3	9
Scleropages jardini	1	1	2	0	6	7	2	8
Arius leptaspis	1	0	1	1	0	1	0	0
Neosiluris hyrtili	0	0	2	1	2	0	11	6
Hephaestus fuliginosus	0	1	1	1	0	1	1	0
Glossamia aprion	0	0	0	0	0	2	2	1
Lates calcarifer	0	0	0	0	1	2	0	0
Toxotes chatareus	0	3	0	1	0	0	0	0
Arius midgleyi	0	0	1	0	0	0	0	0
Total no. fish	**104**	**123**	**92**	**35**	**69**	**52**	**106**	**65**
Total Species	**13**	**13**	**16**	**13**	**11**	**12**	**11**	**9**

Table 3.5. Numbers of fish sampled by seine net from each site before and after the opening of the road crossing on Jim Jim Creek.

	Jim Jim Creek				Twin Falls Creek			
	upstream		downstream		upstream		downstream	
Scientific Name	Before	After	Before	After	Before	After	Before	After
Craterocephalus marianae	189	301	124	13	284	383	135	938
Melanotaenia nigrans	57	36	106	11	28	7	32	66
Craterocephalus stercusmuscarum	57	63	38	52	13	1	5	24
Melanotaenia splendida inornata	48	24	29	40	57	35	53	89
Amniataba percoides	8	0	0	3	2	4	0	0
Glossogobius giuris	6	2	5	1	3	0	1	0
Leiopotherapon unicolor	2	2	0	0	0	1	0	0
Ambassis agrammus	0	1	0	33	0	0	0	0
Ambassis macleayi	0	0	0	5	0	0	0	0
Pseudomugil gertrudae	0	0	0	0	2	0	1	0
Mogurnda mogurnda	0	0	0	0	2	0	1	0
Pingalla midgleyi	0	0	0	0	1	1	0	0
Strongylura krefftii	0	0	0	0	1	0	0	0
Glossamia aprion	0	0	0	1	0	0	0	0
Total no. fish	**367**	**429**	**302**	**159**	**393**	**432**	**228**	**1117**
Total No. of Species	**7**	**7**	**6**	**9**	**10**	**7**	**7**	**4**

3.3.4 Multivariate measures of paired-site dissimilarity of fish community structure

For calculating an overall measure of the structure of the fish community, the numerical data from both gill netting and seine netting were combined (added together). Bray-Curtis dissimilarity measures comparing the structure of the fish community between upstream and downstream sites in each stream were calculated using both raw abundance and log-transformed abundance data. This transformation reduces the influence of the more abundant fish in favour of the less abundant species in the computation of dissimilarity.

The dissimilarity index provided a convenient measure of the overall difference in fish community structure between the upsteam and downstream sites before and after the opening of the road crossing. These data are shown in table 3.6. Dissimilarity values for the raw, untransformed dataset were higher than for the transformed data, but the dissimilarity derived from both datasets showed similar patterns. The dissimilarity between the upstream and downstream sites increased in both streams after the road opened. However, the size of the increase was considerably larger in Jim Jim Creek, 0.17 or 155% for the transformed data set, compared to only 0.07, or 35%, in Twin Falls Creek.

Table 3.6. Bray Curtis dissimilarity values for fish community structure based on combined data from gill net and seine samples using both untransformed abundance data and log transformed data from 4 sites on Jim Jim and Twin Falls Creeks before and after the opening of a road crossing on Jim Jim Creek.

	Untransformed data		Transformed data	
	Jim Jim - upstream vs downstream	Twin Falls - upstream vs downstream	Jim Jim - upstream vs downstream	Twin Falls - upstream vs downstream
Before	0.23	0.32	0.10	0.21
After	0.64	0.45	0.29	0.28
Difference	0.41	0.13	0.19	0.07
% change	+178	+ 41	+ 190	+ 33

3.3.5 Multivariate ordination

The relationship of the different fish samples to one another is shown graphically by a 2 dimensional SSH MDS ordination of the log transformed data in figure 3.29 and the untransformed data in figure 3.31. In both analyses there is a clear separation of the communities in the two streams, this being more pronounced with the transformed data. These figures also show how the communities at the sites changed in the ordination space during the sampling interval. The community structure of the two Twin Falls Creek sites moved largely in the same direction so that there was not a large increase in the dissimilarity between the two sites. In contrast, the two Jim Jim Creek sites moved in different directions (opposite with the transformed data and at right angles with the untransformed data) and this resulted in a large increase in the dissimilarity between the two Jim Jim Ck sites.

The fish species that were significantly correlated with the ordination space in the principal axis correlation analysis are shown in table 3.7 and their direction of influence on the ordination pattern is shown in figures 3.30 & 3.32. Seven species were significantly correlated at $p<0.05$ with at least one of the ordination patterns. The influence of most of these species was directed at the separation of the communities in the two streams. The influence of only two

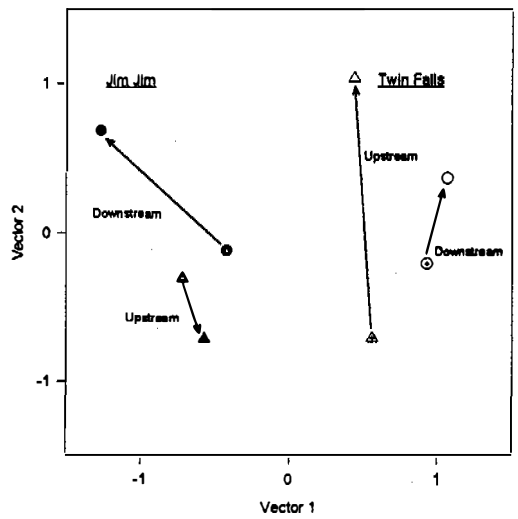
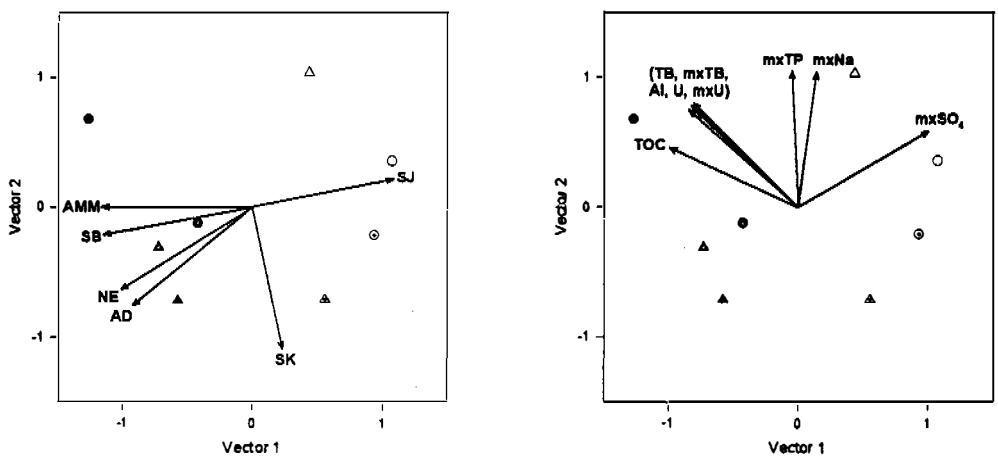


Figure 3.29. HMDS ordination of fish community structure using **log_{10} (x+1) transformed** data. Arrows indicate the direction of change in fish community structure for each site before and after the opening of the road crossing on Jim Jim Creek.

Solid symbols - Jim Jim Creek; Open symbols - Twin Falls Creek;
Triangle symbol - upstream site; Circle symbol - downstream site;
2 dimensions; stress = 0.16



(a) (b)

Figure 3.30 Principal axis correlation of (a) individual fish species and (b) Physico-chemical parameters for the ordination space of fish community structure (**log_{10} transformed data)** in figure 3.29. Only significant variables ($p<0.05$) are shown.

Solid arrows indicate direction of influence of variables
Refer to figure3.27 for description of symbols (shapes) indicating site and time.
Fish species codes are shown in table 3.9 and codes for physico-chemical parameters are shown in table 3.10.

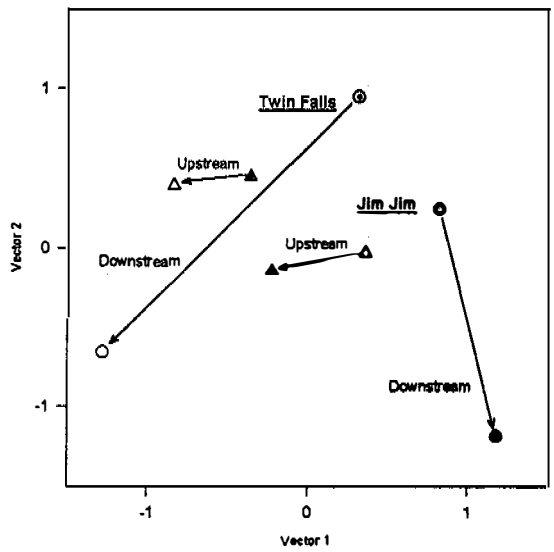
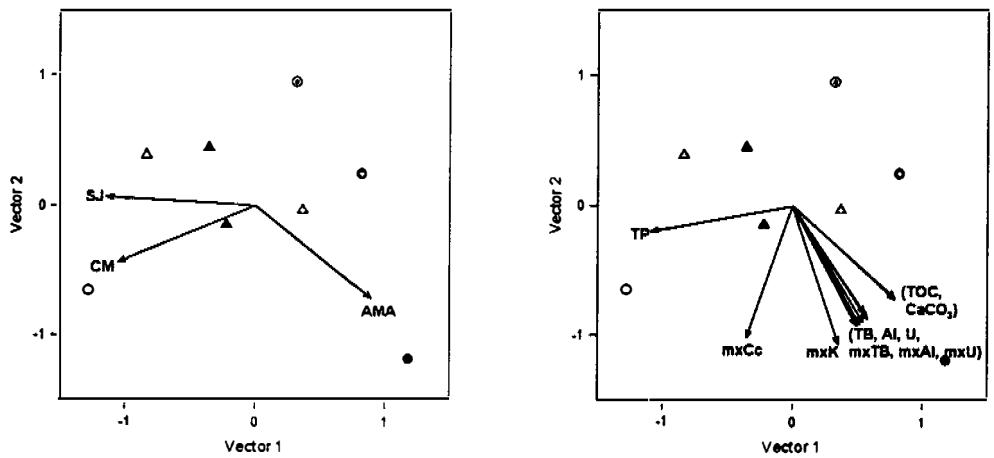


Figure 3.31. SSHMDS ordination of fish community structure in Jim Jim Creek and Twin Falls Creek using **untransformed** data. Arrows indicate the direction of change in fish community structure for each site before and after the opening of the road crossing on Jim Jim Creek.

Solid symbol - indicates Jim Jim Creek;
Open symbols - indicates Twin Falls Creek;
Triangle symbol - indicates upstream site;
Circle symbol - indicates downstream site;
Ordination performed using 2 dimensions; stress = 0.13



(a) (b)

Figure 3.32 Direction of influence of (a) individual fish species numbers (character symbols) and (b) Physico-chemical parameters correlated with the ordination space of fish community structure **(untransformed data)** in Jim Jim Creek and Twin Falls Creeks.

Solid arrows indicate parameters significant at $p \leq 0.05$;
Refer to figure 7.27 for description of symbols (shapes) indicating site and time.
Fish species codes are shown in table 7.9 and codes for physico-chemical parameters are shown in table 7.10.

species, *C. marianae* and *S. krefftl*, appeared to be mainly related to the temporal changes in community structure.

In the analysis of correlation of physico-chemical parameters, the corresponding values for the downstream site on Jim Jim Creek were taken as the mean of the values recorded for macroinvertebrate sites JJ2 and JJ3 in the two periods, before and after the road opened. Also included in the analysis was the maximum value of each physico-chemical parameter recorded in each period (from section 3.1 above) as an indication of a pulse event.

Table 3.7 Principle axis correlation coefficients (R) for fish species variables significantly correlated with the fish ordination community space using either untransformed or log10 (x+1) transformed fish abundance data. Monte Carlo probability derived from 100 random starts is indicated by 'p'. * indicates $p \leq 0.05$

Fish species	Code	Untransformed ordination		Transformed ordination	
		R	p	R	p
Scleropages jardini	SJ	0.87	0.03 *	0.86	0.03 *
Craterocephalus marianae	CM	0.93	0.03 *	0.72	0.12
Ambassis agrammus	AMA	0.87	0.05 *	0.75	0.09
Ambassis macleayi	AMM	0.74	0.12	0.90	0.01 *
Strongylura krefftl	SK	0.69	0.13	0.92	0.04 *
Anodontiglanis dahli	AD	0.54	0.42	0.95	0.01 *
Syncomistes butleri	SB	0.50	0.45	0.91	0.02 *
Nematalosa erebi	NE	0.17	0.90	0.87	0.03 *

Table 3.8 Principle axis correlation coefficients (R) for water physico-chemical variables significantly correlated with the fish community ordination space using either untransformed or log10 (x+1) transformed fish abundance data. Monte Carlo probability derived from 100 random starts is indicated by 'p'. * indicates $p \leq 0.05$

Parameter	Code	Untransformed ordination		Transformed ordination	
		R	p	R	p
Mean Aluminium	Al	0.89	0.02 *	0.76	0.03 *
Mean Total Organic Carbon	TOC	0.92	0.02 *	0.78	0.04 *
Maximum Uranium	mxU	0.88	0.03 *	0.76	0.05 *
Mean Uranium	U	0.88	0.04 *	0.76	0.05 *
Mean Turbidity	TB	0.87	0.04 *	0.75	0.05 *
Mean $CaCO_3$	$CaCO_3$	0.85	0.02 *	0.74	0.08
Maximum Chlorophyll-c	mxCc	0.90	0.03 *	0.30	0.68
Maximum Turbidity	mxTB	0.87	0.04 *	0.74	0.06
Maximum Potassium	mxK	0.86	0.04 *	0.74	0.08
Mean Total Phosphate	TP	0.87	0.04 *	0.71	0.15
Maximum Aluminium	mxAl	0.87	0.05 *	0.75	0.07

Eleven physico-chemical parameters were significantly correlated with the ordination pattern (table 3.8). In both ordinations the direction of influence of turbidity, total organic carbon, aluminium, uranium and alkalinity ($CaCO_3$) was in the direction of the temporal change in the fish community of the downstream Jim Jim site (figures 3.30 and 3.32). Maximum values of chlorophyl c, sodium and sulphate and total phosphorus were also significantly correlated and in a direction associated with temporal change in community structure rather than difference between the two streams. These patterns lend support to the inference of an effect of increased turbidity, and possible related effects (eg Al), on fish community structure.

3.3.6 Condition factors

C. marianae

The relationship between length and weight calculated for *C. marianae* from all sites and times combined was:

Log weight (g) = -11.9352 + 3.1332 Log Length (mm); $R^2 = 0.982$, $p<0.001$.

Condition factors were calculated using this regression equation to predict the expected weight of each fish. The condition factors for each sample are compared in figure 3.33 which shows the mean, standard error and 95% confidence limits of the mean. Samples for which the 95% confidence limits overlap are not significantly different from one another. The effect of location and sample time on condition were examined by ANOVA (table 3.9). Although there was a significant increase in condition of this species between the sample times, there was no difference in condition between the upstream and downstream sites on either occasion. The ANOVA also indicated a significant interaction between the effects (site and time) but this was unrelated to the potential effect of the road crossing.

There was thus no evidence of impaired nutrition (food availability) for *C marianae* downstream of the road crossing after it was opened to traffic. The increase in condition during the sample interval was apparently related to the reproductive cycle with increased gonad size late in the Dry season. Although gonads were not examined in this study, many gravid females were observed in Jim Jim Creek samples in October.

Table 3.9. Results of 2-way ANOVA examining the effect of time (before and after the opening of the road crossing) and site (upstream and downstream sites on 2 streams) on the condition factor of the fish *Craterocephalus marianae*. Design: 1-SITE, 2-TIME.

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	.096078	1202	.084746	1.13372	.334265
2	1	.945196	1202	.084746	11.15333	.000865
1,2	3	.179962	1202	.084746	2.12356	.095497

A. percoides

The relationship between length and weight calculated for *A. percoides* from all sites and times combined was:

Log weight (g) = -11.1922 + 3.0392 Log length (mm); $R^2 = 0.984$, $p< 0.01$.

Condition factors were calculated using the regression equation to predict the expected weight of each fish, and are compared in figure 3.34. Results of ANOVA examining the effects of location and sample time on condition are shown in table 3.10. In this species, there was no significant increase in condition between the sample times. There were significant effects of site in the October samples with the condition of fish at the upstream Twin Falls Creek site being higher than that at the upstream site on Jim Jim Creek. However, there were no significant differences between the upstream and downstream sites in the same stream on either occasion. There was no significant interaction between the effects, site and time.

There was, therefore, no evidence of impaired nutrition for *A. percoides* following the opening of the road crossing.

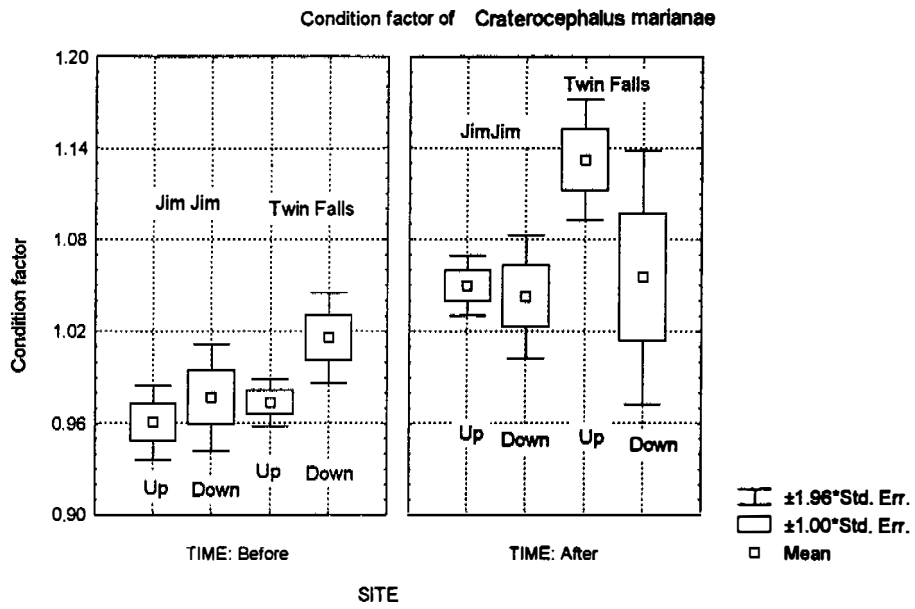


Figure 3.33 Condition factors of *Craterocephalus marianae* before and after the opening of the road crossing on Jim Jim Creek.

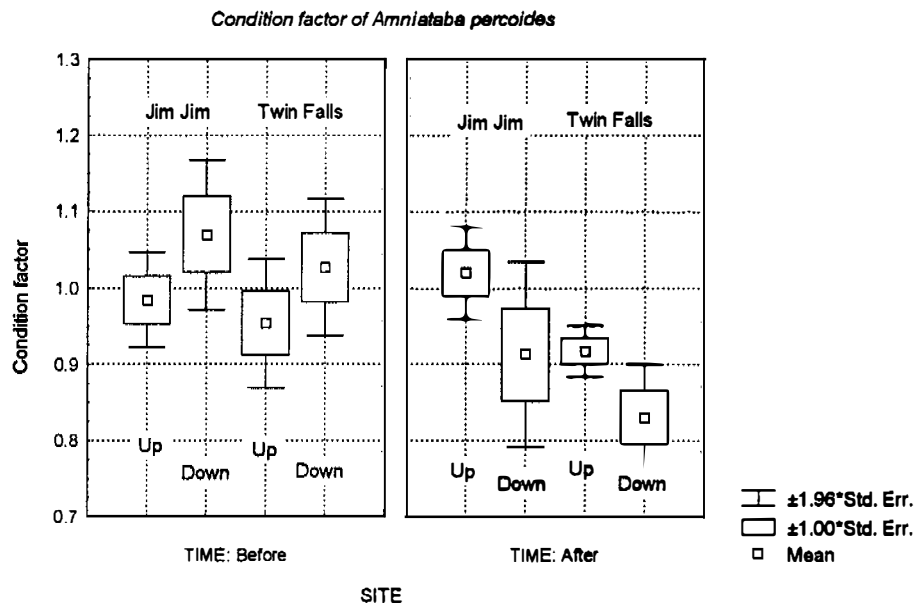


Figure 3.34. Condition factors of *Amniataba percoides* before and after the opening of the road crossing on Jim Jim Creek.

Table 3.10. Results of 2-way ANOVA examining the effect of time (before and after the opening of the road crossing) and site (upstream and downstream sites on 2 streams) on the condition factor of the fish *Amniataba percoides*. Design: 1-SITE, 2-TIME

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	3	.042335	123	.028291	1.496400	.218892
2	1	.196546	123	.028291	6.947277	.009476
1,2	3	.084656	123	.028291	2.992296	.033568

3.3.7 Length frequency distribution

Comparison of the length frequency distribution of measurements made on fresh specimens and specimens of *C. marianae* preserved in 70% alcohol showed that preservation had little impact on fish length (figure 3.35) and the pattern of length frequency. Nevertheless, for consistency the length frequency distribution of *C. marianae* was examined using only preserved specimens (figure 3.36). Before the opening of the road crossing, the size distribution at all sites was very similar with a major peak in abundance of fish in the 30-45 mm LCF range and very few fish less than 25 mm. The only difference between streams was a higher proportion of fish larger than 50 mm in Jim Jim Creek.

Three months after the opening of the road crossing the size distribution of *C. marianae* changed with the presence of a much larger proportion of small fish less than 30 mm LCF (figure 3.36). This indicated significant recruitment of young fish during the sample interval at all sites. At the three sites unaffected by the road crossing (JJ1, TF1 & TF2) the distribution pattern was bimodal indicating the continued presence of high numbers of the 30-40 mm size class that was dominant in the June sample and which was now roughly 5 mm larger. However, at site JJ2 downstream of the crossing there were very few larger fish >50mm and the proportion of the 30-40 mm size class present in June was much lower than at the upstream site JJ1 (figure 3.36).

Thus, as well as a dramatic decline in the density of *C. marianae* downstream of the crossing there was also a change in the population structure to one which contained a lower proportion of older fish.

4 Discussion

4.1 Physical and chemical variables

Turbidity, resulting from suspended sediment derived from the Jim Jim Creek road crossing was observed to rise to levels averaging 60 NTU immediately downstream of the crossing against a high water clarity background (averaging less than 5 NTU) for this system. Observed turbidity levels were strongly correlated with inorganic suspended solids in the water, the levels of which peaked at 100 mg/L. Such elevated levels are cause for concern, particularly in view of the apparent biological changes detected downstream.

A gradient of turbidity and suspended solids was observed downstream of the road crossing, with the highest concentrations occurring immediately downstream of the crossing. Measurements taken 1 km downstream of the road crossing indicate that the levels of turbidity experienced this far downstream (averaging approximately 30 NTU), although not as high as immediately downstream from the crossing, were still well above background.

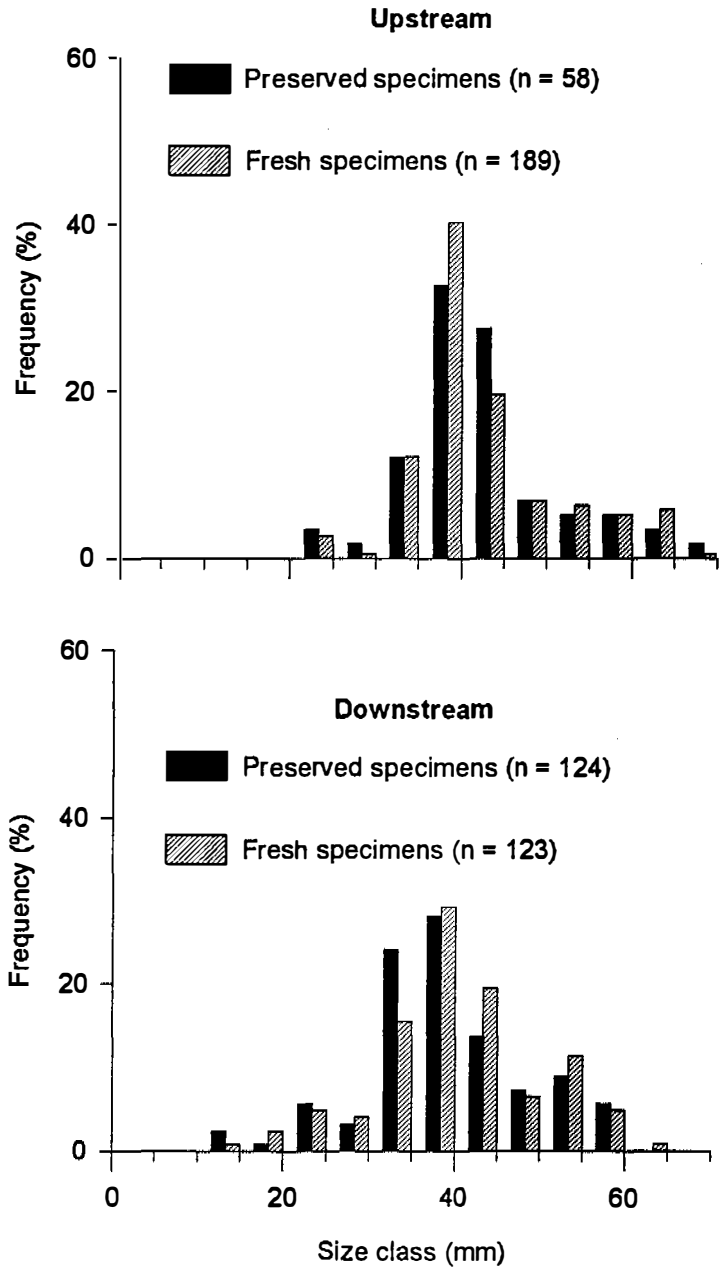


Figure 3.35 Effect of preservation in 70% alcohol on length of *Craterocephalus marianae* specimens collected from the upstream and downstream sampling sites at Jim Jim Creek on 29-30 May, 1996.

Preserved specimens were taken from the same sample as the fresh specimens at both sites.

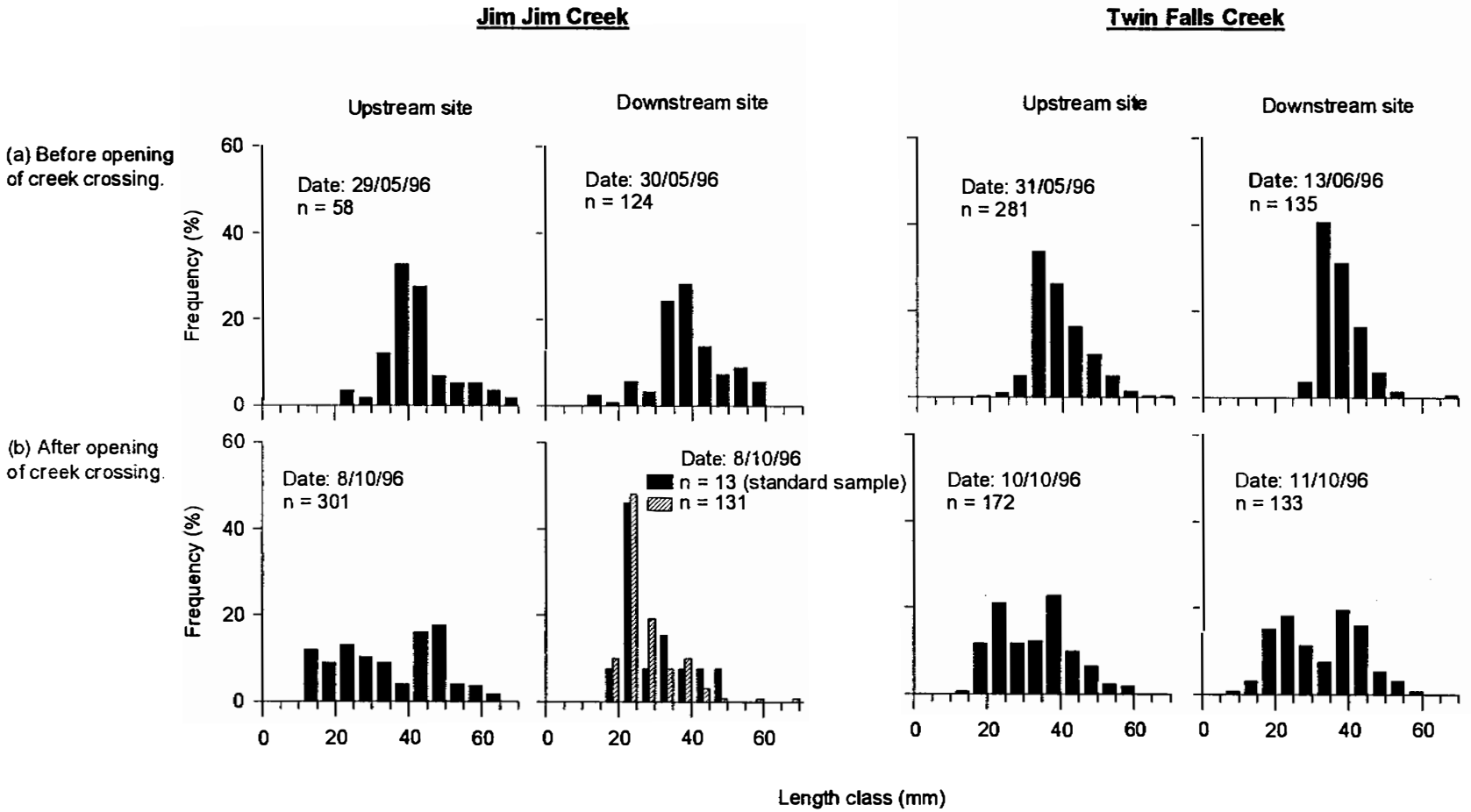


Figure 3.36. Length frequency distributions for *Craterocephalus marianae* at each site before (a) and after (b) the opening of the road crossing at Jim Jim Creek

There was a delay in the rise and subsequent peak of turbidity levels after the opening of the crossing which may be attributed to the time taken for the relatively clean scoured sand deposited on the creek-bed during the Wet season to be eroded away from sections of the crossing to expose the finer sediment that underlies the sand. After peaking in August, the turbidity and suspended solids steadily declined but remained elevated until the end of the study in October - collectively incorporating the duration of the main tourist season. Unfortunately it was not possible to directly determine how this pattern related to traffic levels on the creek crossing because of equipment (traffic count) malfunction. However, if a consistent proportion of traffic to Jim Jim, for which there were data, also visited Twin Falls then it can be concluded that the decline in turbidity was associated to some extent with lower traffic levels later in the Dry season. As well as less traffic, there was also a decline in water level at this time and the lower water velocity associated with this would also reduce the distance suspended particles would be transported.

Associated with the increased suspended solids load arising in Jim Jim Creek downstream of the crossing and after the road opening, was a marked elevation in the levels of iron and aluminium. Given that these metals would be present predominately in particulate and non-toxic form, they are assumed to have had little effect, if any, on changes to biotic communities observed downstream of the crossing late in the Dry season.

The discolouration of the water due to suspended sediment was readily apparent for at least 1 km downstream of the crossing from July, and was still obvious at the conclusion of the study (and tourist season) in October, impacting considerably on the aesthetic value of the creek. The ecological significance of this observed increase in suspended solids is best assessed by the biotic changes that occur in response to the disturbance (see below). Nevertheless, it is worth noting that the levels of optical turbidity and suspended solids observed for a distance of 1000 m downstream of the Jim Jim Creek road crossing substantially exceed the guidelines set for Australian waters (ANZECC 1992). These guidelines recommend that seasonal mean turbidity of a waterway should not change by more than 10 percent (when measured nephelometrically, as in this study), whereas increases of up to 1200 and 600 percent were observed 200 m and 1000 m downstream of the road crossing, respectively.

4.2 Macroinvertebrates

4.2.1 Macroinvertebrate communities of Jim Jim Creek and Twin Falls creeks

The major macroinvertebrate habitats present throughout the Dry season and sampled in this study were sand and edge rootmat. Also present during the Wet season and early Dry season were edge macrophyte (aquatic plant) habitats, which were left exposed due to receding water levels by July 1996. The macroinvertebrate fauna colonising the rootmat habitat and sand habitat were quite similar in terms of taxa richness at the family level, although there was some evidence for greater patch variability in the sand habitat.

The high seasonality in creek flow was strongly reflected in the macroinvertebrate communities. The most significant natural change observed was the increase in abundance of macroinvertebrates, in both sand and rootmat habitats, between the months of April and August. This was readily apparent as the creek-bed, clean-scoured by Wet season flows and characterised by low macroinvertebrate abundance in April, gradually developed an abundant

macroinvertebrate community as flow receded. Changes in the taxonomic richness and diversity (at the family level) throughout the season were not apparent, although patchiness was observed among samples and sites in this regard. This patchiness resulted in relatively high variability among samples even in the undisturbed control sites. The natural patchiness of the habitats and a background of temporal change were important factors in assessing possible downstream macroinvertebrate community changes arising from suspended sediment. (Thus, the detection of such changes may be masked to some extent by the large amount of natural variation present.)

4.2.2 Impact-related changes to downstream macroinvertebrate communities

Nature of macroinvertebrate community changes

Distinct macroinvertebrate community changes downstream of the Jim Jim road crossing that could be attributed to turbidity and/or suspended solids were observed in the rootmat habitat immediately downstream of the road crossing (at site JJ2) late in the Dry season (August and September). There was also some evidence of macroinvertebrate community changes occurring 1000 m downstream of the road crossing. The impact detected in rootmat samples was most apparent using multivariate analysis (which measures overall community structure). However, there was a distinct reduction in abundance of macroinvertebrates downstream of the road crossing, particularly of the family Chironomidae - this taxon being consistently the most numerically abundant at all sites, impacted and control.

No changes, outside that explained by natural variability, were observed in the sand habitat. The sand habitat proved extremely variable, possibly masking any impacts upon the fauna of this habitat.

Temporal and spatial extent of impacts downstream

The macroinvertebrate changes observed downstream of the road crossing in the rootmat habitat were only apparent late in the Dry season (and hence study period), with the samples collected in August and September most obviously indicating an impact. This impact-related change occurred approximately 6 weeks after the peak of turbidity and suspended solids.

The delay in the onset of changes to macroinvertebrate communities arising from turbidity could be attributable to a number of factors:

Firstly, previous studies of suspended solids have indicated the duration of exposure to be an important factor in determining biological effects (Newcombe & MacDonald, 1991). It is likely that many invertebrates would withstand a single or brief pulse of suspended sediment without any adverse effects. In contrast, prolonged exposure to suspended sediment, with its associated adverse physiological effects and alteration of habitat characteristics, will often result in mortality or emmigration of aquatic invertebrates.

Secondly, the observed delay in biological response may be a result of suspended sediment affecting reproduction or recruitment rather than causing direct mortality of the resident macroinvertebrate community. In these circumstances, community changes may only be detected after there has been sufficient time for natural 'turnover' of the macroinvertebrate community.

The fact that macroinvertebrate communities were affected in the latter part of the Dry season may also be a consequence of the receding discharge (and hence flow rates) throughout the Dry

season. The higher flows in the early stages of the crossing being open may have been sufficient to keep sediment mobile and thus prevent its smothering effects, whereas later in the season there is more potential for deposition of sediment, to the detriment of benthic macroinvertebrate communities.

Impacts on macroinvertebrate communities were detected 200 m downstream of the road crossing, with only slight evidence of any significant impact 1000 m downstream of the crossing by the conclusion of the macroinvertebrate sampling in mid September. Thus it would appear the levels of suspended sediment experienced 1000 m downstream (despite being elevated and visually obvious) were insufficient to instigate as marked detectable change to macroinvertebrate communities. Nevertheless, despite such localised effects, consideration must be made of the fact that this disturbance constitutes a barrier to the continuity of the escarpment reaches of Jim Jim Creek, possibly impinging on the use of this area of the creek by other fauna (eg. presenting a barrier to migration).

Overseas studies have indicated the occurrence of long-term macroinvertebrate community changes associated with suspended sediment (Campbell & Doeg, 1989). However, considering the seasonality of the Jim Jim Creek system, it would be expected that any macroinvertebrate community changes observed are limited to 'within season', with high Wet season flow flushing the turbid water and subsequent turnover of macroinvertebrates restoring the creek to an undisturbed condition. This was reinforced by observations made prior to the opening of the Jim Jim road crossing, when the downstream sites were observed to be biologically similar to undisturbed sites.

One of the long term effects of elevated sediment on streams in less seasonal environments has been suggested to be habitat alteration by the deposition of sediment. In the case of Jim Jim Creek, the high flows experienced in the Wet season and the resulting 're-sorting' of creek-bed sediments would negate such long term alteration to a large extent. Thus it is likely that the detected macroinvertebrate impact is limited to the late Dry season. It must be emphasised, however, that macroinvertebrates are bioindicators, and other aspects of the ecological disturbance they indicate (such as the impacts on populations of higher consumers, eg fish) may be longer term.

Habitat 'sensitivity'

Despite the taxonomic similarity (at family level) of the rootmat and sand habitat, the macroinvertebrates occurring in rootmat were clearly more sensitive to the suspended sediment downstream. Such differences in 'habitat sensitivity' are not uncommon in studies of macroinvertebrate studies. Furthermore, sand habitats are considered relatively depauperate habitats (Hynes 1970) and as a consequence, the probability of occurrence of taxa sensitive to a particular disturbance would not be as great in this habitat as for habitats of greater complexity and faunal diversity. (Only species-level determinations of current samples could resolve this issue.) In addition, differences in exposure of invertebrates in sand vs rootmat habitat may account for differences in responses. Thus, rootmat is more exposed to the water column and current velocities than the sand-bed where laminar flow conditions prevail. As a consequence, it is possible that rootmat communities are more directly exposed to the abrasive effects of suspended solids than sand communities.

Magnitude of impacts downstream

The impact observed on the rootmat macroinvertebrate communities was most evident as reduced macroinvertebrate abundance, with the reduction in chironomid (non-biting midge) abundance being the most marked change in community structure. (Whilst it is possible that exposure to enhanced concentrations of suspended solids resulted in an overall reduction in abundance of macroinvertebrate taxa, this effect was most evident for chironomids given their high numerical abundances in the present study.)

Although no previous studies of suspended sediment have been reported relating directly to creek environments in the Wet-Dry tropics, numerous studies of the effects of suspended sediment in different environments have observed a reduction in macroinvertebrate abundance (Table 4.1) - eg as a result of clay discharges from a mine in New Zealand (Quinn *et al.* 1992) forestry in southern NSW (Richardson 1985) and for these and other causes reported in numerous northern-hemisphere studies (Newcombe & Macdonald 1991).

The observed downstream impacts on macroinvertebrate communities would be considered subtle as indicated by the fact that no significant changes occurred in taxa presence /absence, by the late onset of the impacts and by the relatively small degree of community change observed. However, these conclusions are pertinent only to family-level data and would probably differ had results been based upon species-level determinations. In studies from other regions, severe impacts resulting from suspended sediment on macroinvertebrate communities often involve disappearance of some taxa, marked reduction in abundance of some taxa, and increased abundance of other taxa which thrive in the high-sediment-load conditions.

In assessing the severity of the impact on macroinvertebrate communities downstream of the Jim Jim Creek road crossing, it could be postulated that the period of impact on Jim Jim Creek was perhaps sufficiently short and the suspended sediment levels sufficiently localised as to result in ecological effects of a minor nature. However, it is worth noting that chironomids are often considered to be relatively tolerant of increased sediment loads. The fact that in this study chironomids were adversely affected may be indicative of the general sensitivity of the macroinvertebrate community as a whole, ie the disturbance, being sufficient to impact on chironomids, was in fact quite large.

Table 4.1. Summary of observations reported by selected studies on the effects of suspended sediment on stream macroinvertebrate communities.

Location	Nature of Disturbance	Observed Impact on Invertebrates	Reference
Australia (SE N.S.W)	Elevated turbidity and sedimentation resulting from forestry activities	Reduced abundances of selected taxa; increased invertebrate drift.	Richardson (1985)
Australia (VIC.)	Elevated suspended sediment plus sedimentation associated with dam construction	Reduced abundances of a range of species.	Chessman *et al* (1987); Doeg *et al* (1987)
Australia (SW W.A)	Suspended inorganic solids (averaging up to 60mg/L, background 5-20mg/L), associated with forestry.	Mean species richness decreased, mean total taxa abundance decreased.	Growns & Davis (1994)
?	20 fold increase in suspended sediment, no appreciable sediment deposition.	Densities of some taxa decreased (including chironomids); some increased (eg oligochates), others unchanged.	Gray & Ward (1982)
Australia (A.C.T)	Elevated suspended solids (up to 560mg/L) following storms, resulting from urban development.	Reduced species richness and macroinvertebrate density.	Hogg & Norris (1991)
New Zealand	Turbidity increases by 7-154 NTU (background of .13 - 8.2 NTU) due to mining activities	Reduced invertebrate densities downstream (by 9-45%).	Quinn (1992)
USA	Elevated suspended sediment, sedimentation identified associated with road construction.	Reduced species richness, abundance and biomass of filter feeding taxa.	Lemly (1982)
USA	Pulses of suspended solids (70-500mg/L) with road construction activities.	Reduced density, abundance and diversity of macroinvertebrate the community.	Cline *et al* (1982)
USA	Short term elevation of suspended solids (up to 1390mg/L); background levels <5mg/L.	Altered species composition, no change in total abundance .	Barton (1977)

4.3 Fish

The fish study showed that there were natural differences between the streams in their fish communities and that there were natural seasonal changes in fish community structure over the Dry season. This situation indicated the importance of including a control stream to provide an adequate background against which to evaluate the changes observed in Jim Jim Creek.

4.3.1 Natural seasonal changes

In such a highly seasonal environment as the Wet-Dry tropics, marked seasonal changes in the community structure of fish (and other biota) are to be expected. Seasonal changes in fish communities in some other creeks in Kakadu National Park have been documented by Bishop et al. (1990). In their study of main-channel escarpment waterbodies of Magela and Nourlangie Creeks, although there was little change in the number of species present, there was a large change in community structure with the greatest change occurring between the mid Wet and the early Dry seasons; the late Dry season community was intermediate between these two structures. Consequently, the large temporal changes represented by the position of the different sites on Jim Jim and Twin Falls creeks in the ordination space in the present study are not unexpected. A potential problem of this for the present study lay in the possibility that such large natural (seasonal) changes in the fish community could mask any effects of the increase in turbidity in Jim Jim Creek, which coincided with the interval between samples (most of the Dry season).

4.3.2 Natural differences among sites

Natural changes in the composition of biota along the length of river systems in response to changes in stream gradient is recorded in many studies around the world. However, Bishop *et al.* (1990) found no evidence for such longitudinal changes from the upstream edge of the floodplain zone to the edge of the escarpment. They did, however, find a relationship between the size of waterbodies and species richness. Thus, although in the present study it was attempted to make all sites as similar as possible, differences in local factors such as pool dimensions could have contributed to the natural differences in the fish community structure between sites in the same stream.

The multivariate analysis using untransformed data, which emphasizes fish abundance, showed that in both streams the downstream sites changed much more than the upstream sites. It suggested that another factor also affecting fish in this section of the catchment might be differences in flow conditions resulting from the retreat of the visible flow back upstream during the late Dry season. Sites further downstream can be exposed to lower, or even zero, discharge for longer periods than sites upstream. At very low flow rates, the amount of available habitat, especially shallow sandy areas, decreases and this could easily influence total population size in pools of some species. *Craterocephalus marianae*, being a sand feeding specialist, could be particulary at risk from this drawdown effect.

This difference in pattern of fish communities between upstream and downstream sites was not the case with the transformed data which places less emphasis on fish abundance.

4.3.3 Differences between streams

There were clear differences in the fish assemblages of the two streams with 7 of the 27 recorded species occurring in only one of the two streams and other species being present at

quite different levels of abundance. Whilst the absence of some species may be an artefact of insufficient sampling effort at the sample site, it does at least indicate a difference between streams in the abundance of those species. Such differences among streams in the upper reaches of river systems appear to be common in this region. This can perhaps be highlighted by the occurrence in Ankarrakarkarmi Creek, a nearby tributary of Jim Jim Creek that enters Jim Jim Ck just upstream of the upstream sampling site, of two other fish species not recorded in either Twin Falls or Jim Jim creeks, the coal grunter (*Hephaestus carbo*) and the banded rainbowfish (*Melanotaenia trifasciata*) (Bishop KA, pers comm.).

It is not surprising then that in the multivariate analysis of fish community structure, the samples from each stream clustered in separate halves of the ordination space in both ordination procedures. This result should probably be seen as a natural difference rather than the result of many years of disturbance from the road crossing.

4.3.4 Historic changes

The only previous data on fish community structure for these streams was for Twin Falls Creek in the main waterbody downstream of the plunge pool of the falls. This was collected in December 1979 by Bishop et al. (1990; table 2.). They recorded 19 species of which two, boney bream (*Nematalosa. erebi*) and archerfish (*Toxotes chatareus*), were not recorded in Twin Falls Creek in the present study but were commonly recorded in Jim Jim Creek. Conversely, the 23 species recorded for Twin Falls Creek in the present study included 7 additional species to the 1979 tally.

Also recorded by Bishop et al. (1990) were both subspecies of *Melanotaenia splendida*, red-tailed rainbowfish (*M. s. australis*) and the chequered rainbowfish (*M .s. inornata*), with *M. s. australis* being the most abundant form. Only *M. s. inornata* was recorded in the present study. As the colour pattern of *M. s. australis* is extremely variable it is possible that this was a misidentification. On the other hand it is also possible that *M. s. australis* has declined at these sites since that time. This situation needs clarification. *M. s. australis* is the dominant subspecies in the upper South Alligator River system.

Comparison of these data suggests that, apart from the possible change in rainbowfish, there have been no major changes in the Twin Falls Creek fish fauna over the last 17 years. It is unfortunate there are no similar data for Jim Jim Creek.

4.3.5 Effects of road crossing traffic on fish community structure

There were major changes in the abundance of some fish species downstream of the road crossing on Jim Jim Creek after the opening of the road crossing to general traffic. Whilst these changes may have been effects of turbidity arising from the Jim Jim Creek road crossing, there is the possibility that they may have been natural events related to seasonal effects. In deciding if the changes were caused by increased suspended solids it is necessary to compare the pattern of change in the 'disturbed' Jim Jim Creek with the change in the 'undisturbed' Twin Falls Creek.

In the absense of any effects of disturbance, it would be expected that the pattern of change would be similar in both streams. However, both the changes in the most abundant species, *C. marianae*, and the multivariate analysis of community structure indicated that this clearly was not the case. This was evidenced by the following:

- Numbers of *C. marianae* declined dramatically downstream of the road crossing whereas they increased at all other sites;
- The fish community structure, as measured by the Bray-Curtis multivariate dissimilarity measure, showed a much larger increase in the paired (upstream-downstream) site comparison in Jim Jim Creek than in Twin Falls Creek; and
- In the ordination patterns, the Twin Falls sites both moved in the same direction while in Jim Jim Creek the two sites moved in different directions.

With such differences between the two streams, it is concluded that there was an unnatural change in the fish community of JimJim Creek as a result of the increase in suspended solids from the road crossing. Such an inference would not have been possible if a control stream had not been a part of the experimental design. However, because there was limited temporal and spatial replication of each treatment it is not possible to apply any statistical measure of confidence to these conclusions.

The only other reported study of effects of siltation from a road crossing on fish in Australia (Richardson 1985) inferred a decline of *Galaxias maculatus* by comparison of two streams, but there was no pre-disturbance data to confirm the effects.

4.3.6 Mechanisms for effects of turbidity on fish

Turbidity was significantly correlated with the ordination patterns of fish community structure and in both cases its influence was in the direction of change in the Jim Jim downstream site. This provided further support to the inference that changes in the fish community were related to the road crossing. However, the ordination analysis showed that a number of chemical parameters in the water were also significantly correlated with the ordination. The influence of most of these was in the same direction as the turbidity vector so it is likely that the disturbance also caused some increase in these parameters. With the exception of aluminium, the increased levels of these chemical parameters were well within ANZECC water quality guidelines and, therefore, unlikely to have been a direct cause of fish mortality. The natural concentrations of aluminium were at all times well above the guideline value for this metal. However, under the prevailing near-neutral pH of creek waters, most of the Al would be present in particulate, non-toxic form.

The mechanism by which the fish were affected by suspended solids is not clear. The study failed to show any effects, either adverse or beneficial, of the disturbance on the condition of two species of fish, *C. marianae* and *A. percoides*. Consequently it is concluded that, although the macroinvertebrate food supply of these fish was also affected by the road crossing, the changes in fish numbers were not caused by an inadequate food supply. This was also found in a study of effects of siltation in a New Zealand stream (Graynoth 1979) which showed that although the population size of the fish *Galaxias divergens* greatly declined and their diet was less diverse, the growth rate of the fish actually increased.

In general, other studies have shown that the most significant cause of declines in fish populations associated with elevated supended solids in streams is sediment deposition on eggs and the alevin stage of larval development (Campbell & Doeg 1989). In the present study it was only possible to evaluate this possibility for *C. marianae*, the most abundant species and the species most clearly affected by increased suspended solids. Length-frequency analysis of

C. marianae showed that recruitment did occur in the period between fish samples. If the early development of embryos and larvae had been impaired by increased sediment deposition downstream of the road crossing the proportion of very small fish in the sample would be expected to be lower at that site than at other sites. This was not the case and so there was no evidence that recruitment was impaired by the increased turbidity.

Conversely, the proportion of larger *C. marianae* downstream of the road crossing declined in comparison with the other sites. This indicated that these larger fish were the individuals affected by the turbidity. By what process the fish were affected is not clear. The decline in numbers could arise from either increased mortality or, more likely, through emigration to avoid the turbid conditions. Movement away from water that causes discomfort (avoidance) is the most obvious process. Avoidance to turbidity by fish has been demonstrated elsewhere (Bisson & Bilby 1982). A less direct avoidance process could result from changes in food supply affecting fish behaviour. Adult *C. marianae* feed mainly on invertebrates in the sand substrate which they extract by filtering from mouthfuls of sand (Macfarlane 1996). They do not appear to rely on vision, which would be impaired by increased turbidity, to obtain their food. Nevertheless, the possibility that qualitative and quantitative changes in those invertebrates could have stimulated the fish to move elsewhere in search of preferred food types cannot be dismissed.

4.3.7 Ecological significance of fish community changes

The annual prolonged flooding of Top End streams scours the stream bed and would remove the fine sediments from the road crossing deposited in Jim Jim Creek during the Dry season. The rejuvenating effect of this process on the stream means that more severe and longer term effects on the fish and invertebrates than those observed in this study are unlikely to occur. However, much longer-term monitoring would be necessary to confirm this.

The permanent waters of the upper reaches of these streams are important refuge sites for fish in the Dry season. The observed reduction in fish numbers must have some adverse effects on the productivity of the Jim Jim Creek system. However, it is not possible to evaluate the scale of such an effect. The steady decline in suspended solids observed between the two downstream sites on Jim Jim Creek suggest that adverse effects on the biota would be unlikely for more than 2 km downstream of the road crossing. An indication of the scale of the impact could be gauged by knowing what proportion of the total permanent water present at the end of the Dry season this affected area constituted. Unfortunately that information is currently lacking.

The fish species most severely affected by the road crossing was *C. marianae*. This species also has a highly restricted distribution, occuring only in the rivers of west Arnhemland, from the South Alligator river east to the Mann River (Larson & Martin 1990). As such it is of high conservation significance for Kakadu National Park which contains much of its known range. For this reason alone it would be appropriate for the park management to consider means of reducing the impact of the road.

5 Recommendations

5.1 Thresholds of effects

The delayed macroinvertebrate response relative to turbidity /suspended solids concentrations, as well as the changing levels of exposure throughout the season, make it difficult to determine a threshold of suspended solids which induced biological effects. It can be concluded, however, that the levels experienced 200 m downstream (peaking at an average of 60 NTU) did result in quantifiable biological changes, whilst the levels experienced 1000 m downstream (peaking at 30 NTU) did not result in strongly evident impacts upon macroinvertebrate communities. Thus a threshold of effects on the macroinvertebrate community lies in the gradient between the levels of suspended sediment occurring at these two sites. Despite the apparently mild effects on macroinvertebrates communities 1000 m downstream, a value averaging 30 NTU should be considered undesirable in view of the very low natural levels of turbidity that would normally be characteristic of this waterway.

The delayed macroinvertebrate response relative to turbidity /suspended solids concentrations, as well as the changing levels of exposure throughout the season, make it difficult to determine a threshold of suspended solids which induced biological effects. It can be concluded, however, that the levels experienced 200 m downstream (peaking at an average of 60 NTU) did result in quantifiable biological changes, whilst the levels experienced 1000 m downstream (peaking at 30 NTU) resulted in only marginal changes to macroinvertebrate communities. Despite the apparently mild effects on macroinvertebrate communities at the Jim Jim Ck site located 1000 m downstream, it is suggested that levels of suspended sediment occurring at this site - 30 NTU or 8 mg/L suspended solids - be regarded as the threshold of effects on the macroinvertebrate communities.

5.2 Alleviation of effects

Given the detection of impacts on biota downstream of the road crossing and the conservation values of the region, it is recommended that steps be taken to alleviate the suspended sediment problem arising from the Jim Jim Creek road crossing. An engineered structure would be preferable to limited crossing usage because even with the latter case, once the clay bed has been exposed, very few vehicles would be required to cause downstream turbidity.

Subsequent monitoring may be undertaken by collection of water samples for measurement of nephelometric turbidity. Turbidity above 5 NTU for any prolonged period would be considered undesirable, with levels of 60 NTU and upwards assumed to be having an adverse effect on the biota of the creek. Levels of 30 NTU or less, although undesirable, may not represent biologically detectable changes. It should be considered that any marked reduction in water clarity downstream represents significant increases in turbidity and may be cause for concern, particularly in efforts to conserve the Jim Jim Creek environment, both biologically and aesthetically.

The present crossing, by way of its depth and substrate is a limitation to the accessibility of Twin Falls. Consequently, in the design of any road crossing on Jim Jim Creek consideration should be given to the likelihood that an improvement in accessibility would result in greater visitation of Twin Falls and an increase in associated impacts on that area.

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APPENDIX A

Macroinvertebrate community structure at sampling sites during the study

SAND

SITE/SAMP. OCCASION	JJ1/1			JJ2/1			JJ3/1			TF1/1			TF2/1		
DATE	25	April	96	25	April	96	25	April	96	1	May	96	1	May	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1306	1307	1308	1315	1316	1317	1324	1325	1326	1352	1353	1354	1358	1359	1360
ACARINA (INDET) (X)	4	7	7	1	0	0	0	2	2	35	78	12	15	29	16
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	2	2	3	4	0	0	0	0	0	2	7	7	1	15	4
CAENIDAE (N)	1	1	1	3	2	0	0	6	14	19	64	25	14	19	28
CERATOPOGONIDAE (L)	1	2	0	27	28	2	0	4	3	10	43	32	18	45	22
CHIRONOMIDAE (L)	12	32	27	21	8	16	12	32	35	60	95	93	28	20	44
CHIRONOMIDAE (P)	0	0	0	2	1	0	0	0	0	4	8	0	0	4	4
COENAGRIONIDAE (L)	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	0	6	0	4	0	0	0	0	1	1	0	2	14	16	22
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
ELMIDAE (L)	2	4	2	1	0	0	0	4	3	1	1	0	0	0	2
ELMIDAE (A)	1	7	4	0	0	0	0	2	4	13	11	9	0	0	0
GOMPHIDAE (L)	0	0	0	0	0	0	0	0	0	5	2	0	2	0	2
HYDROPTILIDAE (L)	1	1	2	1	0	0	0	0	0	3	2	4	2	0	0
LEPTOCERIDAE (L)	1	0	2	0	0	0	0	2	1	1	2	2	0	1	2
OLIGOCHAETE (X)	0	7	0	0	0	11	0	0	0	11	7	4	0	4	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
PYRALIDAE (L)	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
SIMULIDAE (L)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	2	0	0	1	2
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEBRIDAE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SAND

SITE/SAMP. OCCASION	JJ1/2			JJ2/2			JJ3/2			TF1/2			TF2/2		
DATE	8	May	96	8	May	96	8	May	96	15	May	96	15	May	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1407	1408	1409	1416	1417	1418	1425	1426	1427	1705	1706	1707	1714	1715	1716
ACARINA (INDET) (X)	12	4	12	12	16	8	8	10	8	104	136	72	48	28	8
ANISOPTERA (INDET) (L)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	4	0	42	22	18	32	18	8	14	0	0	0	4	0	0
CAENIDAE (N)	12	0	4	0	0	0	4	0	4	4	8	0	12	0	32
CERATOPOGONIDAE (L)	0	0	2	6	4	4	22	6	18	12	8	0	28	16	8
CHIRONOMIDAE (L)	156	76	178	262	188	228	336	218	242	88	88	328	352	140	332
CHIRONOMIDAE (P)	0	0	2	0	0	0	4	0	4	0	0	0	8	4	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	0	2	2	0	6	2	2	0	2	24	24	24	16	12	32
ELMIDAE (L)	34	8	18	4	6	0	6	4	8	12	8	8	0	0	40
ELMIDAE (A)	8	0	0	4	0	0	2	0	0	60	40	0	0	0	0
GOMPHIDAE (L)	6	0	0	0	2	2	0	2	2	0	0	0	4	8	4
HYDROPTILIDAE (L)	4	0	6	0	2	0	0	0	0	0	0	0	0	0	0
LEPTOCERIDAE (L)	4	0	2	2	2	0	0	2	0	4	0	0	0	0	0
OLIGOCHAETE (X)	0	2	0	0	0	0	2	2	2	0	0	0	0	4	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIMULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SAND

SITE/SAMP. OCCASION	JJ1/3			JJ2/3			JJ3/3			TF1/3			TF2/3		
DATE	31	May	96	31	May	96	31	May	96	7	June	96	7	June	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1819	1820	1821	1825	1826	1827	1834	1835	1836	2072	2073	2074	2078	2079	2080
ACARINA (INDET) (X)	52	56	56	76	128	11	40	52	128	44	52	32	20	28	44
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	48	32	0	44	72	0	96	84	4	18	0	4	12	0	8
CAENIDAE (N)	0	8	24	12	12	1	64	48	8	16	8	4	52	52	40
CERATOPOGONIDAE (L)	44	60	0	48	36	9	8	28	48	8	0	0	32	36	20
CHIRONOMIDAE (L)	304	284	2112	516	360	127	552	296	432	560	108	96	352	232	308
CHIRONOMIDAE (P)	4	0	0	12	0	2	0	16	4	12	0	0	0	4	0
COENAGRIONIDAE (L)	4	0	0	0	0	0	0	4	0	0	0	0	0	0	0
CORIXIDAE (N)	0	4	128	32	0	0	0	0	8	2	0	0	16	4	4
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (A)	8	0	0	0	0	0	8	4	0	0	0	0	0	0	0
ECNOMIDAE (L)	32	32	8	40	44	5	56	48	0	24	28	12	24	0	8
ELMIDAE (L)	8	12	24	20	8	4	0	8	0	6	16	0	12	0	0
ELMIDAE (A)	0	8	16	4	8	0	16	12	0	0	12	16	0	0	0
GOMPHIDAE (L)	0	12	8	0	4	0	24	0	0	2	0	0	0	0	0
HYDROPTILIDAE (L)	12	8	32	8	12	0	48	8	4	0	0	4	0	0	0
LEPTOCERIDAE (L)	36	44	16	24	28	7	32	24	24	4	0	0	0	8	4
OLIGOCHAETE (X)	12	4	0	8	0	0	8	4	0	0	0	12	16	0	8
PALAEMONIDAE (X)	0	4	0	0	4	0	0	4	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
SIMULIDAE (L)	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
TABANIDAE (L)	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SAND

SITE/SAMP. OCCASION	JJ1/4			JJ2/4			JJ3/4			TF1/4			TF2/4		
DATE	7	July	96	7	July	96	7	July	96	7	July	96	7	July	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2166	2167	2168	2172	2173	2174	2178	2179	2180	2184	2185	2186	2190	2191	2192
ACARINA (INDET) (X)	28	96	20	80	80	68	88	26	56	16	40	64	56	32	56
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	2	0	0	0	0	8
BAETIDAE (N)	20	96	0	8	32	8	0	4	8	6	36	56	48	32	72
CAENIDAE (N)	0	0	4	48	56	32	8	34	24	46	32	216	64	88	144
CERATOPOGONIDAE (L)	12	48	8	72	16	52	48	26	16	16	4	32	16	32	8
CHIRONOMIDAE (L)	244	196	38	736	568	472	1056	368	500	222	364	800	872	696	1336
CHIRONOMIDAE (P)	0	0	0	0	8	4	24	6	0	0	0	16	0	0	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	0	0	0	0	0	0	8	0	0	16	0	32	8	24	0
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	8	0	12	0	8	0	0	0	0
DYTISCIDAE (L)	4	8	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	16	16	0	0	32	20	0	2	4	6	32	32	48	0	24
ELMIDAE (L)	84	48	55	160	184	92	200	10	72	14	48	16	112	24	24
ELMIDAE (A)	28	0	15	8	24	44	0	4	0	0	0	0	0	0	0
GOMPHIDAE (L)	0	0	1	8	0	4	0	0	0	0	8	0	8	0	0
HYDROPTILIDAE (L)	4	8	0	0	0	0	0	0	0	0	0	0	8	0	8
LEPTOCERIDAE (L)	4	4	0	16	8	20	24	10	0	0	0	0	16	8	8
OLIGOCHAETE (X)	0	0	0	8	0	0	0	0	0	6	0	8	0	16	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
SIMULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SAND

SITE/SAMP. OCCASION	JJ1/5			JJ2/5			JJ3/5			TF1/5			TF2/5		
DATE	25	July	96	25	July	96	25	July	96	25	July	96	25	July	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2254	2255	2256	2260	2261	2262	2266	2267	2268	2272	2273	2274	2278	2279	2280
ACARINA (INDET) (X)	152	88	64	152	24	24	28	168	152	104	48	32	48	24	24
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	48	24	24	0	8	20	36	0	0	8	8	8	0	16	32
CAENIDAE (N)	0	4	24	0	16	8	4	0	0	40	56	24	0	20	12
CERATOPOGONIDAE (L)	88	88	24	88	40	72	68	24	0	24	32	8	4	40	28
CHIRONOMIDAE (L)	648	1336	896	808	304	892	1456	704	864	528	836	264	424	484	732
CHIRONOMIDAE (P)	0	28	32	16	0	16	0	16	8	8	8	0	8	12	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	16	0	0	0	0	0	8	0	8	0	8	0	4	4	4
CULICIDAE (L)	0	0	24	0	8	0	0	0	16	16	8	0	0	4	0
CULICIDAE (P)	16	0	0	0	0	0	0	0	0	0	0	8	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	12	0	0	0	8	0	0	0	0
DYTISCIDAE (A)	0	4	0	0	0	0	4	0	0	0	8	0	0	0	0
ECNOMIDAE (L)	0	44	56	24	0	52	76	32	8	16	32	24	20	16	0
ELMIDAE (L)	336	484	160	208	496	48	184	344	504	376	92	184	120	12	92
ELMIDAE (A)	16	60	0	8	0	0	0	8	0	24	36	48	0	0	0
GOMPHIDAE (L)	16	4	8	0	0	0	0	8	0	0	16	0	0	0	0
HYDROPTILIDAE (L)	16	4	0	0	8	0	12	0	0	0	12	0	0	8	0
LEPTOCERIDAE (L)	8	4	0	24	8	12	36	0	8	0	28	16	0	0	8
OLIGOCHAETE (X)	0	20	16	16	0	0	0	24	0	0	0	0	4	8	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
SIMULIDAE (L)	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	8	0	0	0	4	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

SAND

SITE/SAMP. OCCASION	TF1/6			TF2/6			JJ1/6			JJ2/6			JJ3/6		
DATE	21	Aug	96	21	Aug	96	21	Aug	96	21	Aug	96	21	Aug	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2342	2343	2344	2348	2349	2350	2354	2355	2356	2360	2361	2362	2366	2367	2368
ACARINA (INDET) (X)	48	48	72	72	32	48	48	56	64	16	24	8	72	16	88
ANISOPTERA (INDET) (L)	0	0	0	0	0	8	0	0	0	8	0	0	0	0	0
BAETIDAE (N)	8	16	16	16	8	8	16	0	8	40	8	8	16	0	0
CAENIDAE (N)	16	8	32	16	32	16	8	8	24	32	56	24	40	0	8
CERATOPOGONIDAE (L)	16	24	8	32	16	0	24	72	32	16	16	24	40	8	24
CHIRONOMIDAE (L)	696	976	560	928	704	1264	688	1168	904	976	880	752	1088	400	424
CHIRONOMIDAE (P)	8	16	8	16	16	0	0	0	0	32	0	0	8	8	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	8	8	0	16	0	0	16	0	0	0	0	8	8	0	0
CULICIDAE (L)	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0
CULICIDAE (P)	8	8	0	8	8	0	0	8	0	24	8	8	16	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
ECNOMIDAE (L)	32	64	16	0	32	64	40	48	56	8	40	24	0	16	0
ELMIDAE (L)	608	928	584	1016	536	984	696	712	552	472	864	624	344	224	264
ELMIDAE (A)	0	0	32	48	0	0	0	16	0	0	8	0	8	0	8
GOMPHIDAE (L)	0	0	0	0	8	0	8	0	0	0	0	0	8	0	0
HYDROPTILIDAE (L)	0	0	0	0	0	8	0	0	24	0	0	0	0	0	0
LEPTOCERIDAE (L)	0	8	0	24	0	24	0	24	48	16	16	0	16	8	8
OLIGOCHAETE (X)	0	0	0	0	0	0	0	0	0	16	8	0	0	0	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIMULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SAND

SITE/SAMP. OCCASION	JJ1/7			JJ2/7			JJ3/7			TF1/7			TF2/7		
DATE	18	Sept	96	18	Sept	96	18	Sept	96	18	Sept	96	18	Sept	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2458	2459	2460	2464	2465	2466	2469	2470	2471	2475	2476	2477	2481	2482	2483
ACARINA (INDET) (X)	72	56	48	48	16	8	48	152	144	48	88	256	176	72	72
ANISOPTERA (INDET) (L)	8	0	0	0	0	0	0	0	0	0	0	0	8	0	0
BAETIDAE (N)	24	0	24	0	16	16	8	32	0	0	8	16	16	8	8
CAENIDAE (N)	24	24	24	0	0	8	16	32	0	16	16	0	16	24	16
CERATOPOGONIDAE (L)	24	64	72	56	112	88	32	56	96	24	48	64	16	56	64
CHIRONOMIDAE (L)	672	1072	840	768	624	520	1344	1296	1248	544	696	688	1232	584	864
CHIRONOMIDAE (P)	8	24	16	16	0	0	0	24	32	8	0	16	16	8	8
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	24	16	8	0	0	0	0	0	16	8	0	0	8	8	16
CULICIDAE (L)	0	24	0	0	0	0	0	0	0	0	0	0	0	8	0
CULICIDAE (P)	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	40	48	32	0	0	24	56	88	112	16	0	32	24	32	48
ELMIDAE (L)	688	936	1136	320	368	504	624	1200	464	1048	880	2256	776	760	968
ELMIDAE (A)	8	32	48	0	0	0	24	0	0	32	48	0	8	0	48
GOMPHIDAE (L)	0	0	0	0	16	8	0	8	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	8	0	0	0	32	8	0	0	176	0	0	0	0	0	0
LEPTOCERIDAE (L)	16	8	0	24	16	0	0	0	48	0	16	16	0	0	0
OLIGOCHAETE (X)	0	0	8	8	0	0	0	0	0	0	0	0	0	0	16
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHILOPOTAMIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIMULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEBRIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPHILIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCIRTIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/1			JJ2/1			JJ3/1			TF1/1			TF2/1		
DATE	25	April	96	25	April	96	25	April	96	1	May	96	1	May	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1309	1310	1311	1318	1319	1320	1326	1327	1328	1349	1350	1351	1361	1362	1363
ACARINA (INDET) (X)	30	28	16	6	6	8	14	10	18	36	20	60	4	10	11
ANISOPTERA (INDET) (L)	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0
BAETIDAE (N)	12	6	0	5	1	0	8	8	8	28	44	24	3	2	6
CAENIDAE (N)	8	22	6	1	7	18	44	34	28	44	64	48	4	6	5
CERATOPOGONIDAE (L)	2	2	4	15	19	0	14	12	12	0	4	20	8	16	3
CHIRONOMIDAE (L)	132	48	156	113	293	308	132	136	118	424	104	372	68	156	108
CHIRONOMIDAE (P)	6	2	0	2	5	0	6	0	0	4	16	4	3	0	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
CORIXIDAE (N)	0	0	0	1	1	4	0	0	0	0	0	4	2	2	0
CULICIDAE (L)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	4	0	12	0	0	0
DYTISCIDAE (A)	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
ECNOMIDAE (L)	2	0	0	0	2	0	0	2	0	8	8	0	0	0	0
ELMIDAE (L)	2	4	4	2	0	2	0	0	0	0	0	0	0	0	3
ELMIDAE (A)	4	70	28	2	0	0	6	8	2	8	0	16	4	6	0
GOMPHIDAE (L)	4	2	2	2	8	6	10	4	6	0	16	12	6	0	0
HYDROPSYCHIDAE (L)	0	12	0	1	0	2	4	0	0	4	12	0	0	0	0
HYDROPTILIDAE (L)	2	2	4	2	1	4	2	4	0	12	8	8	2	6	1
LEPTOCERIDAE (L)	10	14	4	1	18	22	20	42	16	12	0	12	6	2	2
LEPTOPHLEBIIDAE (N)	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	8	6	2	7	2	0	2	8	2	0	4	0	0	0	0
PALAEMONIDAE (X)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROTONEURIDAE (L)	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0
PYRALIDAE (L)	2	2	4	0	0	0	4	2	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/2			JJ2/2			JJ3/2			TF1/2			TF2/2		
DATE	8	May	96	8	May	96	8	May	96	15	May	96	15	May	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1410	1411	1412	1419	1420	1421	1428	1429	1430	1702	1703	1704	1711	1712	1713
ACARINA (INDET) (X)	16	20	14	34	24	36	18	38	28	40	64	80	24	20	64
ANISOPTERA (INDET) (L)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	4	16	6	8	6	2	14	22	22	40	8	32	24	24	24
CAENIDAE (N)	6	2	0	4	8	2	18	12	0	32	8	240	32	0	24
CERATOPOGONIDAE (L)	22	22	24	16	16	22	12	18	14	0	8	16	16	0	8
CHIRONOMIDAE (L)	142	108	160	138	134	182	422	286	216	160	128	152	288	120	168
CHIRONOMIDAE (P)	0	4	0	0	0	0	0	0	2	8	0	0	16	0	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	0	0	0	0	0	0	8	2	2	0	0	0	32	0	0
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (A)	0	4	0	2	2	2	0	0	4	0	0	0	0	0	0
ECNOMIDAE (L)	16	16	18	2	6	6	8	10	22	0	0	0	0	8	56
ELMIDAE (L)	0	0	0	0	0	2	4	0	6	8	0	0	0	4	8
ELMIDAE (A)	2	0	0	0	0	4	2	8	0	8	16	24	0	0	16
GOMPHIDAE (L)	0	0	0	0	2	0	2	0	0	0	0	24	0	0	0
HYDROPSYCHIDAE (L)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	2	4	6	4	4	2	0	8	6	0	0	0	0	0	8
LEPTOCERIDAE (L)	8	6	6	2	4	2	6	12	0	16	24	48	0	0	0
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	0	4	0	0	0	0	2	0	2	0	0	8	0	0	0
PALAEMONIDAE (X)	4	2	4	0	4	0	2	2	2	0	0	8	0	0	0
PROTONEURIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/3			JJ2/3			JJ3/3			TF1/3			TF2/3		
DATE	31	May	96	31	May	96	31	May	96	7	June	96	7	June	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	1819	1820	1821	1828	1829	1830	1834	1835	1836	2075	2076	2077	2081	2082	2083
ACARINA (INDET) (X)	40	48	24	36	56	72	32	30	132	12	24	16	16	28	44
ANISOPTERA (INDET) (L)	0	0	0	0	8	0	0	0	0	0	4	0	0	0	0
BAETIDAE (N)	28	200	16	28	0	0	52	4	0	16	156	12	36	16	8
CAENIDAE (N)	12	24	8	16	16	24	8	6	48	44	108	32	12	0	268
CERATOPOGONIDAE (L)	56	48	24	44	80	120	8	42	44	12	24	4	16	16	16
CHIRONOMIDAE (L)	368	720	3152	316	648	896	352	308	472	248	224	116	336	272	648
CHIRONOMIDAE (P)	0	16	48	0	16	0	0	4	16	4	0	4	8	0	0
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
CORIXIDAE (N)	0	84	32	0	0	0	0	0	12	0	0	0	0	0	16
CULICIDAE (L)	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
CULICIDAE (P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
DYTISCIDAE (A)	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	24	8	8	28	56	40	16	4	12	24	64	32	28	32	28
ELMIDAE (L)	8	64	72	0	48	16	0	0	0	0	0	0	0	0	12
ELMIDAE (A)	0	12	0	4	56	24	4	6	24	16	8	8	4	0	0
GOMPHIDAE (L)	4	0	16	0	8	16	0	4	0	0	0	4	0	0	4
HYDROPSYCHIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	4	28	8	0	0	0	12	0	12	0	0	4	0	0	8
LEPTOCERIDAE (L)	12	8	0	8	72	64	16	4	48	8	8	0	12	12	0
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
OLIGOCHAETE (X)	0	16	0	8	0	0	4	10	0	4	0	0	8	0	8
PALAEMONIDAE (X)	0	0	0	4	0	0	0	0	0	0	4	0	4	0	0
PROTONEURIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	8	0	4	0	0	0	0	0	0	0	0	0	0	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/4			JJ2/4			JJ3/4			TF1/4			TF2/4		
DATE	7	July	96	7	July	96	7	July	96	7	July	96	7	July	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2169	2170	2171	2175	2176	2177	2181	2182	2183	2187	2188	2189	2193	2194	2195
ACARINA (INDET) (X)	96	136	40	40	40	48	96	88	32	48	64	120	128	88	48
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
BAETIDAE (N)	72	56	72	72	104	144	328	360	104	224	224	360	216	280	152
CAENIDAE (N)	32	24	64	32	32	112	160	128	88	248	168	256	280	112	264
CERATOPOGONIDAE (L)	240	64	112	56	64	80	40	72	24	24	104	0	0	72	0
CHIRONOMIDAE (L)	656	400	528	688	568	432	784	680	464	856	1392	1208	1096	856	1736
CHIRONOMIDAE (P)	0	8	0	8	0	0	8	40	16	16	16	32	0	0	0
COENAGRIONIDAE (L)	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORIXIDAE (N)	0	8	0	0	0	0	0	0	8	0	8	48	16	0	0
CULICIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
CULICIDAE (P)	0	8	0	0	0	0	0	0	0	0	8	0	8	0	0
DYTISCIDAE (L)	8	0	0	0	0	0	0	0	0	0	0	0	16	0	0
DYTISCIDAE (A)	0	0	8	0	0	8	0	0	0	8	0	0	0	0	0
ECNOMIDAE (L)	40	32	40	8	0	8	16	24	24	72	80	48	48	32	72
ELMIDAE (L)	56	24	24	0	0	0	8	0	0	0	0	0	0	0	8
ELMIDAE (A)	56	24	24	0	8	0	0	0	8	0	0	0	0	24	24
GOMPHIDAE (L)	0	16	0	0	0	0	8	8	0	0	0	0	0	0	0
HYDROPSYCHIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	0	8	8	0	0	8	0	0	0	24	16	8	0	16	0
LEPTOCERIDAE (L)	0	8	8	0	16	8	0	0	0	56	48	56	0	24	24
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	8	0	16	24	0	0	0	0	0	0	0	0	0	0	0
PALAEMONIDAE (X)	0	8	0	0	0	0	8	0	0	0	0	8	8	0	0
PROTONEURIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	8	0	0	0	0	0	0	0	8	0	0	0	0	0	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/5			JJ2/5			JJ3/5			TF1/5			TF2/5		
DATE	25	July	96	25	July	96	25	July	96	25	July	96	25	July	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2257	2258	2259	2263	2264	2265	2269	2270	2271	2275	2276	2277	2281	2282	2283
ACARINA (INDET) (X)	96	76	96	248	188	48	104	48	88	56	144	96	80	44	48
ANISOPTERA (INDET) (L)	0	0	0	0	12	0	0	0	0	0	0	0	0	0	8
BAETIDAE (N)	80	28	16	32	24	24	120	248	72	88	128	56	112	72	16
CAENIDAE (N)	16	16	16	128	40	32	272	152	208	24	168	176	248	16	48
CERATOPOGONIDAE (L)	56	40	24	40	96	64	136	168	48	40	16	32	16	72	24
CHIRONOMIDAE (L)	348	348	400	336	584	412	712	864	904	728	680	1072	784	384	992
CHIRONOMIDAE (P)	0	0	8	0	0	16	24	8	8	0	8	16	8	4	8
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
CORIXIDAE (N)	8	0	0	0	0	20	24	0	24	16	24	8	16	12	0
CULICIDAE (L)	0	0	0	0	0	0	24	8	0	0	0	0	0	12	0
CULICIDAE (P)	0	0	8	0	0	0	0	0	0	0	0	8	0	0	0
DYTISCIDAE (L)	0	0	0	0	0	0	8	0	0	0	8	0	16	0	0
DYTISCIDAE (A)	0	0	8	16	0	0	8	0	0	0	0	0	0	0	0
ECNOMIDAE (L)	16	16	8	8	4	40	24	24	0	32	8	40	48	12	56
ELMIDAE (L)	32	8	40	0	8	4	0	96	0	48	64	8	0	24	0
ELMIDAE (A)	24	28	48	16	4	8	0	8	0	8	0	8	0	0	0
GOMPHIDAE (L)	4	4	0	0	8	4	0	24	0	8	8	8	0	0	0
HYDROPSYCHIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	8	16	8	0	0	4	24	24	8	32	40	48	32	8	8
LEPTOCERIDAE (L)	12	28	8	64	56	16	0	16	16	16	32	56	32	24	24
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	0	0	8	0	0	4	0	8	0	0	0	0	0	0	8
PALAEMONIDAE (X)	0	4	0	24	8	4	8	8	0	0	8	8	0	0	8
PROTONEURIDAE (L)	0	0	0	8	0	4	0	0	0	0	0	8	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	8	12	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	4	0	0	0	8	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	4	0	0	12	16	0	8	0	0	0	16	0	0	8

ROOTMAT

SITE/SAMP. OCCASION	TF1/6			TF2/6			JJ1/6			JJ2/6			JJ3/6		
DATE	21	Aug	96	21	Aug	96	21	Aug	96	21	Aug	96	21	Aug	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2345	2346	2347	2351	2352	2353	2357	2358	2359	2363	2364	2365	2369	2370	2371
ACARINA (INDET) (X)	96	32	24	40	72	88	72	88	40	112	56	40	40	8	120
ANISOPTERA (INDET) (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAETIDAE (N)	208	168	296	64	88	120	32	64	40	48	40	8	80	8	248
CAENIDAE (N)	136	128	168	104	80	64	0	16	136	24	56	24	40	24	48
CERATOPOGONIDAE (L)	0	8	24	16	8	24	32	56	80	40	24	0	16	16	64
CHIRONOMIDAE (L)	656	776	608	456	632	688	528	392	1192	168	216	96	240	224	928
CHIRONOMIDAE (P)	0	16	40	0	0	24	0	0	8	0	16	0	0	0	8
COENAGRIONIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
CORIXIDAE (N)	8	8	16	0	16	16	0	16	0	152	48	32	0	0	8
CULICIDAE (L)	0	0	0	0	8	8	0	8	0	0	0	0	0	8	16
CULICIDAE (P)	0	0	0	8	8	0	0	0	0	0	0	0	0	0	8
DYTISCIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	8	16
DYTISCIDAE (A)	0	0	0	0	0	0	8	0	8	80	16	16	0	0	8
ECNOMIDAE (L)	8	8	48	16	8	16	0	0	32	8	8	8	16	32	16
ELMIDAE (L)	24	8	24	8	8	0	80	128	16	8	0	8	32	0	120
ELMIDAE (A)	8	16	8	8	16	8	32	8	8	24	0	0	8	16	0
GOMPHIDAE (L)	0	0	16	8	0	16	0	0	0	0	8	0	0	0	0
HYDROPSYCHIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	8	16	8	8	8	0	0	0	16	0	0	0	24	0	0
LEPTOCERIDAE (L)	8	0	0	8	24	8	8	8	32	56	16	24	16	8	8
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	0	8	8	0	0	0	0	8	0	0	0	8	0	0	0
PALAEMONIDAE (X)	8	0	16	8	0	0	0	0	0	16	0	8	0	0	0
PROTONEURIDAE (L)	0	0	0	0	0	0	0	16	0	0	0	8	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0

ROOTMAT

SITE/SAMP. OCCASION	JJ1/7			JJ2/7			JJ3/7			TF1/7			TF2/7		
DATE	18	Sept	96	18	Sept	96	18	Sept	96	18	Sept	96	18	Sept	96
REPLICATE NO.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ERISS SAMPLE NUMBER	2461	2462	2463	2466	2467	2468	2472	2473	2474	2478	2479	2480	2484	2485	2486
ACARINA (INDET) (X)	184	144	96	56	64	152	64	120	72	56	80	112	56	104	96
ANISOPTERA (INDET) (L)	0	0	8	0	0	0	0	0	0	0	0	8	0	0	0
BAETIDAE (N)	16	32	64	32	56	16	104	56	40	32	176	200	128	8	96
CAENIDAE (N)	32	16	32	8	16	24	24	40	32	0	16	144	112	88	144
CERATOPOGONIDAE (L)	24	96	48	16	24	24	112	120	72	24	24	96	16	64	16
CHIRONOMIDAE (L)	432	904	656	112	120	136	904	928	776	264	576	528	728	928	624
CHIRONOMIDAE (P)	0	16	0	8	0	24	0	24	40	0	8	40	8	24	0
COENAGRIONIDAE (L)	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CORDULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
CORIXIDAE (N)	0	0	0	40	80	144	8	24	0	16	32	16	8	0	16
CULICIDAE (L)	8	0	8	0	0	0	8	0	0	8	8	16	0	0	16
CULICIDAE (P)	8	0	0	8	0	0	0	0	0	0	0	0	0	0	0
DYTISCIDAE (L)	0	0	0	0	8	8	0	8	16	0	16	0	0	0	8
DYTISCIDAE (A)	0	0	0	88	0	0	0	8	8	0	16	40	16	0	0
ECNOMIDAE (L)	8	0	40	8	8	16	24	24	48	0	0	56	24	16	24
ELMIDAE (L)	88	40	56	0	8	0	32	80	48	104	88	8	0	0	16
ELMIDAE (A)	16	0	56	0	40	72	8	8	8	8	8	0	0	32	8
GOMPHIDAE (L)	0	24	8	16	0	8	0	0	0	0	0	16	0	0	8
HYDROPSYCHIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HYDROPTILIDAE (L)	8	32	16	0	8	8	16	16	16	8	16	8	24	16	8
LEPTOCERIDAE (L)	0	56	32	40	48	40	24	48	16	8	0	80	32	0	40
LEPTOPHLEBIIDAE (N)	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
LIBELLULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETE (X)	8	0	0	0	0	0	0	8	0	8	0	0	16	0	8
PALAEMONIDAE (X)	0	0	0	8	48	8	0	0	8	0	0	8	8	8	8
PROTONEURIDAE (L)	0	0	8	0	24	8	0	0	0	0	0	0	0	0	0
PYRALIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TABANIDAE (L)	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
TIPULIDAE (L)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA (INDET.) (L)	0	0	0	0	0	16	8	0	0	0	0	8	0	0	16

APPENDIX B

Fish community structure at sampling sites during the study

Table B1 Fish sampled at Jim Jim Creek upstream site on 29/05/96 & 30/05/96, before the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	25	*Gill-netting	74	6.930	93	12.670
			139	41.600	70	5.190
			110	23.700	76	6.790
			120	32.030	123	28.800
			137	42.680	140	47.500
			122	31.170	76	7.480
			134	38.240	108	21.830
			109	21.490	73	6.090
			92	12.780	89	11
			70	5.380	84	9.520
			88	10.360	99	14.730
			98	16.110	139	44.540
			82	9.060		
Anodontiglanis dahli	7	Gill-netting	365	nd	311	168
			350	nd	385	nd
			348	nd	463	nd
			424	nd		
Arius leptaspis	1	Gill-netting	330	nd		
Ambassis macleayi	7	Gill-netting	69	7	57	4
			73	9	59	5
			67	6	64	6
			68	7		
Leiopotherapon unicolor	1	Gill-netting	105	18		
Megalops cyprinoides	2	Gill-netting	202	98	312	400
Melanotaenia splendida inornata	1	Gill-netting	90	10		
	(40)	*Seine-netting	nd	nd	45	0.743
			32	0.273	45	0.880
			33	0.295	47	0.991
			33	0.343	52	1.298
			34	0.344	53	1.312
			34	0.358	54	1.295
			35	0.365	54	1.361
			35	0.388	54	1.422
			35	0.401	55	1.440
			36	0.387	55	1.471
			36	0.556	55	1.647
			37	0.497	55	1.848
			39	0.519	56	1.710
			39	0.528	56	1.796
			39	0.568	56	1.927

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B1 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. splendida inornata (cont.)			40	0.561	60	1.921
			40	0.534	57	1.610
			40	0.564	66	2.556
			40	0.574	74	4.275
			40	0.648	78	5.381
	48	Seine-netting	43	nd	38	nd
			38	nd	38	nd
			38	nd	38	nd
			38	nd	37	nd
			37	nd	37	nd
			37	nd	35	nd
			35	nd	50	nd
			50	nd	46	nd
			57	nd	57	nd
			41	nd	41	nd
			34	nd	41	nd
			39	nd	34	nd
			39	nd	39	nd
			31	nd	39	nd
			55	nd	31	nd
			79	nd	55	nd
			32	nd	79	nd
			46	nd	32	nd
			37	nd	46	nd
			38	nd	37	nd
			34	nd	38	nd
			30	nd	34	nd
			39	nd	30	nd
			42	nd	31	nd
Nematalosa erebi	10	Gill-netting	225	184	185	100
			197	98	195	102
			165	70	165	nd
			173	72	182	90
			210	nd	198	112
Pingalla midgleyi	4	Gill-netting	125	42	108	26
			100	20	72	7
Syncomistes butleri	7	Gill-netting	210	163	275	nd
			233	240	345	nd
			184	115	232	268
			144	50		
Scleropages jardini	1	Gill-netting	510	nd		
Strongylura kreffti	5	Gill-netting	400	116	340	66
			406	122	425	130

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B1 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
S. kreffti(cont.)			314	52		
Neosiluris ater	33	Gill-netting	330	nd	405	nd
			210	76	259	nd
			390	nd	325	nd
			268	nd	263	nd
			340	nd	328	nd
			325	300	295	nd
			340	nd	310	nd
			298	nd	280	nd
			355	nd	295	nd
			325	nd	235	nd
			265	nd	243	nd
			270	nd	275	nd
			290	nd	268	nd
			295	nd	217	nd
			370	nd	225	nd
			325	nd	178	38
			340	nd		
Craterocephalus marianae	189		58	nd	55	nd
			56	nd	57	nd
			52	nd	41	nd
			63	nd	34	nd
			58	nd	39	nd
			64	nd	40	nd
			45	nd	37	nd
			42	nd	55	nd
			34	nd	62	nd
			44	nd	40	nd
			39	nd	23	nd
			40	nd	43	nd
			37	nd	37	nd
			41	nd	54	nd
			39	nd	53	nd
			41	nd	49	nd
			35	nd	48	nd
			39	nd	58	nd
			34	nd	64	nd
			39	nd	49	nd
			34	nd	65	nd
			36	nd	46	nd
			34	nd	62	nd
			41	nd	45	nd
			44	nd	42	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B1 (cont.)

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			45	nd	39	nd
			37	nd	37	nd
			22	nd	37	nd
			60	nd	35	nd
			58	nd	32	nd
			54	nd	36	nd
			39	nd	34	nd
			40	nd	33	nd
			39	nd	35	nd
			40	nd	37	nd
			44	nd	38	nd
			47	nd	39	nd
			37	nd	37	nd
			37	nd	35	nd
			44	nd	39	nd
			38	nd	39	nd
			41	nd	37	nd
			38	nd	40	nd
			39	nd	42	nd
			43	nd	36	nd
			28	nd	42	nd
			40	nd	40	nd
			48	nd	41	nd
			40	nd	43	nd
			50	nd	37	nd
			55	nd	41	nd
			24	nd	38	nd
			37	nd	45	nd
			50	nd	38	nd
			34	nd	45	nd
			45	nd	37	nd
			47	nd	37	nd
			35	nd	35	nd
			43	nd	32	nd
			39	nd	36	nd
			39	nd	34	nd
			69	nd	33	nd
			40	nd	35	nd
			64	nd	37	nd
			36	nd	36	nd
			57	nd	33	nd
			35	nd	24	nd
			55	nd	37	nd
			36	nd	37	nd
			55	nd	38	nd
			39	nd	39	nd
			57	nd	37	nd
			49	nd	35	nd
			35	nd	39	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B1 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			55	nd	39	nd
			62	nd	37	nd
			40	nd	40	nd
			23	nd	42	nd
			43	nd	36	nd
			37	nd	42	nd
			54	nd	40	nd
			53	nd	41	nd
			49	nd	43	nd
			48	nd	37	nd
			58	nd	41	nd
			64	nd	42	nd
			49	nd	38	nd
			65	nd	45	nd
			62	nd	38	nd
			45	nd	43	nd
			42	nd	39	nd
			39	nd	38	nd
			37	nd	38	nd
			37	nd	37	nd
			41	nd		
C. marianae (cont.)	(58)	*Seine-netting	58	2.433	41	0.688
			70	4.598	45	0.896
			65	3.085	43	0.724
			58	2.283	40	0.593
			64	3.180	41	0.651
			59	2.178	40	0.673
			43	0.838	38	0.558
			53	1.662	40	0.682
			54	1.919	42	0.773
			49	1.200	35	0.471
			42	0.753	39	0.636
			46	1.020	36	0.493
			50	1.511	35	0.407
			46	0.995	38	0.500
			39	0.667	37	0.424
			36	0.456	37	0.468
			51	1.340	44	0.836
			37	0.580	37	0.520
			42	0.753	40	0.613
			38	0.575	41	0.665
			42	0.690	35	0.413
			44	0.833	34	0.438
			45	0.867	37	0.452
			43	0.729	34	0.386
			42	0.711	39	0.545
			41	0.650	25	0.161
			38	0.541	27	0.217
			38	0.775	21	0.096

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B1 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			35	0.418	35	0.422
Craterocephalus stercusmuscarum	45	*Seine-netting	20	0.042	25	0.130
			20	0.042	26	0.114
			20	0.045	27	0.122
			20	0.055	27	0.135
			20	0.056	27	0.156
			21	0.055	27	0.156
			21	0.068	28	0.164
			21	0.560	29	0.124
			22	0.074	29	0.145
			22	0.074	29	0.170
			23	0.053	29	0.203
			23	0.070	29	0.210
			23	0.078	31	0.247
			24	0.065	32	0.241
			24	0.070	33	0.218
			24	0.071	33	0.251
			24	0.094	33	0.256
			24	0.095	35	0.274
			24	0.102	35	0.300
			24	0.110	35	0.317
			25	0.096	39	0.464
			25	0.101	48	0.687
			25	0.114		
Glossogobius giuris	4	*Seine-netting	41	0.426	45	0.554
			42	0.468	46	0.495
Melanotaenia nigrans	34	*Seine-netting	22	0.097	29	0.167
			24	0.099	29	0.170
			24	0.109	29	0.172
			24	0.118	29	0.183
			25	0.104	29	0.184
			25	0.138	29	0.194
			25	0.139	30	0.192
			26	0.128	30	0.233
			26	0.128	30	0.247
			26	0.146	30	0.256
			27	0.122	32	0.273
			27	0.123	32	0.283
			27	0.168	33	0.281
			27	0.233	34	0.256
			28	0.148	35	0.360
			28	0.165	35	0.361
			28	0.168	36	0.301

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B2 Fish sampled at Jim Jim Creek upstream site on 7/10/96 & 8/10/96, after the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	27	*Gill-netting	114	21.185	127	33.344
			127	37.450	24	14.110
			96	13.592	91	10.649
			68	5.698	152	53.924
			70	5.509	134	38.120
			127	36.424	134	39.261
			130	37.284	122	26.265
			143	42.707	120	24.579
			149	59.578	123	29.789
			136	39.008	120	28.969
			128	29.452	85	9.090
			130	31.988	76	5.682
			106	17.714	75	6.881
			90	12.837		
Anodontiglanis dahli	6	Gill-netting	251	96	301	170
			264	123	343	230
			295	168	364	450
Ambassis macleayi	1	Gill-netting	60	5.200		
Hephaestus fuliginosus	1	Gill-netting	325	700		
Leiopotherapon unicolor	3	Gill-netting	150	63	211	180
			178	97		
	2	*Seine-netting	114	19.876	130	30.295
Megalops cyprinoides	9	Gill-netting	200	115	287	289
			218	145	308	375
			238	171	341	515
			260	226	344	540
			276	222		
Nematalosa erebi	46	Gill-netting	142	54	181	107
			149	57	190	120
			149	64	190	130
			152	64	191	113
			153	54	192	114
			160	68	193	122
			161	75	193	129
			164	74	194	121
			164	78	195	128
			164	80	195	132
			165	87	195	132
			165	89	197	136
			166	70	197	137

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* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B2 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
N. erebi (cont.)			168	80	199	128
			169	84	203	141
			170	82	206	156
			172	91	210	159
			173	90	213	160
			174	96	221	173
			177	97	222	184
			180	104	223	189
			180	105	246	245
			180	110	181	94
Pingalla midgleyi	6	Gill-netting	80	10	96	19
			92	15	103	24
			95	17	104	22
Syncomistes butleri	8	Gill-netting	209	179	248	320
			232	248	250	340
			236	266	280	430
			246	333	295	530
Scleropages jardini	1	Gill-netting	337	228		
Strongylura kreffti	3	Gill-netting	342	65	478	250
			378	89		
Neosiluris ater	9	Gill-netting	217	77	320	300
			226	84	324	289
			269	113	331	300
			274	177	335	288
			318	230		
Toxotes chatareus	3	Gill-netting	187	130	249	246
			193	138		
Ambassis agrammus	1	*Seine-netting	20	0.105		
Craterocephalus marianae	301	*Seine-netting	12	0.009	35	0.408
			12	0.016	35	0.417
			13	0.012	35	0.422
			13	0.016	35	0.447
			13	0.020	35	0.449
			13	0.022	35	0.489
			13	0.024	35	0.495
			13	0.054	35	0.543
			14	0.017	35	0.588
			14	0.017	36	0.185
			14	0.018	36	0.455
			14	0.019	36	0.488
			14	0.021	36	0.535

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nd indicates no available data.

Table B2 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			14	0.023	36	0.539
			14	0.023	36	0.541
			14	0.023	37	0.527
			14	0.024	38	0.644
			14	0.025	39	0.660
			14	0.026	40	0.751
			14	0.026	40	0.801
			14	0.028	40	0.826
			14	0.032	41	0.765
			15	0.021	41	0.822
			15	0.025	42	0.832
			15	0.026	42	0.884
			15	0.026	42	0.889
			15	0.026	42	0.906
			15	0.026	43	0.948
			15	0.028	43	0.952
			15	0.028	43	0.978
			15	0.030	43	0.994
			15	0.031	44	0.922
			15	0.031	44	0.943
			15	0.032	44	0.980
			15	0.035	44	0.995
			15	0.036	44	1.005
			16	0.035	44	1.006
			16	0.039	44	1.007
			16	0.039	44	1.027
			16	0.040	44	1.038
			16	0.041	44	1.058
			16	0.044	44	1.060
			16	0.045	44	1.129
			16	0.049	44	1.188
			17	0.044	45	0.999
			17	0.048	45	1.035
			17	0.057	45	1.046
			18	0.051	45	1.066
			18	0.066	45	1.068
			19	0.066	45	1.070
			19	0.067	45	1.101
			19	0.068	45	1.110
			19	0.075	45	1.114
			19	0.077	45	1.116
			19	0.084	45	1.121
			19	0.087	45	1.122
			19	0.097	45	1.138
			20	0.061	45	1.145
			20	0.068	45	1.151
			20	0.068	45	1.157
			20	0.075	45	1.157

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Table B2 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			20	0.085	45	1.162
			20	0.095	45	1.171
			21	0.095	45	1.190
			21	0.097	45	1.200
			21	0.102	45	1.205
			21	0.104	45	1.209
			21	0.109	45	1.229
			22	0.095	45	1.239
			22	0.098	46	1.033
			22	0.103	46	1.074
			22	0.108	46	1.102
			22	0.117	46	1.109
			22	0.119	46	1.112
			22	0.120	46	1.138
			22	0.130	46	1.178
			22	0.141	46	1.183
			23	0.100	46	1.192
			23	0.106	46	1.219
			23	0.114	46	1.313
			23	0.117	46	1.359
			23	0.127	47	1.163
			23	0.132	47	1.179
			23	0.134	47	1.194
			23	0.136	47	1.203
			23	0.140	47	1.235
			23	0.149	47	1.249
			23	0.168	47	1.257
			24	0.120	47	1.268
			24	0.127	47	1.284
			24	0.135	47	1.295
			24	0.138	47	1.311
			24	0.138	47	1.405
			24	0.148	48	1.235
			24	0.158	48	1.253
			25	0.133	48	1.317
			25	0.135	48	1.375
			25	0.137	48	1.380
			25	0.147	48	1.442
			25	0.150	48	1.534
			25	0.155	49	1.338
			25	0.171	49	1.356
			26	0.175	49	1.392
			26	0.179	49	1.395
			26	0.190	49	1.398
			26	0.211	49	1.404
			26	0.221	49	1.432
			27	0.197	49	1.469
			27	0.216	49	1.495

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Table B2 (cont.).

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			28	0.210	49	1.498
			28	0.220	49	1.528
			28	0.222	49	1.548
			29	0.224	50	1.275
			29	0.226	50	1.285
			29	0.245	50	1.335
			29	0.246	50	1.372
			29	0.251	50	1.384
			29	0.266	50	1.409
			29	0.267	50	1.451
			29	0.310	50	1.452
			30	0.224	50	1.503
			30	0.243	50	1.555
			30	0.248	51	1.566
			30	0.259	51	1.580
			30	0.266	51	1.596
			30	0.268	51	1.640
			30	0.268	51	1.652
			30	0.271	52	1.677
			30	0.275	52	1.897
			30	0.302	52	1.923
			30	0.304	53	1.747
			30	0.316	54	1.727
			30	0.325	54	1.755
			31	0.264	55	2.168
			31	0.325	56	2.058
			31	0.342	56	2.381
			32	0.328	56	2.390
			32	0.335	57	2.205
			32	0.349	57	2.229
			33	0.120	57	2.390
			33	0.348	58	2.335
			33	0.366	58	2.519
			33	0.393	59	2.528
			34	0.134	60	2.605
			34	0.353	60	2.861
			34	0.389	61	2.689
			34	0.394	61	2.791
			34	0.411	61	2.832
			34	0.422	61	2.966
			34	0.449	63	2.916
			34	0.505		
Craterocephalus stercusmuscarum	63	*Seine-netting	16	0.052	30	0.229
			17	0.049	30	0.233
			19	0.068	30	0.234
			23	0.091	31	0.209

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Table B2 (cont.).

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. stercusmuscarum (cont.)			23	0.096	31	0.227
			23	0.121	31	0.233
			24	0.110	31	0.235
			25	0.165	31	0.242
			26	0.135	31	0.243
			27	0.119	31	0.260
			27	0.136	31	0.276
			27	0.143	32	0.244
			27	0.147	33	0.247
			27	0.152	33	0.252
			27	0.155	34	0.268
			27	0.156	34	0.278
			27	0.170	35	0.263
			27	0.199	35	0.290
			28	0.149	35	0.295
			28	0.172	35	0.309
			28	0.184	35	0.323
			28	0.248	36	0.285
			29	0.186	37	0.339
			29	0.188	37	0.348
			29	0.200	37	0.370
			29	0.210	38	0.409
			30	0.178	38	0.428
			30	0.193	40	0.417
			30	0.194	40	0.423
			30	0.204	41	0.539
			30	0.215	45	0.630
			30	0.228		
Glossogobius giuris	2	*Seine-netting	68	1.753	80	2.741
Melanotaenia splendida inornata	24	*Seine-netting	23	0.116	34	0.314
			23	0.120	34	0.375
			24	0.126	35	0.453
			24	0.146	37	0.488
			24	0.208	38	0.594
			26	0.165	40	0.689
			26	0.194	41	0.668
			27	0.194	43	0.756
			28	0.203	50	1.298
			30	0.250	55	1.538
			31	0.296	64	2.453
			32	0.316	85	6.907
Melanotaenia nigrans	36	*Scine-netting	28	0.202	32	0.284
			28	0.212	32	0.290
			28	0.222	33	0.292
			29	0.210	33	0.312
			29	0.210	33	0.313
			29	0.243	33	0.316

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Table B2 (cont.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. nigrans (cont.)			30	0.219	33	0.330
			30	0.244	33	0.469
			30	0.251	34	0.331
			30	0.269	35	0.367
			30	0.292	36	0.401
			30	0.305	36	0.442
			31	0.270	37	0.378
			31	0.280	37	0.447
			31	0.286	37	0.463
			31	0.299	38	0.456
			32	0.249	39	0.454
			32	0.272	43	0.665

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

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Table B3 Fish sampled at Jim Jim Creek downstream site on 23/05/96 & 24/05/96, before the opening of the Jim Jim Creek crossing.

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	23	*Gill-netting	126	33.845	76	7.012
			117	28.668	120	22.544
			118	29.516	73	6.366
			71	6.055	79	7.534
			142	44.235	99	14.388
			110	27.576	118	30.776
			80	9.108	75	6.558
			117	36.153	90	11.621
			137	47.243	77	8.118
			115	38.850	145	56.225
			80	7.898	110	19.693
			94	14.107		
Anodontiglanis dahli	7	Gill-netting	297	nd	354	nd
			309	nd	280	nd
			307	nd	296	nd
			305	nd		
Arius midgleyi	1	Gill-netting	580	nd		
Arius leptaspis	1	Gill-netting	244	nd		
Ambassis macleayi	2	Gill-netting	60	5.000	62	6.000
Hephaestus fuliginosus	1	Gill-netting	300	nd		
Leiopotherapon unicolor	5	Gill-netting	87	12.000	162	64.000
			163	80.000	158	66.000
			189	122.000		
Megalops cyprinoides	1	Gill-netting	190	80.000		
Melanotaenia splendida inornata	4	Gill-netting	104	17.000	108	20.000
			80	8.000	88	12.000
Nematalosa erebi	15	Gill-netting	167	68.000	172	80.000
			148	38.000	148	40.000
			165	68.000	160	64.000
			144	46.000	152	60.000
			162	66.000	174	82.000
			157	52.000	159	66.000
			160	66.000	155	58.000
			144	44.000		
Neosiluris hyrtlii	2	Gill-netting	184	nd	229	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

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nd indicates no available data.

Table B3 (cont.).

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Pingalla midgleyi	6	Gill-netting	107	18.000	69	6.000
			72	7.000	79	6.000
			67	6.000	89	13.000
Syncomistes butleri	4		159	68.000	257	320.000
			254	315.000	159	70.000
Scleropages jardini	2		432	nd	478	nd
Strongylura kreffti	2		375	104.000	360	82.000
Neosiluris ater	16		293	nd	315	nd
			230	nd	205	nd
			258	nd	408	nd
			295	nd	244	nd
			270	nd	315	nd
			289	nd	310	nd
			345	nd	307	nd
			235	nd	348	nd
Craterocephalus marianae	124	*Seine-netting	35	0.427	43	0.941
			36	0.474	45	1.161
			35	0.489	36	0.488
			39	0.408	46	1.135
			36	0.460	39	0.597
			39	0.404	35	0.449
			39	0.416	35	0.400
			40	0.432	39	0.605
			36	0.503	40	0.668
			34	0.374	37	0.460
			35	0.429	35	0.447
			38	0.584	41	0.759
			36	0.449	37	0.524
			35	0.401	38	0.629
			40	0.611	40	0.746
			33	0.403	35	0.411
			19	0.053	34	0.416
			31	0.326	36	0.476
			42	0.716	35	0.430
			28	0.391	34	0.352
			34	0.422	33	0.342
			35	0.391	33	0.385
			33	0.401	34	0.389
			35	0.398	43	0.635
			35	0.364	58	2.005
			34	0.380	57	2.115
			33	0.322	50	1.395
			36	0.429	57	2.231
			34	0.374	55	1.846

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Table B3 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			23	0.087	53	1.569
			30	0.171	54	1.692
			34	0.395	49	1.259
			25	0.115	43	0.848
			28	0.144	43	0.810
			23	0.113	45	0.943
			26	0.168	40	0.734
			22	0.102	38	0.578
			14	0.030	43	0.802
			22	0.094	48	1.172
			14	0.027	42	0.719
			15	0.017	33	0.566
			58	2.410	40	0.674
			57	2.015	42	0.752
			55	1.902	41	0.708
			60	2.494	43	0.746
			58	2.297	40	0.693
			51	1.437	42	0.783
			54	1.903	38	0.681
			53	1.512	42	0.887
			39	0.807	41	0.772
			54	1.834	39	0.688
			53	1.657	37	0.464
			55	1.893	46	1.089
			50	1.499	38	0.563
			38	0.536	34	0.437
			40	0.750	39	0.603
			34	0.980	22	0.116
			47	1.093	25	0.099
			54	1.803	37	0.523
			41	0.780	39	0.595
			50	1.533	40	0.666
			47	1.061	34	0.393
Craterocephalus stercusmuscarum	38	*Seine-netting	15	0.016	27	0.133
			15	0.023	28	0.074
			17	0.035	28	0.133
			18	0.040	28	0.135
			19	0.034	28	0.145
			19	0.041	28	0.146
			22	0.068	28	0.155
			23	0.070	29	0.123
			23	0.092	29	0.157
			24	0.084	29	0.185
			24	0.097	30	0.160
			24	0.105	30	0.172
			25	0.083	30	0.222
			25	0.091	31	0.205
			25	0.100	31	0.206

[11] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

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Table B3 (cont.).

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. stercusmuscarum (cont.)			26	0.129	32	0.203
			27	0.119	33	0.242
			27	0.121	35	0.296
			27	0.122	37	0.323
Glossogobius giuris	5	*Seine-netting	28	0.108	45	0.413
			36	0.213	47	0.554
			45	0.387		
Melanotaenia splendida inornata	(16)	*Seine-netting	25	0.135	50	1.131
			30	0.245	55	1.306
			38	0.423	55	1.396
			41	0.600	55	1.623
			42	0.672	56	1.941
			43	0.850	58	2.054
			44	0.831	59	2.024
			45	0.895	65	3.138
	29	Seine-netting	60	nd	16	nd
			56	nd	44	nd
			45	nd	19	nd
			61	nd	19	nd
			21	nd	52	nd
			54	nd	48	nd
			44	nd	22	nd
			61	nd	33	nd
			43	nd	48	nd
			44	nd	51	nd
			60	nd	38	nd
			68	nd	43	nd
			47	nd	44	nd
			61	nd	54	nd
			55	nd		
Melanotaenia nigrans	(95)	*Seine-netting	16	0.031	24	0.092
			18	0.095	24	0.094
			19	0.051	24	0.097
			19	0.064	24	0.098
			20	0.058	24	0.098
			21	0.053	24	0.098
			21	0.059	24	0.100
			21	0.060	24	0.107
			21	0.070	24	0.112
			21	0.079	24	0.119
			21	0.085	25	0.085
			22	0.066	25	0.089
			22	0.070	25	0.091
			22	0.073	25	0.096
			22	0.078	25	0.098

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B3 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. nigrans (cont.)			22	0.080	25	0.102
			22	0.088	25	0.107
			22	0.089	25	0.108
			22	0.093	25	0.113
			22	0.096	25	0.116
			22	0.120	25	0.116
			23	0.071	25	0.117
			23	0.072	25	0.124
			23	0.076	25	0.134
			23	0.077	25	0.140
			23	0.077	25	0.145
			23	0.079	25	0.147
			23	0.081	26	0.094
			23	0.086	26	0.107
			23	0.086	26	0.120
			23	0.086	26	0.126
			23	0.086	26	0.166
			23	0.087	27	0.111
			23	0.087	27	0.121
			23	0.089	27	0.129
			23	0.090	27	0.129
			23	0.101	27	0.133
			23	0.102	27	0.140
			24	0.066	27	0.144
			24	0.073	27	0.152
			24	0.079	27	0.159
			24	0.080	28	0.132
			24	0.082	28	0.154
			24	0.082	29	0.158
			24	0.083	29	0.195
			24	0.086	30	0.194
			24	0.088	34	0.103
			24	0.092		
	106	Seine-netting	25	nd	24	nd
			28	nd	28	nd
			24	nd	28	nd
			25	nd	24	nd
			26	nd	27	nd
			32	nd	24	nd
			23	nd	28	nd
			24	nd	26	nd
			28	nd	28	nd
			25	nd	27	nd
			26	nd	28	nd
			23	nd	23	nd
			23	nd	25	nd
			24	nd	28	nd
			28	nd	29	nd
			24	nd	25	nd

[11] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B3 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. nigrans (cont.)			26	nd	27	nd
			27	nd	22	nd
			27	nd	25	nd
			28	nd	21	nd
			31	nd	26	nd
			24	nd	22	nd
			25	nd	24	nd
			23	nd	23	nd
			28	nd	22	nd
			24	nd	23	nd
			27	nd	25	nd
			27	nd	24	nd
			23	nd	25	nd
			28	nd	25	nd
			27	nd	27	nd
			23	nd	23	nd
			25	nd	25	nd
			26	nd	23	nd
			23	nd	25	nd
			25	nd	29	nd
			24	nd	24	nd
			27	nd	23	nd
			28	nd	34	nd
			24	nd	24	nd
			26	nd	26	nd
			26	nd	24	nd
			24	nd	24	nd
			24	nd	27	nd
			24	nd	27	nd
			24	nd	26	nd
			29	nd	27	nd
			26	nd	29	nd
			25	nd	25	nd
			24	nd	25	nd
			20	nd	28	nd
			24	nd	32	nd
			27	nd	24	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B4 Fish sampled at the Jim Jim Creek downstream site on 7/10/96 & 8/10/96, after the opening of the Jim Jim Creek crossing.

Species	No. of fish	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	6	*Gill-netting	97	13.926	115	26.88
			75	6.839		
		*Seine-netting	56	3.092	95	14.712
			72	5.419		
Anodontiglanis dahli	3	Gill-netting	286	140	319	216
			302	160		
Arius leptaspis	1	Gill-netting	252	275		
Hephaestus fuliginosus	1	Gill-netting	356	900		
Leiopotherapon unicolor	4	Gill-netting	80	10	163	64
			86	9	193	123
Megalops cyprinoides	2	Gill-netting	195	95	232	170
Melanotaenia splendida inornata	3	Gill-netting	86	6	95	13
			87	11		
	40	*Seine-netting	13	0.021	28	0.209
			15	0.024	28	0.211
			16	0.029	30	0.238
			16	0.036	32	0.352
			20	0.077	34	0.443
			21	0.077	35	0.399
			21	0.079	35	0.404
			21	0.081	35	0.411
			21	0.083	36	0.456
			21	0.086	37	0.462
			21	0.088	37	0.56
			22	0.097	37	0.602
			22	0.101	38	0.543
			22	0.102	38	0.557
			23	0.098	40	0.595
			23	0.099	46	0.997
			23	0.107	52	1.392
			25	0.143	55	1.511
			26	0.169	69	3.334
			26	0.179	91	8.183
Nematalosa erebi	5	Gill-netting	170	98	175	100
			170	104	181	110
			174	96		
Neosiluris hyrtlii	1	Gill-netting	207	60		
Pingalla midgleyi	2	Gill-netting	72	7.2	75	8.5

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B4 (cont.).

Species	No. of fish	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Syncomistes butleri	4	Gill-netting	nd	nd	199	152
			154	52	253	301
Neosiluris ater	2	Gill-netting	196	50	270	141
Toxotes chatareus	1		226	233		
Ambassis agrammus	33	*Seine-netting	9	0.032	34	0.561
			12	0.024	34	0.565
			13	0.024	34	0.575
			13	0.035	35	0.55
			14	0.028	35	0.559
			14	0.032	35	0.616
			14	0.035	35	0.649
			15	0.037	35	0.672
			16	0.046	37	0.688
			17	0.042	37	0.713
			22	0.226	38	0.782
			27	0.321	38	0.789
			30	0.377	38	0.811
			32	0.491	39	0.902
			32	0.492	41	0.898
			33	0.467	41	1.075
			34	0.556		
Ambassis macleayi	5	*Seine-netting	41	1.045	52	2.02
			42	1.691	52	2.346
			48	1.977		
Craterocephalus marianae	13	*Seine-netting	20	0.077	26	0.199
			21	0.093	34	0.441
			22	0.108	35	0.551
			23	0.114	37	0.534
			23	0.129	45	1.017
			24	0.133	48	1.333
			25	0.162		
(4th and 5th net sweep from non-standard sample)	118	*Seine-netting	17	0.044	25	0.175
			17	0.055	25	0.175
			19	0.054	25	0.177
			19	0.061	25	0.178
			20	0.061	25	0.181
			20	0.07	25	0.182
			20	0.073	25	0.183
			20	0.078	25	0.189
			20	0.082	25	0.194
			20	0.088	25	0.195

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B4 (cont.).

Species	No. of fish	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			20	0.092	26	0.177
			20	0.107	26	0.177
			21	0.125	26	0.198
			22	0.095	26	0.202
			22	0.104	26	0.209
			22	0.105	26	0.23
			22	0.105	26	0.239
			22	0.105	27	0.178
			22	0.121	27	0.195
			22	0.129	27	0.195
			22	0.159	27	0.201
			22	0.228	27	0.202
			23	0.102	27	0.208
			23	0.108	28	0.209
			23	0.11	28	0.216
			23	0.113	28	0.219
			23	0.115	28	0.235
			23	0.12	29	0.254
			23	0.125	29	0.264
			23	0.131	30	0.235
			23	0.14	30	0.264
			23	0.143	30	0.271
			24	0.108	30	0.272
			24	0.116	30	0.299
			24	0.119	32	0.384
			24	0.122	34	0.394
			24	0.124	34	0.411
			24	0.124	35	0.507
			24	0.125	35	0.512
			24	0.129	35	0.514
			24	0.132	35	0.518
			24	0.134	35	0.527
			24	0.135	36	0.612
			24	0.138	37	0.737
			24	0.148	38	0.234
			24	0.155	39	0.262
			24	0.157	39	0.657
			24	0.16	39	0.723
			25	0.131	40	0.718
			25	0.147	40	0.753
			25	0.151	40	0.789
			25	0.154	40	0.8
			25	0.154	40	0.823
			25	0.16	40	0.862
			25	0.16	44	1.107
			25	0.161	45	0.965
			25	0.162	45	1.079
			25	0.163	60	3.332
			25	0.173	69	4.361

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B4 (cont.)

Species	No. of fish	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Craterocephalus stercusmuscarum	52	*Seine-netting	18	0.058	26	0.119
			18	0.066	27	0.123
			19	0.044	27	0.125
			19	0.055	27	0.149
			20	0.052	27	0.149
			20	0.053	28	0.097
			20	0.053	28	0.158
			20	0.057	28	0.168
			21	0.066	29	0.181
			22	0.071	30	0.172
			22	0.072	30	0.182
			22	0.082	30	0.197
			22	0.121	31	0.179
			23	0.077	31	0.22
			23	0.084	31	0.257
			23	0.085	32	0.218
			23	0.086	32	0.226
			23	0.087	32	0.244
			24	0.082	32	0.251
			24	0.092	32	0.318
			25	0.107	33	0.282
			25	0.113	34	0.311
			25	0.114	36	0.349
			25	0.116	37	0.374
			25	0.116	38	0.41
			26	0.114	45	0.743
Glossamia aprion	1	*Seine-netting	111	23.452		
Glossogobius giuris	1	*Seine-netting	49	0.632		
Melanotaenia nigrans	11	*Seine-netting	20	0.217	28	0.181
			21	0.07	29	0.234
			25	0.377	31	0.209
			27	0.151	31	0.236
			28	0.166	33	0.266
			28	0.176		

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 Fish sampled at the Twin Falls Creek upstream site on 30/05/96 & 31/05/96, before the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	11	*gill-netting	83	10.130	97	17.150
			86	10.600	80	7.150
			126	33.491	89	11.970
			102	17.290	130	35.760
			108	22.140	91	10.985
			95	13.340		
	2	*seine-netting	52	2.620	54	2.34
Anodontiglanis dahli	2	gill-netting	327	nd	222	nd
Lates calcarifer	1	gill-netting	225	134		
Leiopotherapon unicolor	15	gill-netting	151	60	157	78
			114	26	156	68
			170	90	177	100
			151	66	167	73
			222	236	166	82
			198	132	102	20
			210	178	90	12
			163	80		
Megalops cyprinoides	8	gill-netting	246	180	229	142
			245	180	200	113
			222	162	308	nd
			187	90	193	92
Melanotaenia splendida inornata	5	gill-netting	86	7	75	6
			114	24	103	16
			107	20		
	57	seine-netting	60	nd	53	nd
			59	nd	30	nd
			53	nd	18	nd
			58	nd	29	nd
			42	nd	48	nd
			60	nd	59	nd
			39	nd	50	nd
			47	nd	30	nd
			37	nd	18	nd
			29	nd	42	nd
			39	nd	39	nd
			84	nd	31	nd
			62	nd	44	nd
			57	nd	57	nd
			51	nd	44	nd
			53	nd	55	nd
			44	nd	43	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. splendida inornata (cont.)			28	nd	24	nd
			43	nd	57	nd
			43	nd	44	nd
			45	nd	39	nd
			47	nd	59	nd
			60	nd	66	nd
			19	nd	60	nd
			33	nd	29	nd
			56	nd	21	nd
			56	nd	19	nd
			20	nd	43	nd
			35	nd		
Mogurnda mogurnda	2	Seine-netting	28	nd	40	nd
Neosiluris hyrtlii	2	gill-netting	175	34	185	40
Pseudomugil gertrudae	2	seine-netting	21	nd	21	nd
Pingalla midgleyi	1	gill-netting	73	7		
	1	seine-netting	66	nd		
Scleropages jardini	6	gill-netting	420	nd	357	nd
			384	nd	346	nd
			353	nd	367	nd
Strongylura kreffti	5	gill-netting	362	90	305	44
			338	76	380	93
			330	60		
	1	seine-netting	262	nd		
Neosiluris ater	13	gill-netting	264	nd	281	nd
			206	nd	217	nd
			205	nd	236	nd
			250	nd	247	nd
			225	nd	263	nd
			220	nd	242	nd
			234	nd		
Craterocephalus marianae	(281)	*Seine-netting	55	1.732	40	0.613
			45	0.990	43	0.786
			53	1.404	39	0.645
			49	1.314	39	0.591
			52	1.389	29	0.557
			60	2.501	39	0.601
			48	1.103	34	0.453
			49	1.113	51	1.411
			50	1.552	36	0.965
			55	1.703	36	0.500

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* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			44	0.873	42	0.740
			49	1.224	48	1.141
			42	0.766	42	0.733
			55	1.720	38	0.634
			42	0.796	40	0.618
			49	1.240	38	0.595
			48	1.084	39	0.634
			42	0.855	37	0.548
			49	1.262	39	0.603
			47	1.155	33	0.359
			44	0.844	38	0.526
			38	0.568	38	0.487
			39	0.663	35	0.434
			42	0.848	37	0.529
			38	0.652	36	0.423
			49	1.240	33	0.335
			55	1.675	35	0.428
			43	0.840	33	0.358
			35	0.404	40	0.660
			40	0.668	39	0.515
			45	0.944	35	0.417
			38	0.570	37	0.517
			40	0.685	35	0.452
			37	0.532	36	0.460
			38	0.542	40	0.638
			41	0.652	33	0.339
			45	0.940	33	0.356
			41	0.782	34	0.389
			39	0.609	28	0.263
			41	0.737	34	0.368
			46	1.015	35	0.380
			35	0.429	32	0.289
			33	0.361	34	0.378
			33	0.389	38	0.506
			39	0.616	34	0.393
			32	0.302	32	0.297
			35	0.428	32	0.327
			33	0.400	34	0.412
			35	0.452	38	0.470
			39	0.544	40	0.591
			39	0.647	33	0.352
			42	0.815	36	0.432
			37	0.535	33	0.360
			36	0.458	34	0.361
			33	0.412	34	0.385
			30	0.225	37	0.413
			33	0.297	35	0.443
			30	0.269	32	0.336
			35	0.449	34	0.352

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			31	0.257	33	0.351
			33	0.328	33	0.326
			68	3.414	32	0.275
			53	1.586	32	0.338
			51	1.450	34	0.390
			46	1.206	30	0.256
			45	0.944	33	0.348
			54	1.553	32	0.259
			54	1.701	33	0.282
			50	1.318	33	0.340
			44	0.891	28	0.214
			48	1.149	33	0.345
			46	1.037	33	0.330
			35	0.433	22	0.086
			38	0.586	23	0.083
			35	0.447	49	1.271
			44	0.809	61	2.624
			43	0.802	43	0.861
			46	0.921	43	0.827
			44	1.425	41	0.790
			56	1.740	50	1.337
			49	1.153	44	0.952
			50	1.240	42	0.801
			39	0.602	57	1.862
			44	0.788	48	1.262
			32	0.287	41	0.696
			35	0.431	43	0.841
			41	0.684	37	0.629
			45	0.867	32	0.351
			36	0.494	50	1.431
			44	0.885	39	0.649
			35	0.418	40	0.716
			36	0.492	50	1.437
			30	0.293	40	0.786
			35	0.433	52	1.535
			48	1.015	39	0.657
			41	0.743	41	0.705
			44	0.807	38	0.730
			40	0.654	40	0.720
			35	0.477	37	0.564
			40	0.655	38	0.547
			38	0.563	36	0.503
			40	0.615	39	0.616
			42	0.699	39	0.569
			42	0.764	35	0.450
			42	0.722	33	0.443
			41	0.673	34	0.451
			34	0.396	41	0.732
			34	0.354	40	0.652

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			34	0.404	42	0.828
			30	0.312	57	1.925
			34	0.372	35	0.500
			33	0.328	37	0.599
			33	0.383	38	0.623
			33	0.395	39	0.600
			33	0.358	36	0.492
			34	0.389	36	0.555
			38	0.526	39	0.592
			32	0.327	34	0.415
			35	0.446	35	0.465
			37	0.497	35	0.460
			31	0.304	34	0.374
			31	0.308	36	0.510
			33	0.371	37	0.516
			30	0.270	35	0.464
			34	0.370	35	0.519
			31	0.281	39	0.629
			34	0.384	30	0.330
			30	0.269	31	0.405
			20	0.071	32	0.347
			51	1.460	30	0.298
			35	0.450	33	0.425
			54	1.650	34	0.458
			44	0.855	33	0.334
			38	0.573	33	0.378
			38	0.386	31	0.314
			48	1.197	30	0.264
			41	0.843	28	0.237
			41	0.752	32	0.357
			42	0.724	32	0.320
			47	1.172	22	0.089
			46	1.167		
	284	Seine-netting	44	nd	31	nd
			43	nd	60	nd
			39	nd	32	nd
			30	nd	39	nd
			35	nd	44	nd
			34	nd	48	nd
			34	nd	51	nd
			37	nd	48	nd
			39	nd	42	nd
			36	nd	52	nd
			44	nd	40	nd
			31	nd	36	nd
			40	nd	35	nd
			39	nd	37	nd
			38	nd	42	nd
			40	nd	42	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			33	nd	42	nd
			32	nd	33	nd
			30	nd	33	nd
			29	nd	43	nd
			37	nd	50	nd
			33	nd	30	nd
			25	nd	41	nd
			35	nd	35	nd
			36	nd	36	nd
			37	nd	37	nd
			35	nd	50	nd
			35	nd	46	nd
			36	nd	51	nd
			35	nd	51	nd
			40	nd	40	nd
			35	nd	35	nd
			37	nd	53	nd
			35	nd	42	nd
			34	nd	43	nd
			35	nd	43	nd
			31	nd	36	nd
			34	nd	42	nd
			33	nd	48	nd
			31	nd	39	nd
			31	nd	47	nd
			31	nd	46	nd
			28	nd	46	nd
			22	nd	32	nd
			41	nd	31	nd
			38	nd	38	nd
			34	nd	38	nd
			36	nd	42	nd
			40	nd	33	nd
			34	nd	39	nd
			51	nd	40	nd
			38	nd	38	nd
			34	nd	55	nd
			43	nd	35	nd
			30	nd	44	nd
			35	nd	52	nd
			37	nd	35	nd
			38	nd	51	nd
			35	nd	37	nd
			34	nd	37	nd
			37	nd	49	nd
			39	nd	40	nd
			33	nd	38	nd
			42	nd	44	nd
			51	nd	42	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			42	nd	42	nd
			55	nd	40	nd
			45	nd	40	nd
			48	nd	53	nd
			35	nd	33	nd
			44	nd	34	nd
			45	nd	54	nd
			45	nd	54	nd
			34	nd	51	nd
			38	nd	34	nd
			38	nd	48	nd
			35	nd	40	nd
			40	nd	40	nd
			44	nd	43	nd
			31	nd	39	nd
			44	nd	36	nd
			40	nd	44	nd
			48	nd	46	nd
			42	nd	33	nd
			40	nd	39	nd
			47	nd	35	nd
			32	nd	50	nd
			41	nd	34	nd
			34	nd	41	nd
			38	nd	44	nd
			38	nd	42	nd
			33	nd	43	nd
			30	nd	35	nd
			33	nd	42	nd
			48	nd	56	nd
			52	nd	33	nd
			40	nd	32	nd
			33	nd	39	nd
			40	nd	48	nd
			36	nd	37	nd
			35	nd	32	nd
			36	nd	39	nd
			40	nd	41	nd
			42	nd	35	nd
			34	nd	33	nd
			43	nd	36	nd
			35	nd	47	nd
			37	nd	33	nd
			43	nd	43	nd
			35	nd	25	nd
			33	nd	68	nd
			35	nd	24	nd
			34	nd	58	nd
			32	nd	59	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			39	nd	64	nd
			39	nd	51	nd
			34	nd	45	nd
			50	nd	33	nd
			48	nd	44	nd
			45	nd	45	nd
			34	nd	48	nd
			50	nd	43	nd
			41	nd	41	nd
			54	nd	27	nd
			36	nd	37	nd
			50	nd	33	nd
			54	nd	47	nd
			45	nd	23	nd
			40	nd	44	nd
			42	nd	40	nd
			33	nd	33	nd
			36	nd	49	nd
			32	nd	46	nd
			37	nd	40	nd
			36	nd	55	nd
			34	nd	44	nd
			39	nd	40	nd
			33	nd	42	nd
			38	nd	34	nd
			30	nd	31	nd
			36	nd	37	nd
			33	nd	35	nd
Craterocephalus stercusmuscarum	13	*Seine-netting	18	0.044	24	0.118
			18	0.080	24	0.174
			19	0.039	25	0.125
			20	0.057	28	0.142
			21	0.077	28	0.213
			23	0.122	37	0.346
			23	0.235		
	(7)	Seine-netting	27	nd	21	nd
			59	nd	20	nd
			22	nd	26	nd
			39	nd		
Glossogobius giuris	(1)	*Seine-netting	31	0.139		
	3	Seine-netting	37	nd	34	nd
			39	nd		
Melanotaenia nigrans	28	*Seine-netting	16	0.032	50	1.131
			16	0.049	51	1.251
			19	0.044	52	1.344
			20	0.055	54	1.404

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B5 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. nigrans (cont.)			29	0.127	55	1.441
			29	0.164	55	1.520
			29	0.185	55	1.559
			29	0.196	56	1.995
			30	0.212	57	1.787
			37	0.292	58	1.803
			38	0.463	59	1.960
			42	0.737	59	1.961
			42	0.838	65	2.607
			42	1.113	80	5.040
	(20)	Seine-netting	19	nd	31	nd
			27	nd	28	nd
			22	nd	30	nd
			28	nd	29	nd
			27	nd	25	nd
			24	nd	54	nd
			27	nd	27	nd
			26	nd	26	nd
			28	nd	25	nd
			28	nd	28	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B6 Fish sampled at the Twin Falls Creek upstream site on 9/10/96 & 10/10/96, after the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	11	*gill-netting	64	4.887	75	7.416
			69	6.005	86	10.25
			70	5.917	91	13.239
			71	6.037	93	13.315
			72	6.051	120	25.069
			72	6.311		
	4	*seine-netting	63	4.168	88	10.935
			78	8.501	107	20.369
Arius leptaspis	1	gill-netting	200	170		
Glossamia aprion	2	gill-netting	nd	nd	158	66
Hephaestus fuliginosus	1	gill-netting	212	198		
Lates calcarifer	2	gill-netting	251	162	251	180
Leiopotherapon unicolor	5	gill-netting	151	64	172	88
			164	80	195	124
			168	78		
	1	*seine-netting	135	34.23		
Megalops cyprinoides	5	gill-netting	216	142	244	160
			221	155	277	298
			236	156		
Melanotaenia splendida inornata	4	gill-netting	80	6.1	85	7.9
			85	7.	87	9
	35	*seine-netting	22	0.100	36	0.556
			22	0.114	37	0.535
			23	0.131	37	0.585
			23	0.145	38	0.543
			24	0.146	40	0.573
			24	0.151	40	0.695
			25	0.132	41	0.594
			25	0.154	41	0.635
			26	0.188	41	0.724
			26	0.210	42	0.726
			30	0.317	43	0.846
			33	0.360	43	0.986
			33	0.403	44	0.922
			35	0.451	46	1.143
			35	0.469	47	1.984
			36	0.477	52	1.397
			nd	nd	nd	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B6 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. splendida inornata (cont.)			nd	nd	nd	nd
			nd	nd		
Pingalla midgleyi	4	gill-netting	72	8.1	93	16.6
			88	13	111	26.4
	1	*seine-netting	82	9.339		
Syncomistes butleri	1	gill-netting	163	74		
Scleropages jardini	7	gill-netting	331	290	362	400
			334	315	376	453
			337	301	390	409
			357	403		
Neosiluris ater	9	gill-netting	157	138	256	144
			213	70	257	124
			221	90	297	194
			235	98	328	270
			244	111		
Craterocephalus marianae	(172) o 383	*seine-netting	15	nd	34	0.594
			16	nd	35	nd
			16	0.033	35	nd
			16	0.036	35	nd
			16	0.041	35	nd
			16	0.062	35	nd
			17	0.045	35	nd
			17	0.054	35	nd
			17	0.065	35	nd
			18	nd	35	0.579
			18	0.064	35	0.579
			19	nd	35	0.654
			19	0.063	36	nd
			19	0.065	36	nd
			19	0.065	36	nd
			19	0.068	36	0.362
			19	0.129	36	0.576
			20	nd	36	0.634
			20	0.072	36	0.644
			20	0.078	36	0.664
			20	0.105	37	nd
			21	nd	37	nd
			21	nd	37	nd
			21	nd	37	nd
			21	nd	37	nd
			21	nd	37	0.74
			21	nd	37	0.75
			21	nd	38	nd

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* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B6 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			21	nd	38	nd
			21	0.075	38	nd
			21	0.086	38	nd
			21	0.09	38	0.599
			21	0.094	38	0.748
			21	0.095	39	nd
			21	0.104	39	nd
			22	nd	39	nd
			22	nd	39	nd
			22	nd	39	nd
			22	nd	39	0.631
			22	0.105	39	0.638
			22	0.123	39	0.698
			22	0.138	39	0.726
			23	nd	39	0.739
			23	nd	39	0.763
			23	0.105	39	0.831
			23	0.119	40	nd
			23	0.122	40	nd
			23	0.132	40	nd
			23	0.165	40	0.569
			24	nd	40	0.787
			24	0.125	40	0.914
			24	0.133	41	nd
			24	0.171	41	0.819
			24	0.196	42	nd
			25	nd	42	0.954
			25	0.174	43	nd
			25	0.251	43	nd
			26	nd	43	0.966
			26	0.135	43	1.021
			27	nd	43	1.024
			27	nd	44	nd
			27	nd	44	1.073
			27	nd	44	1.151
			27	0.181	45	nd
			27	0.208	45	nd
			28	nd	45	1.043
			28	nd	45	1.133
			28	nd	45	1.169
			28	nd	46	nd
			28	nd	46	nd
			28	0.233	46	1.08
			28	0.264	46	1.163
			29	0.203	46	1.192
			29	0.228	47	1.322
			29	0.251	47	1.429
			30	nd	48	nd
			30	nd	48	1.36
			32	nd	50	1.502

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B6 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			33	nd	50	1.697
			34	nd	51	1.812
			34	nd	52	1.563
			34	nd	52	1.835
			34	nd	55	1.956
			34	nd	56	2.008
			34	0.536	58	nd
			34	0.537	59	2.588
Melanotaenia nigrans	7	*seine-netting	29	0.231	32	0.238
			30	nd	32	0.316
			31	0.236	35	0.417
			31	0.273		
Craterocephalus stercusmuscarum	1	*seine-netting	nd	nd		

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 Fish sampled at the Twin Falls Creek downstream site on 12/06/96 & 13/06/96, before the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	15	*gill-netting	100	17.328	100	16.732
			94	14.528	74	6.940
			86	10.480	125	32.350
			112	27.543	126	38.729
			113	24.923	70	4.692
			66	4.926	85	11.249
			112	27.918	94	13.308
			76	7.203		
Glossamia aprion	2	gill-netting	120	28	106	20
Hephaestus fuliginosus	1	gill-netting	156	75		
Leiopotherapon unicolor	3	gill-netting	193	120	185	124
			183	122		
Megalops cyprinoides	2	gill-netting	229	184	229	176
Melanotaenia splendida inornata	38	gill-netting	92	11	93	13
			121	27	99	15.5
			105	18.5	90	11
			97	15	82	7
			110	23	75	7
			108	21	86	8.5
			106	18	103	18
			91	11	104	19
			89	10.5	72	5.5
			85	13	94	13
			94	9	97	14.5
			105	18	100	16
			90	12	85	9
			77	7	95	13
			95	14	80	9
			97	16	107	21
			93	14	91	11
			82	8	104	18
			98	15	115	18
	(49)	*seine-netting	26	0.142	49	1.154
			27	0.172	50	1.125
			29	0.196	52	1.498
			29	0.205	52	1.636
			30	0.189	55	1.072
			31	0.290	55	1.899
			38	0.491	55	1.949
			38	0.555	55	2.093
			38	0.594	56	1.972

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. splendida inornata (cont.)			39	0.518	56	2.006
			39	0.578	56	2.031
			39	0.604	56	2.084
			43	0.701	58	1.620
			44	0.747	59	1.650
			44	0.750	59	2.403
			45	0.809	64	2.495
			45	0.897	68	3.540
			45	0.935	70	3.741
			45	0.981	77	5.848
			45	1.002	81	6.061
			47	1.110	85	8.034
			47	1.131	90	9.920
			47	1.142	105	13.660
			48	0.884	113	20.152
			48	1.680		
	53	seine-netting	114	nd	60	nd
			47	nd	88	nd
			32	nd	70	nd
			55	nd	50	nd
			59	nd	39	nd
			55	nd	84	nd
			78	nd	26	nd
			53	nd	48	nd
			52	nd	58	nd
			38	nd	56	nd
			20	nd	58	nd
			104	nd	60	nd
			49	nd	53	nd
			50	nd	44	nd
			38	nd	44	nd
			49	nd	41	nd
			43	nd	30	nd
			45	nd	34	nd
			56	nd	28	nd
			49	nd	70	nd
			59	nd	46	nd
			31	nd	93	nd
			39	nd	40	nd
			29	nd	37	nd
			44	nd	64	nd
			27	nd	44	nd
			34	nd		
Neosiluris hyrtlii	11	gill-netting	186	nd	143	20
			180	nd	187	43
			149	nd	157	29
			167	nd	141	20
			178	nd	203	52

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
N. hyrtlii (cont.)			142	nd		
Pingalla midgleyi	19	gill-netting	74	8	72	7
			84	13	69	6
			75	8	87	12.5
			84	12	96	15.5
			89	13	75	9
			85	11	77	8
			70	6	66	5
			73	7	67	6.5
			98	18	96	19.5
			83	11		
Scleropages jardini	2	gill-netting	319	263	345	330
Strongylura kreffti	7	gill-netting	302	41	438	180
			345	72	325	60
			346	102	295	50
			346	82		
Neosiluris ater	6	gill-netting	277	nd	213	88
			210	nd	227	92
			242	106	211	76
Craterocephalus marianae	135	*seine-netting	36	0.398	32	0.327
			37	0.515	38	0.576
			50	1.466	38	0.565
			52	1.566	34	0.370
			39	0.621	32	0.302
			37	0.548	68	3.416
			35	0.491	41	0.758
			34	0.444	47	1.057
			42	0.843	48	1.042
			38	0.586	43	0.795
			42	0.835	38	0.584
			40	0.643	43	0.833
			44	1.007	43	0.850
			44	0.840	43	0.896
			35	0.466	44	0.898
			33	0.606	44	0.916
			35	0.462	36	0.517
			33	0.423	38	0.560
			35	0.556	38	0.590
			38	0.546	50	1.306
			38	0.547	48	1.218
			38	0.582	45	0.896
			41	0.813	52	1.678
			43	0.830	43	0.88
			49	1.130	44	0.917

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			41	0.785	42	0.748
			50	1.311	43	0.894
			39	0.940	40	0.687
			37	0.501	43	0.864
			46	1.116	36	0.535
			40	0.681	36	0.478
			35	0.429	39	0.618
			42	0.769	36	0.474
			35	0.487	39	0.554
			33	0.368	36	nd
			35	0.476	40	0.635
			39	0.585	39	0.594
			38	0.581	39	0.593
			37	0.533	33	0.377
			35	0.460	37	0.507
			36	0.514	38	0.597
			36	0.471	33	0.344
			36	0.466	35	0.470
			40	0.675	34	0.409
			37	0.473	34	0.392
			34	0.412	33	0.344
			35	0.523	41	0.715
			34	0.441	34	0.460
			31	0.754	36	0.467
			35	0.494	34	0.427
			34	0.393	38	0.533
			35	0.405	33	0.331
			35	0.477	35	0.430
			32	0.327	31	0.319
			35	0.503	33	0.411
			33	0.38	34	0.403
			32	0.35	32	0.339
			30	0.302	34	0.372
			38	0.460	36	0.511
			33	0.350	34	0.433
			33	0.355	32	0.321
			31	0.303	31	0.307
			29	0.268	32	0.339
			32	0.334	28	0.250
			32	0.325	31	0.317
			32	0.347	30	0.286
			32	0.320	30	0.510
			32	0.319		
	(119)	seine-netting	44	nd	35	nd
			39	nd	39	nd
			43	nd	34	nd
			34	nd	32	nd
			65	nd	29	nd
			36	nd	38	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			34	nd	35	nd
			33	nd	36	nd
			38	nd	34	nd
			40	nd	36	nd
			48	nd	35	nd
			36	nd	32	nd
			35	nd	34	nd
			49	nd	35	nd
			37	nd	49	nd
			34	nd	32	nd
			33	nd	32	nd
			38	nd	36	nd
			39	nd	37	nd
			34	nd	30	nd
			35	nd	48	nd
			38	nd	34	nd
			29	nd	38	nd
			47	nd	45	nd
			30	nd	43	nd
			36	nd	33	nd
			44	nd	53	nd
			35	nd	39	nd
			38	nd	35	nd
			42	nd	33	nd
			35	nd	37	nd
			36	nd	43	nd
			49	nd	44	nd
			43	nd	38	nd
			48	nd	40	nd
			43	nd	37	nd
			42	nd	32	nd
			38	nd	35	nd
			40	nd	38	nd
			39	nd	37	nd
			50	nd	26	nd
			37	nd	35	nd
			41	nd	34	nd
			42	nd	34	nd
			38	nd	34	nd
			34	nd	44	nd
			39	nd	35	nd
			37	nd	43	nd
			34	nd	45	nd
			31	nd	32	nd
			35	nd	39	nd
			31	nd	37	nd
			32	nd	36	nd
			45	nd	31	nd
			39	nd	35	nd

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B7 (cont.).

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			34	nd	38	nd
			43	nd	30	nd
			35	nd	32	nd
			36	nd	34	nd
			33	nd		
Craterocephalus stercusmuscarum	5	*seine-netting	30	0.133	35	0.274
			30	0.197	36	0.28
			33	0.054		
	(4)	seine-netting	36	nd	35	nd
			30	nd	30	nd
Glossogobius giuris	1	*seine-netting	47	0.455		
Melanotaenia nigrans	32	*seine-netting	21	0.058	29	0.243
			22	0.079	30	0.182
			23	0.110	30	0.186
			24	0.078	30	0.215
			24	0.101	31	0.185
			26	0.106	32	0.217
			26	0.116	34	0.329
			26	0.119	34	0.901
			27	0.147	35	0.309
			27	0.153	35	0.388
			28	0.173	36	0.279
			28	0.180	36	0.298
			29	0.157	36	0.373
			29	0.161	38	0.416
			29	0.185	44	0.176
			29	0.186	45	0.625
	(23)	seine-netting	33	nd	35	nd
			36	nd	25	nd
			34	nd	23	nd
			23	nd	32	nd
			28	nd	31	nd
			28	nd	37	nd
			43	nd	36	nd
			31	nd	36	nd
			43	nd	27	nd
			30	nd	28	nd
			30	nd	26	nd
			28	nd		
Pseudomugil gertrudae	1	seine-netting	23	nd		
Mogurnda mogurnda	1	seine-netting	nd	nd		

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B8 Fish sampled at the Twin Falls Creek downstream site on 10/10/96 & 11/10/96, after the opening of the Jim Jim Creek crossing.

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Amniataba percoides	7	*gill-netting:	71	5.04	74	6.74
			80	8.08	66	4.61
			79	6.58	71	6.22
			86	11.03		
Glossamia aprion	1	gill-netting:	141	46.0		
Leiopotherapon unicolor	9	gill-netting:	139	42.0	189	130
			142	50.0	197	130
			157	61.0	197	145
			165	75.0	209	122
			184	110.0		
Melanotaenia splendida inornata	7	gill-netting:	77	6.1	87	9
			79	7.0	89	10
			79	8.0	90	9.1
			87	9.0		
	89	*seine-netting:	88	7.79	25	0.11
			84	5.85	60	2.04
			74	4.33	60	2.32
			64	2.32	54	1.55
			74	4.41	57	1.70
			79	4.75	64	2.36
			65	2.99	55	1.66
			70	3.58	55	1.56
			56	1.72	60	2.14
			73	4.36	49	0.99
			70	4.43	56	1.68
			60	2.38	49	0.96
			71	3.33	45	0.60
			72	nd	45	0.87
			54	1.46	42	0.58
			42	0.81	35	0.42
			51	1.37	45	0.78
			52	1.49	56	0.47
			53	1.59	35	0.36
			39	0.51	30	0.29
			38	0.47	35	0.40
			39	0.48	32	0.29
			45	0.95	25	0.16
			53	1.50	24	0.11
			82	5.24	21	0.08
			65	3.04	20	0.07
			67	2.50	50	1.17
			64	2.84	40	0.70
			62	2.71	33	0.37

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B8 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
M. splendida inornata (cont.)			58	1.62	23	0.20
			69	2.54	24	0.18
			61	nd	26	0.14
			65	1.48	21	0.07
			54	1.38	20	0.07
			45	0.93	20	0.08
			45	0.87	18	0.05
			40	0.62	21	0.06
			30	0.24	19	0.11
			29	0.22	16	0.03
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd		
Neosiluris hyrtlii	6	gill-netting:	145	20	173	37.00
			148	19	179	35.00
			165	30	182	42.00
Pingalla midgleyi	22	gill-netting:	66	6	77	8.50
			69	7	78	9.00
			70	7	79	10.00
			70	8	79	13.20
			72	7	80	10.00
			72	8	80	10.50
			73	7	90	15.00
			73	7	92	15.50
			75	8	92	16.00
			75	9	94	17.00
			75	9	97	18.10
Scleropages jardini	8	gill-netting:	278	170	348	360
			308	270	360	380
			317	260	364	420
			336	300	365	445
Strongylura kreffti	1	gill-netting:	352	70		
Neosiluris ater	4	gill-netting:	202	65	220	89
			216	77	232	95
Craterocephalus marianae	(133) of 938	*seine-netting:	56	2.10	39	0.72
			37	0.62	22	0.10
			44	nd	23	0.11
			45	1.12	37	nd
			51	1.63	30	nd
			41	0.83	27	0.19

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B8 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			44	1.19	20	0.08
			47	1.35	20	0.09
			46	1.30	9	0.03
			44	nd	13	0.11
			23	0.10	42	0.83
			42	0.76	19	0.07
			44	0.96	27	0.18
			42	0.81	18	0.04
			45	1.03	22	0.08
			39	nd	27	0.18
			25	nd	44	0.87
			26	0.18	42	0.76
			25	0.17	38	0.62
			27	nd	40	0.58
			15	0.02	25	0.16
			29	0.26	34	0.37
			39	0.61	40	0.67
			55	1.77	37	0.19
			49	1.27	39	nd
			34	0.36	42	nd
			39	0.63	29	nd
			44	1.01	11	0.04
			37	0.57	22	0.07
			20	0.08	45	nd
			17	0.06	22	0.08
			40	0.62	40	0.66
			43	nd	40	0.68
			40	0.69	35	nd
			42	0.79	29	nd
			32	0.36	20	0.06
			37	0.48	33	0.14
			48	1.22	42	nd
			22	0.10	24	0.13
			37	0.56	23	0.11
			42	0.71	37	nd
			28	0.22	30	0.64
			37	0.57	45	nd
			18	0.05	21	nd
			23	0.12	28	0.06
			38	0.60	20	0.08
			22	0.07	19	0.07
			33	0.50	25	0.14
			38	0.51	27	0.16
			41	0.79	27	nd
			23	nd	24	nd
			38	nd	20	0.07
			46	nd	17	0.04
			53	nd	18	0.04
			23	nd	18	nd
			37	nd	18	0.05

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B8 (cont.)

Species	[1]No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. marianae (cont.)			35	nd	20	0.07
			49	1.29	24	0.12
			40	0.73	22	nd
			35	0.45	28	0.21
			34	nd	17	0.04
			24	nd	22	0.09
			23	0.10	17	0.04
			34	0.42	15	0.03
			17	0.05	20	0.07
			37	0.58	55	1.78
			48	1.29		
Melanotaenia nigrans	66	*seine-netting:	48	0.82	41	0.42
			50	1.00	33	0.29
			49	0.88	30	0.23
			49	0.85	35	0.34
			49	1.30	40	0.56
			45	0.77	29	0.19
			40	0.52	37	0.36
			44	0.74	38	0.38
			52	1.23	36	0.30
			38	0.35	37	0.32
			39	0.50	35	0.29
			45	0.61	38	0.34
			29	0.13	44	0.55
			47	0.65	33	0.19
			43	0.46	30	0.11
			42	0.55	31	0.16
			35	0.30	36	0.31
			37	0.23	34	0.27
			36	0.35	34	nd
			38	0.39	31	0.24
			40	0.39	35	0.32
			31	0.15	41	0.53
			30	0.14	32	0.25
			33	0.24	41	0.43
			38	0.45	29	0.13
			33	0.16	31	0.16
			37	0.32	32	0.45
			31	0.15	32	0.20
			35	0.28	29	0.13
			36	0.33	22	0.06
			44	0.56	22	nd
			36	0.40	16	0.03
			35	0.15	13	0.02
Craterocephalus stercusmuscarum	39	*seine-netting:	39	0.39	32	0.2
			42	0.42	32	0.21
			25	0.11	31	0.19
			32	0.21	35	0.11

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

Table B8 (cont.)

Species	[1] No. of fish.	Sampling technique	Length (mm)	Weight (g)	Length (mm)	Weight (g)
C. stercusmuscarum (cont.)			33	0.2	29	0.1
			30	0.18	29	0.12
			30	0.21	21	0.05
			34	0.29	24	0.06
			36	0.32	22	nd
			33	0.24	21	0.03
			40	0.29	18	0.03
			30	0.18	23	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd	nd	nd
			nd	nd		

[1] Numbers without brackets are the total number of fish sampled by a given sample technique. Numbers in brackets indicate that this group of fish are a subsample of the total sampled which was measured in a different state of preservation (see *). The subsample number is NOT in addition to the total number

* Indicates that, for this group of fish, measurements were taken from alcohol preserved specimens

nd indicates no available data.

APPENDIX C

Results of multivariate analysis of fish community structure data

Table C1 Principle axis correlation coefficients (R) and associated Monte-Carlo probability (p) derived from a PCC analysis of physico-chemical parameters against the SSH ordination space of fish community data (**Log_{10} transformed**; Bray & Curtis dissimillarity values).

Vector 1 and Vector 2 are coordinates indicating direction of influence from the origin in the SSH ordination space.

Note: Parameters were measured before and after opening of JimJim creek crossing at sampling sites on Jim Jim and Twin Falls Creeks. Mean and maximum values were calculated from samples taken on a monthly basis (April - May 1996, for the 'before' group; and June - October, 1996, for the 'after' group). 'Downstream' values at site JJ3 were calculated as a mean of data from both sites, JJ2 and JJ3 (see Figure 1). Table sorted by significance level (p)

Desciption	Code	Vector 2	Vector 1	R	p
Maximum Sodium	mxNa	0.1268	0.9919	0.88	0.01
Maximum Sulphate	mxSO4	0.8642	0.5031	0.86	0.02
Mean Aluminium	Al	-0.7469	0.6650	0.76	0.03
Maximum Total Phosphate	mxTP	-0.0505	0.9987	0.87	0.04
Mean Total Organic Carbon	TOC	-0.9075	0.4201	0.78	0.04
Maximum Uranium	mxU	-0.7248	0.6889	0.76	0.05
Mean Uranium	U	-0.7230	0.6909	0.76	0.05
Maximum Ortho-Phosphate	mxOrP	-0.7312	0.6822	0.83	0.06
Maximum Iron	mxFe	-0.4112	0.9115	0.81	0.06
Mean Turbidity	TB	-0.7076	0.7066	0.75	0.06
Maximum Turbidity	mxTB	-0.6958	0.7183	0.74	0.06
Maximum Aluminium	mxAl	-0.7106	0.7036	0.75	0.07
Maximum Potassium	mxK	-0.6765	0.7365	0.74	0.08
Mean CaCO3	CaCO	-0.8367	0.5477	0.74	0.08
Mean Zinc	Zn	-0.8793	0.4763	0.74	0.08
Mean Lead	Pb	-0.7117	0.7025	0.74	0.09
Mean Dissolved Organic Carbon	DOC	-0.3091	-0.9510	0.82	0.10
Maximum Suspended Solids	mxSUS	-0.7351	0.6780	0.75	0.10
Maximum Copper	mxCu	-0.7116	0.7025	0.74	0.10
Maximum Lead	mxPb	-0.7116	0.7025	0.74	0.11
Mean Potassium	K	-0.4139	0.9103	0.76	0.12
Mean Manganese	Mn	-0.0753	0.9972	0.75	0.13
Mean Copper	Cu	-0.7116	0.7025	0.74	0.13
Maximum Chloride	mxCl	-0.6673	0.7448	0.74	0.13
Maximum Manganese (HPLC method)	mxMn	-0.1168	0.9931	0.73	0.13
Mean Chromium	Cr	-0.7117	0.7025	0.74	0.14
Maximum Zinc	mxZn	-0.9294	0.3691	0.73	0.15
Mean Total Phosphate	TP	0.6976	0.7164	0.71	0.15
Maximum Chromium	mxCr	-0.7116	0.7025	0.74	0.17
Mean Manganese (ICPMS method)	MnIC	0.0237	0.9997	0.72	0.17
Mean Sodium	Na	0.5803	0.8144	0.68	0.19
Mean Iron	Fe	-0.5243	0.8515	0.69	0.20
Maximum Manganese (ICPMS method)	mxMnIC	-0.1875	0.9823	0.69	0.22
Maximum Magnesium	mxMg	-0.7068	0.7074	0.66	0.24
Maximum Conductivity	mxCon	-0.6818	0.7315	0.66	0.25
Mean Sulphate	SO4	0.9555	-0.2948	0.62	0.27
Mean pH	pH	0.6571	0.7538	0.63	0.28
Maximum pH	mxpH	0.5373	0.8434	0.66	0.30
Mean Ortho-Phosphate	OrP	-0.9095	0.4157	0.54	0.35
Maximum HCO3	mxHCO3	-0.9387	0.3447	0.56	0.41
Conductivity	Con	0.8838	-0.4678	0.56	0.42
Maximum CaCO3	mxCaCO	-0.9509	0.3095	0.56	0.47
Mean Chlorophyll-b	Cb	-0.5570	-0.8305	0.51	0.51
Mean Magnesium	Mg	-0.6460	0.7633	0.51	0.56
Maximum Total Organic Carbon	mxTOC	-0.8871	-0.4616	0.49	0.66
Maximum Calcium	mxCal	-0.9812	-0.1932	0.43	0.67
Mean Total Chlorophyll	TC	-0.8520	-0.5236	0.34	0.67
Maximum Chlorophyll-c	mxCc	0.0718	0.9974	0.30	0.68
Maximum Dissolved Organic Carbon	mxDOC	-0.9805	-0.1965	0.42	0.69
Mean Chlorophyll-c	Cc	-0.5949	0.8038	0.42	0.75
Mean Calcium	Ca	-0.0089	-1.0000	0.21	0.76
Maximum Chlorophyll-b	mxCb	0.1967	-0.9805	0.19	0.76
Mean Calcium	Cal	-0.6003	-0.7998	0.39	0.79
Mean HCO3	HCO3	-0.8887	0.4585	0.29	0.80
Mean Chloride	Cl	-0.8741	0.4858	0.31	0.81
Mean Suspended Solids	SUS	-0.7641	0.6451	0.74	0.83
Mean Chlorophyll-a	mxCa	0.5121	-0.8590	0.23	0.85
Maximum Total Chlorophyll(a,b,c)	mxTC	0.9992	-0.0393	0.17	0.86

Table C2 Principle axis correlation coefficients (R) and associated Monte-Carlo probability (p) derived from a PCC analysis of physico-chemical parameters against the SSH ordination space of fish community data (**untransformed**; Bray & Curtis dissimillarity values).

Vector 1 and Vector 2 are coordinates indicating direction of influence from the origin in the SSH ordination space.

Note: Parameters were measured before and after opening of JimJim creek crossing at sampling sites on Jim Jim and Twin Falls Creeks. Mean and maximum values were calculated from samples taken on a monthly basis (April - May 1996, for the 'before' group; and June - October, 1996, for the 'after' group). 'Downstream' values at site JJ3 were calculated as a mean of data from both sites, JJ2 and JJ3 (see Figure 1). Table sorted by significance level (p)

Desciption	Code	Vector 2	Vector 1	R	p
Mean Total Organic Carbon	TOC	0.7344	-0.6787	0.92	0.02
Mean Aluminium	Al	0.5167	-0.8562	0.89	0.02
Mean CaCO3	CaCO	0.7426	-0.6697	0.85	0.02
Maximum Chlorophyll-c	mxCc	-0.3334	-0.9428	0.90	0.03
Maximum Uranium	mxU	0.5567	-0.8307	0.88	0.03
Mean Uranium	U	0.5518	-0.8340	0.88	0.04
Maximum Turbidity	mxTB	0.4657	-0.8849	0.87	0.04
Mean Total Phosphate	TP	-0.9837	-0.1797	0.87	0.04
Mean Turbidity	TB	0.4766	-0.8791	0.87	0.04
Maximum Potassium	mxK	0.3105	-0.9506	0.86	0.04
Maximum Aluminium	mxAl	0.4914	-0.8709	0.87	0.05
Conductivity	Con	-0.9860	0.1668	0.82	0.06
Maximum Suspended Solids	mxSUS	0.4544	-0.8908	0.87	0.07
Maximumtotal Chlorophyll(a,b,c)	mxTC	-0.5937	-0.8047	0.82	0.07
Mean Lead	Pb	0.5224	-0.8527	0.86	0.09
Maximum Chloride	mxCl	0.2204	-0.9754	0.82	0.09
Mean Chlorophyll-c	Cc	0.0450	-0.9990	0.82	0.09
Maximum Copper	mxCu	0.5224	-0.8527	0.86	0.10
Mean Dissolved Organic Carbon	DOC	0.6570	0.7539	0.75	0.10
Maximum Lead	mxPb	0.5224	-0.8527	0.86	0.11
Mean Zinc	Zn	0.4666	-0.8845	0.85	0.11
Mean Sulphate	SO4	0.0150	0.9999	0.78	0.11
Mean Potassium	K	0.0099	-1.0000	0.83	0.12
Maximum Magnesium	mxMg	0.3372	-0.9414	0.79	0.12
Maximum Conductivity	mxCon	0.2435	-0.9699	0.78	0.12
Mean Copper	Cu	0.5224	-0.8527	0.86	0.13
Maximum Zinc	mxZn	0.4446	-0.8957	0.82	0.13
Mean Chromium	Cr	0.5224	-0.8527	0.86	0.14
Mean Ortho-Phosphate	OrP	0.9532	-0.3023	0.71	0.14
Mean Chloride	Cl	-0.3573	-0.9340	0.70	0.16
Maximum Chromium	mxCr	0.5224	-0.8527	0.86	0.17
Mean Sodium	Na	-0.9922	-0.1248	0.72	0.19
Mean Iron	Fe	0.3842	-0.9233	0.67	0.19
Maximum Manganese (ICPMS method)	mxMnIC	-0.4122	-0.9111	0.65	0.21
Maximum Ortho-Phosphate	mxOrP	0.0889	-0.9960	0.66	0.23
Maximum Iron	mxFe	0.2352	-0.9719	0.63	0.24
Mean Manganese	Mn	-0.4716	-0.8818	0.65	0.25
Maximum CaCO3	mxCaCO	0.1966	-0.9805	0.58	0.26
Maximum HCO3	mxHCO3	0.2029	-0.9792	0.58	0.29
Maximum pH	mxpH	-0.7501	-0.6613	0.63	0.30
Mean Magnesium	Mg	0.0904	-0.9959	0.67	0.31
Mean Manganese (ICPMS method)	MnIC	-0.6143	-0.7891	0.58	0.32
Maximum Manganese (HPLC method)	mxMn	-0.5359	-0.8443	0.57	0.41
Mean Chlorophyll-b	Cb	-0.2957	-0.9553	0.49	0.41
Maximum Sulphate	mxSO4	-0.9594	0.2821	0.44	0.51
Mean Chlorophyll-a	mxCa	-0.7751	-0.6318	0.53	0.52
Maximum Sodium	mxNa	-0.7532	-0.6578	0.49	0.55
Mean HCO3	HCO3	-0.2041	-0.9790	0.44	0.58
Maximum Chlorophyll-b	mxCb	-0.6270	-0.7790	0.74	0.62
Maximum Total Organic Carbon	mxTOC	-0.0362	-0.9993	0.41	0.69
Mean Suspended Solids	SUS	0.4089	-0.9126	0.89	0.70
Mean Calcium	Ca	-0.6200	-0.7846	0.26	0.70
Maximum Calcium	mxCal	0.0142	-0.9999	0.43	0.71
Mean pH	pH	-0.9523	-0.3052	0.36	0.71
Mean Total Chlorophyll	TC	-0.1714	-0.9852	0.66	0.72
Maximum Total Phosphate	mxTP	-0.6790	-0.7342	0.27	0.79
Mean Calcium	Cal	-0.5470	-0.8371	0.26	0.83
Maximum Dissolved Organic Carbon	mxDOC	-0.0572	-0.9984	0.18	0.86