Stuart Oil Shale Project Terrestrial and Aquatic Flora and Fauna Studies

Report 18: Biological Monitoring of Aquatic Environments –Winter 2002 Survey

to

Southern Pacific Petroleum (Development)

by
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Centre for Environmental MANAGEMENT
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Table of Contents

List of Tables

List of Figures

1.0 Executive summary

This report presents results for the winter 2002 survey of aquatic flora and fauna within the Gladstone Mt Larcom region as part of the ongoing biological monitoring for the Stuart Oil Shale Project near Targinie. In order to relate this survey to previous monitoring events, this report also presents data from all seven surveys previously conducted, including from spring 1997 to winter 2001.

A total of 15 sites were monitored in 2002. These included ten dam sites all of which are artificial dams or farm dams build across drainage lines (S1-S6 and R1-R4) and five creek pools sites (Boat Ck1, Larcom Ck1, Humpy Ck1, Scrubby Ck1 and Teningie Ck1). Dam and creek pools were seen to differ in their physical and biological compositions this year and for previous years, therefore, site comparisons were made within each habitat type.

Information presented within this report includes data on the physical and chemical attributes of water quality (e.g. pH, dissolved oxygen, conductivity, salinity, temperature, secchi depth) and the abundance of aquatic macrophytes, macroinvertebrates, fish and waterbirds at each site.

Water levels were the lowest recorded at most sites except dams S2 and S3, which receive water released from the mine site. Water quality parameters were generally similar to past measurements although conductivity at sites S2 and S3 continued to increase and measurements were beyond ranges previously recorded. Macroinvertebrate family richness decreased at most sites and this is though to be reflective of lowered water levels and drought conditions. Chironomid relative abundance increased at most sites, most likely reflective of the higher tolerance of these invertebrates to factors associated with decreased water level (for example, fluctuations of water quality and decreased macrophytes). Site S2 showed a high decline of sensitive taxa (from nine to three species) possibly due to the decrease in water quality (increase in conductivity), however general richness was maintained most likely due to a comparatively stable water level.

Relationships between water level, physico/chemical, macrophyte and macroinvertebrate parameters were explored to give insight into interactions between biological parameters and aids interpretation of changes within data over time. Several relationships were seen to be habitat specific (interactions within dams differed from those within creeks), highlighting the necessity of restricting sites comparisons to each habitat.

The incidence of biotic decline apparent at most sites within this survey is thought to be due to the ongoing drought, an effect which was amplified in creeks sites. However, the decreases in water quality and sensitive taxa at sites S2 and S3 (in view of these sites proximity and receiving influence from the mine) emphasise the possibility of negative impact and warrant further monitoring.

2.0 Introduction

This report presents the results for the winter 2002 survey (10th to 14th July) of aquatic fauna and flora within the Gladstone – Mt Larcom region as part of the ongoing biological monitoring for the Stuart project near Targinie. Previous monitoring was undertaken in spring 1997, summer and winter 1998, summer and winter 1999, winter 2000 and winter 2001 (Houston *et al.* 2000a,b,c,d, Price *et al.* 2001, Rogers *et al* 2002). In order to relate this survey to previous monitoring events, this report also presents data from all seven surveys previously conducted.

Fifteen sites representing a cross section of the aquatic environments that lie within the Southern Pacific Petroleum Stuart Stage 1 and 2 Mining Lease (ML80003), the Stage 2 Mining Lease Application area, and the surrounding district were monitored during the winter 2001 survey. Twelve of these 15 sites were monitored in earlier surveys (Houston *et al.* 2000a,b,c,d, Figure 1). Three additional sites were introduced in the winter 2000 survey including 'Hart's Dam' (S6) an artificial dam within the Targinie amphitheatre, and Scrubby and Teningie Creeks both riverine (creek pool) sites representing up-catchment conditions prior to and after the proposed Stage 2 development.

To accommodate further requirements for Stage 2, some modifications to the monitoring programme were made. These included removal of site designations as sentinel or reference based on proximity to the mine site but retention of geomorphological designations as "dam" or "creek" sites. The sentinel designation was originally designed to identify sites within catchments receiving runoff from current and planned Stage 1 mining activities, however, it was recognized that all sites (both sentinel and reference) could receive indirect impacts such as air shed outfalls. Furthermore, with the planned expansion of the mine under Stage 2, Boat and Humpy Creeks (formerly designated as reference sites) could be directly influenced by Stuart Oil Shale mining activities. The new approach overcomes these problems and allows unbiased interpretation of how the sites "fall out" in regard to health, based on specific physico-chemical and biological parameters. It also recognizes the possible influence of other developments in the region on previous "reference sites".

3.0 Study Area

Site details including GPS locations are provided in Appendix 1. Specifically, the study area included the catchments of Boat, Humpy, Larcom, Scrubby and Teningie Creeks with several additional unnamed drainage gullies on the Stuart mining lease. All of the ten dam sites were farm dams or gullies formed by embankments across drainage lines. Two of these, R2 and R3, were considerably smaller than the other 6 dams. The creek sites sampled in this survey were ephemeral pools and included Boat Ck1, Humpy Ck1, Larcom Ck1, Scrubby Ck1 and Teningie Ck1. Most dam and creek sites are affected by current land-use activities within their catchments including:

- cattle grazing – stock watering, trampling of waterbody edges and possible increased sediment and nutrient inputs;
- horticulture – drift and runoff of pesticides from crops, pumping for irrigation and nutrient inputs; and
- domestic – pumping.

On the Stage 1 Mining Lease several land management activities are associated with the Stuart Project:

- Forestry activities within the Stage 1 mining lease commenced in mid-1997 and finished mid-1998 and encompassed catchments of gullies B, C and D. Selective clearing practices were used and land was disturbed by track construction and tree-fall.

- Clearing of land for the plant site on the Stage 1 mining lease commenced in August 1997 but did not impinge on catchments of gullies B, C, D or E.

Clearing of land for the mine commenced in June 1998 affecting only the catchment of Gully C.

- Damming of Gully C below the mining pit occurred in November 1998 to allow settlement of excess sediment from the water prior to its release back into Gully C. This water also included groundwater from the mining pit (mine-water).
- Possible occasional airshed inputs (e.g. SO_x, NO_x, hydrocarbon etc.) associated with testing of the processing plant prior to full-scale operation of the mine and processing plant.

Thus, in addition to potential impacts from land-use practices, dam sites S2 and S3 could potentially be affected by:

I. clearing of the mine site;

II. changes in flow regime;

III. changes in water quality associated with the incorporation of groundwater into the surface run-off water released into Gully C following settlement of suspended solids and

IV. airborne pollutants including gaseous emissions, ash, and other carbon-based particulates.

4.0 Methodology

Site assessments included general site descriptions, physical and chemical analysis of water quality and surveys of assemblages of aquatic macrophytes, macroinvertebrates, fish and waterbirds.

4.1 Site Description

Site dimensions and dominant physical characteristics were described. The vertical distance between a fixed reference point and the surface of the waterbody represented the change in water level and was measured with a clinometer and a measuring pole placed at the water's edge. Site photographs were taken from a reference point and any recent disturbances such as cattle or water extraction were noted. A site diagram was made in order to record details of where each type of sample (e.g. macroinvertebrates; fish) was taken and these same locations within each site were then revisited on subsequent sampling occasions.

4.2 Water Quality

Water quality parameters recorded at each site included pH, conductivity, dissolved oxygen and temperature, within the surface 30 cm of water (Horiba U10 Water Checker). The mean value of five replicates for each parameter at each site was used as the values for these parameters. The time of day was recorded to assist in interpreting results and sampling was conducted prior to activities likely to alter the water quality. Results for dissolved oxygen are presented in % saturation (in order to compare results with National Water Quality Management Strategy (NWQMS) guidelines), mg/L (Figure 4) and both % saturation and mg/L for comparative purposes (Appendix 4). The relationship used to convert mg/L to % saturation was:

- % saturation (dissolved oxygen) = (oxygen mg/L) * (32.6 + temperature °C) / (482.5-(salinity ‰ * 0.003-(2.6 * temperature °C * 10^{-5}))) * 100

To assess possible impacts, NWQMS guidelines were followed if possible (NWQMS 1999). With the exception of dissolved oxygen for all waterbody types, and conductivity and pH for lowland creeks, water quality guidelines were largely undefined for the majority of site types (mostly farm dams) investigated in this study. For dissolved oxygen, a trigger level of 90% saturation was defined by NWQMS (1999) for all waterbody types including wetlands (the waterbody type most closely resembling farm dams). For the remaining parameters, a "fall out" approach was taken based on comparison of waterbodies of similar morphology (eg comparison among dam pools and comparison among creek pools). Hence the 'triggers' for changes in pH and conductivity at sites were values that far exceeded the norm for that waterbody (comparison of past data) or waterbody type (comparison to other water bodies of similar morphology).

The strength of associations between selected physico/chemical parameters and the composition of macroinvertebrates and macrophytes were later examined by correlation analysis.

4.3 Aquatic Macrophytes

Aquatic macrophyte species at each site were either identified in the field (Sainty and Jacobs 1994), or a sample of each collected for identification by the Queensland Herbarium. Along creek pools, collections were confined to a 50 m reach encompassing the site.

To characterize the habitat where the invertebrates were sampled, the average percentage contribution of plant species present in six 1m² quadrats was recorded. Each quadrat was randomly positioned along the bank. The growth habit of plants was classified as emergent, floating-attached, free-floating or submergent according to Sainty and Jacobs (1994).

4.4 Aquatic Macroinvertebrates

Aquatic macroinvertebrates were sampled using kick nets (a triangular frame, 35 cm along the base and 30 cm sides, supporting a bag comprising 0.3 by 0.9 mm mesh) and standard techniques (Duivenvoorden 1995). At each site three replicate, one-minute kick net samples were collected from shallow waters along the edge of the river banks (30 to 70 cm depth). Previous studies had shown that three replicate samples were sufficient to characterize taxonomic richness and abundance of invertebrates at a site (Houston *et al.* 1999). Collected material was preserved in 100% ethanol and returned to the laboratory for processing. The samples were then sorted and specimens identified to family level using the keys of Williams (1980) and Dean (1991). Samples were retained for future reference at Central Queensland University. From this data family richness (total number of macroinvertebrate families present) and abundance (total number of individuals) was calculated.

4.5 Vertebrate Fauna

Fish assemblages were assessed by catching fish in small baited traps and a seine net where possible and recording numbers and species captured. Incidental observations were also recorded. The fish traps comprised rectangular frames (450 mm long, 250 mm wide and 250 mm deep) covered in 3 mm mesh and baited with aquarium fish pellets. Eight fish traps were set for two hours in a minimum depth of 40 cm among macrophytes where possible. Traps were checked after two hours and all fish identified and counted.

The seine net (12 mm nylon mesh) was 10 m long and 2 m deep. Where possible, the net sampled a portion of the bank's edge 10 m long by 5 m wide. If this was not possible we sampled 50 m^2 of shallow waters near the bank's edge. The physical characteristics of some sites restricted the use of the seine net and sites with extensive thick macrophyte growth, excessive fallen tree debris or depths greater than 1.5 m could not be sampled with the seine net.

All fish captured were identified in the field and counted. Most were returned to the water, however two specimens of each species were retained for verification of the field identifications. Fish were identified using keys in Allen (1989). From this data species richness (total number of fish species recorded from all sampling methods at a site) and species relative abundance (total number of fish captured in the eight bait traps at each site) was calculated.

4.6 Avian Fauna

Waterbirds were observed opportunistically immediately after arriving at a site and identified using Slater et al. (1994). During the remainder of the site survey, any other waterbirds that approached the site were recorded. The cumulative number of birds per site was later calculated.

4.7 Statistical Analysis

Spatial and inter annual differences between fish and avian communities at the fifteen stations were examined using Bray-Curtis (B-C) dissimilarity measures (Bray and Curtis 1957). The B-C dissimilarity measure is given by the following relationship:

$$\delta_{jk} = \frac{\sum_{i=1}^{s} \left| nij - nik \right|}{\sum_{i=1}^{s} \left(nij - nik \right)}$$

where n_{ij} = the number of the *i*th species in the *j*th sample, n_{ik} = the number of the *i*th species in the *k*th sample and δ_{jk} = dissimilarity between the *j*th and *k*th samples summed over all *s* species.

For each annual or biannual sampling period the total numbers of individuals of each species was calculated for each site (i.e. data from the three invertebrate replicates were summed). Fourth root transformations were applied to all data before calculating B-C dissimilarity measures. These transformations were made to prevent abundance species form influencing the B-C dissimilarity measures excessively (Clarke and Green 1988, Clarke 1983).

Bray-Curtis dissimilarity measures calculated (for all fifteen sites) resulted in a triangular matrix, which was used to map the site inter-relationship in two dimensions using multidimensional scaling (MDS). MDS plots a measure of similarity between objects in two or more dimensions so the distances between objects correspond closely to their similarities and ecologically meaningful patterns become more apparent (Gamito and Raffaelli 1992). The computer package PRIMER (Clarke and Gorley 2001) was employed for ordinations in this study. The final configurations presented are the best solutions (i.e. exhibited the lowest 'stress' values or least distortion) from a minimum of 50 starts.

The statistical significance of regional and inter-annual differences in freshwater macroinvertebrate family abundance and richness was examined using two-way fixed factor analysis. In the ANOVA models, sampling regions were derived from station groups recognised in MDS ordinations, while the eight sampling surveys comprised the other fixed factor (year). Homogeneity of variance was examined using Levene's test and heterogeneity removed using a fourth root transformation when necessary.

4.8 Water level, physico/chemical, macrophyte and macroinvertebrate relationships

The strength of associations between macroinvertebrate family richness and abundance, physico/chemical parameters and the composition of macrophytes and birds present were examined using Pearson's correlation analysis (Zar 1984).

5.0 Results

5.1 Site description

An index of water levels for this and previous surveys and the change in these water levels from the 2001 winter survey is shown in Table 1. It is clear that with the exception of S2 and S3, the level of water at all sites is very low compared to previous years and indicative of extended drought conditions. Sites S2 and S3 are located within Gully C and receive surface runoff and ground water released from the mining site following settlement of suspended solids. Some of the variability seen in water level decreases could indicate differences in dam size or local rainfall but most likely also reflect factors that vary locally including pumping (R2), stock watering (S4,R1,R2,R3,R4, LarcomCk1) and groundwater recharge differences.

Comparison of photos with the previous survey showed that there were slight increases in macrophytes at S1, S4, S6 and R1. Other sites deceased in macrophyte cover (S3,R3,R4, BCK1,LCK1,SCK1,TCk1) or remained similar to the previous year (S2,S5,R2,HCK1).

5.2 Water Quality

Mean values for pH, conductivity, dissolved oxygen, salinity and temperature are provided in Table2, while raw data is presented in Appendix 4. No water quality measurements were taken at R3, as water depth at this site in July 2002 was too low to permit sampling.

- Although pH values were quite high at many sites (>8.0 at sites S4, S6, R2, R4, LarcomCk1 and Scrubby Ck1), most values were similar to the previous survey and within the range of measurements taken in the past. Exceptions were dam S6 where pH was substantially lower than previously measured (decrease of 1.2) and Scrubby Ck1, where pH was considerably higher (increase of 2.8).
- Conductivity fluctuated within farm dams in July 2002; measurements at some dams increased compared to the previous year (S1, S2, S3, R1) while others decreased (S4, S5, S6, R2, R4). Measurements at sites S2 and S3 were beyond those previously recorded for these sites and were high compared to other dam sites. Conductivity levels increased at all creek sites from 2001 measurements except LarcomCk1 where conductivity decreased by 400uS/cm. Conductivity measurements at LarcomCk1 have constantly been considerably lower than that of other low lying coastal creeks

within this study. There was a large increase in conductivity at this site in 1999 and 2000 and subsequent decrease over latter years is suggestive of saline groundwater intrusion at this site in 1999 and 2000. Greatest conductivity increases were at TeningieCk1 and BoatCk1 (674.0 and 396.0 respectively) and the increase at Teningie Ck1 exceeded the NWQMS compliance level for lowland creeks of a 500 µS increase.

- Of the nine dam sites sampled, five (S2, S4, R1, R2, R4) reached compliance with NWQMS standards for percent dissolved oxygen of 90% saturated. Percent dissolved oxygen levels at other dams were close to guidelines (S1-85%, S3-72.5%, S5-83.2%) except S6 where percent DO decreased by 144% from July 2001 to a low of 39.6% dissolved oxygen. Dissolved oxygen at creek sites decreased to or remained at non-compliance levels except Scrubby Ck1 where oxygen levels were measured at 106.8%.
- Temperature increased at most dam sites (S2, S3, S4, S5) by up to 4.9°C between winter 2001 and winter 2002 and decreased at others (S1, S6 and R1) by up to 3.9°C. In contrast all creek sites showed temperature decreases of 0 to 2.8 °C.
- Unfortunately salinity was not recorded (why) at two dam sites (S6 and R3) and four creek sites (Boat Ck1, Humpy Ck1, Scrubby Ck1 and Teningie Ck1) in the winter 2002 survey. However, for sites where salinity data are available, no changes occurred from the previous year.
- Secchi depth was high at most sites where data was available, often exceeding maximum pond depth. Clarity was decreased at R2 however, where secchi depth was reduced from 2001 by 20cm. Unfortunately secchi depth was not recorded at site S6 and depth at R3 did not permit sampling. A > sign depicts where secchi depth was greater than maximum depth of the sampling area.

5.3 Aquatic macrophytes

A total of 30 species of macrophytes was found in association with the fifteen freshwater dam and creek sites in the 2002 freshwater survey (Table 3). Species richness ranges from 1-12 species at dam sites and 3-6 species at creek sites. The most commonly encountered macrophytes were *Persicaria decipiens*, *Nymphaea violacea* and *Nymphoides indica*, each occurring at 8 of the 15 sites (7 dam, 1 creek). *Potamogeton crispis* was the next most frequently encountered macrophyte, occurring at 7 of the 15 sites (5 dam, 1 creek) followed by *Potamogeton pectinalis* occurring at 6 sites (4 dam 1 creek).

In general total macrophyte cover was low compared with previous years, although total cover at some sites increased marginally (S1, S4, S5, R2 and HumpyCk1) or substantially (S6 and R1) from the 2001 winter survey.

Quantification of macrophyte cover from within the invertebrate sampling area at each site (Table 4) showed that the majority of dams were dominated by floating attached macrophyte cover. Exceptions were sites S2 and S3 where emergent vegetation dominated and S6 and R2 where submerged vegetation was the prevailing guild. Conversely, a range of macrophyte habit guilds dominated creek sites (BoatCk1-floating attached, TeningieCk1-emergent, LarcomCk1 and Scrubby Ck1-submerged and HumpyCk1-floating). Only one dam (S6), of the fifteen freshwater sites, recorded a greater percentage of macrophyte cover than open water in the invertebrate sampling area (Table 4).

Charophytes are macroscopic green algae with relatively complex reproductive structures and are widely regarded as plants sensitive to changes in turbidity (Schwarz *et al* 1999, Cassanova and Brock 1999a). Two species of charophyte were recorded in the 2002 winter survey –

Nitella, found only at S3 and ScrubbyCk1 and *Chara vulgaris* – present at sites S1, S5, ScrubbyCk1 and Teningie Ck1.

5.4 Aquatic Macroinvertebrates

A total of 17 orders and 72 families been found over the past 8 surveys with 14 orders and 41 families represented in the current survey (Table 5). Absent orders included Colembolla, Neuroptera and Megaloptera. Diptera (flies, mosquitos, midges) was by far the most abundant order representing 71.5% of the total abundance. Gastropoda (snails) were the next most frequently collected taxa (8.6%), followed by Hemiptera (bugs - 7.2%), Odonata (dragonflies – 4.4%), Ephemeroptera (mayflies – 3.2%) and Coleoptera (beetles – 2.7%). Remaining orders contributed less than 1% to total abundance. As in previous years larvae of the chironomid flies dominated the Diptera constituting 65.4% of the total catch of all invertebrates.

Abundance was highly variable between sites and was principally driven by numbers of Diptera, which were the dominant taxa at every site (Table 6). The next two most dominant taxa were frequently Gastopoda and Hemiptera and less frequently Coleoptera, Ephemeroptera, Odonata and Decapoda (Table 7). Family richness was also highly variable (R3 - 10 to S6 –23) across waterbodies and the range was slightly higher within dams (10-23 families) than creeks (11-22 families). Further to this there was a general decline in family richness from the previous year and richness values in most creeks (Boat, Humpy, Larcom, Teningie) and one dam (R3) were the lowest recorded throughout the duration of this study (1997-2002) (Table 7).

Tolerant taxa

Diptera from the family Chironomidae are known to be tolerant to disturbance, due in part to their adaptations to low oxygen conditions, which makes them an ideal indicator of oxygen depleted conditions (Jeffries and Mills 1990, Williams 1980, Resh *et al* 1995). The major proportion of total abundance at each site throughout this study was from the above family (Table 8).

Sensitive taxa

It is well known that Bivalvia, Decapoda, Ephemeroptera, Gastropoda and Trichoptera are widely regarded as either disturbance tolerant or sensitive to stream acidification (references in Houston *et al* 1999). Table 7 shows the change in taxa richness of these taxa for the duration of this study. The single Bivalve family represented within this study has been typically present in low abundance at both Larcom Ck1 (found only at this site in the present survey) and Boat Ck1 and was found at R1 in earlier years. Decapod richness was lower than usual at several sites (S1, S2, S3 and Boat Ck1) in 2002. Particularly noteworthy is the absence of this order from S1 where in the past both families have been represented. Ephemeroptera were also absent from S1 where this taxa is usually present, however, at most sites richness of this order remained the same as the previous year. Gastropods were well represented at S1 (3 families present) but generally decreased at most sites from 2001. This was similar for Trichoptera where 10 sites suffered losses in richness, some substantial (Table 6). When changes in family richness of the five sensitive taxa were pooled (Table 6) there was a net change from a loss of 6 families (S2) to a gain of 2 families (S4) within dam sites. Creek sites recorded a net loss of 7 families (Humpy Ck1) to a gain of one family (Scrubby Ck1).

Results of a two-way ANOVA to assess differences in macroinvertebrate abundance between sampling dates and sites are presented in Table 9a. This table shows there were significant differences ($p<0.001$) in abundance between both sampling dates and stations and additionally, significant date*station interaction. A plot of marginal means aids interpretation of this result (Figures 2a, b and c). Post-hoc Student-Newman-Keuls analysis (Table 9b) indicated that abundance was significantly higher at sites R3 and S6 than at all other sites. From observations of the mean abundances of individual orders it is clear that much of the elevated abundance at these sites is the primarily the result of high densities of Dipterans (Table 6) at these sites.

Post-hoc Student-Newman-Keuls analysis shows that estimates of macroinvertebrate abundance for each sampling date differ significantly (Table 9c). It is apparent that collective invertebrate abundance in summer-99 was significantly lower than all other years. In assessing mean abundances of individual orders it appears this is primarily due to decreased numbers of chironomid Dipterans in summer compared to winter months. This is confirmed by the highest abundances occurring in winter 98, winter 2001 and winter-2000. Spring 97, winter 02, autumn 98 and winter 99 were in a medium subset for abundance.

Analysis of variance was also used to formally test the statistical significance of date and site on invertebrate species richness. There was significant ($p<0.001$) date, station and date*station terms (Table 10a, marginal means plotted in Figures 3a, b and c). A post-hoc Student-Newman-Keuls test for differences in richness between stations (Table 10b) revealed that invertebrate richness was significantly lower at stations Teningie and Humpy Ck1 than all other stations. Despite the large number of subsets, differences in richness between remaining were not significant. Post-hoc Student-Newman-Keuls test for differences in richness between dates shows that invertebrate family richness was significantly lower in winter 02 and winter 98 than all other years (Table 10c). This table also shows that richness was significantly lower in winter02 than in winter 98.

In light of the highly variable nature of family richness and abundance over the duration of this study, correlation analysis was undertaken to better understand driving forces behind changes and to determine the existing relationships between macroinvertebrate richness and abundance and physico/chemical and macrophyte parameters. This will be addressed in section 5.7 - Water level, physico/chemical, macrophyte and macroinvertebrate relationships.

Macroinvertebrate community analysis

The family level ordination including all invertebrate data was seen in previous years to show an ecological gradient that was influenced by the habitat type and this separation is basically maintained, although less clear, with inclusion of 2002 data (Figure 4). This ordination (including data from 1997 to 2002) is also strongly influenced by the effect of season, with winter surveys separating from spring, summer and autumn surveys (Figure 5). To counter these habitat and seasonal influences the winter dam sites only were compared and in the resultant plot no structural patterns are apparent that can be explained by spatial or temporal variation in invertebrate family community structure (Figure 6).

5.5 Vertebrate Fauna

A total of six species of fish were recorded from the fifteen freshwater sites sampled during winter 2002 (Table 11a and 11b) with 13 species of fish cumulatively recorded at these sites since 1997. The most widely distributed species in 2002 were *Ambassis agassizii* (Agassiz's Perchlett) and *Hypseleotris spA* (Midgley's Gudgeon), each occurring at five of the fifteen sites. *Melanotaenia splendita splendita* (The Rainbow Fish) and the *Hypseleotris compressus* (Empire Gudgeon) were found at three sites and *Gambuisa holbrooki* was encountered at two sites. The remaining fish species were present at one site only.

Creek sites once again displayed the greatest species richness (HumpCk1 –four species and LarcomCk1 – three species). At remaining sites one or two species were found, except sites S1, S2 and R3 where no fish were captured or sighted. The lack of fish for a second consecutive year at S2 and R3 contrasts with previous captures at these sites.

In general, species diversity across all fifteen freshwater sites was low in winter 2002 compared to previous years, reflecting the influence of the extended dry season. Species richness at all dam and creek sites decreased or remained the same as the previous year (except S3 and LarcomCk1 where species richness increased slightly). Fish abundance at dam sites was also quite low compared to previous years. At the majority of dam sites abundance decreased from the previous year (S4,S6,R1,R2,R4) or remained at zero (S1,S2,R3), although numbers of fish at S3 did increase. Conversely, fish abundance increased at all creek sites except HumpyCk1 where abundance declined. In contrast to past surveys where dams have contained the highest numbers of fish, a creek site in winter 2002 (Humpy Ck1) had the greatest fish abundance.

Pisces community analysis

The species level MDS ordination of 1997-2002 data shows a pronounced ecological separation into two zones that appears to be influenced by the habitat of the water body (dam or creek) (Figure 7a). While most of the observed inter-zonal dissimilarity is due to the occurrence of different suites of species within dams and creeks, there is also a general decline in abundance (Figure 7a) and increase in species richness (Figure 7b) from one zone (dam sites) to the other (creek sites). The dam sites are, for example, typically dominated by elevated abundances of one or two species, whereas creek sites frequently contain three or four species in lower numbers. Furthermore, some individual sites tend to cluster through the years indicating presence of similar species assemblages (Figure 8).

5.6 Avian Fauna

There were a total of thirteen species of waterbird sighted across all fifteen freshwater sites in the 2002 winter survey, with 25 species of bird cumulatively recorded at these sites since summer 1998. The most frequently encountered species was the Black Duck, observed at six sites, followed by the Eastern Swamp Hen, White-faced Heron, White Egret and Darter (each found at four sites) and the White-eyed duck or Hardhead and Pied Cormorant (three sites). Remaining species were present at one or two sites only.

Species diversity was generally high in winter 2002 compared to previous years. Dam sites contained higher species richness compared to creek sites, reflecting the influence of the extended dry season on the activity of birds (Table 12). Sites S5 recorded the most bird species (six species) followed by S4, S6 and S2 (five species) and R1 (three species). At remaining sites (S1,S2,R2,R3,R4, BoatCk1, LarcomCk1, HumpyCk1, ScrubbyCk1 and TeningieCk1) one, two or no birds were noted.

Across all sampling surveys the highest cumulative number of birds recorded was at sites R4 and S5 (twelve species), followed by S2 and S4 (nine species) and R1 and S3 (six species). Cumulative numbers of birds were higher in dams than creeks (range 3-12 of compared to 0-4) and have been since onset of sampling. Waterbirds have only ever been observed at two (LarcomCk1 and ScrubbyCk1) of the five creek sites.

Avian community analysis

Presence/absence data was used to assess the community structure of birds over the 8 year survey. Sites S3W99, LS99, R4W02 and S3W00 appeared as extreme outliers (due to different species being present at these sites) and were therefore removed from the analysis. On removal of these outliers there are no structural patterns apparent that can be explained by spatial or seasonal variation in community structure (Figure 9).

5.7 Biotic Decline Score

To enable comparisons within dam and creek sites over a range of biotic variables, selected indices were tabulated and incidence of decline was summed to achieve a Biotic Decline Score (Table 13). The biotic decline scores ranged from 1(S5, S6, R1) to 5(R3, R4) within dam sites and 3 (LCK1, SCK1) to 6 (BCk1) within creek sites.

5.8 Water level, physico/chemical, macrophyte and macroinvertebrate relationships

Dams

Correlation results of relationships between water quality parameters, macroinvertebrate indices and macrophyte indices at SPP dam sites are presented in Table 14. Most water quality parameters at dam sites did not vary with water level, however a positive significant relationship existed between water level and conductivity. This would suggest that at dam sites increased conductivity levels are representative of turbidity associated with surface runoff (ions entering a water body increase with rain especially in cleared areas). The pH in dam sites varied positively and significantly with dissolved oxygen and submerged macrophytes (as for creek sites). Other relationships between physico/chemical variables included conductivity and salinity (as expected). Total macrophytes were significantly correlated with invertebrate family richness, and water level varied positively (and significantly) with the number of taxa present in dam sites. Abundance of invertebrates varied significantly with pH, conductivity, and salinity and negatively with temperature.

Creeks

Correlation results of relationships between water quality parameters, macroinvertebrate indices and macrophyte indices at SPP creek sites are presented in Table 15. Physico/chemical parameters at creek sites failed to show significant relationships with water level. The existing relationships between various phys/chem parameters and macrophytes present were most likely related. For example ph correlated significantly with conductivity, submerged macrophytes and dissolved oxygen (as for dam sites) and temperature varied with conductivity. Submerged macrophytes also varied with salinity and dissolved oxygen, and total macrophytes (representing a group in which submerged macrophytes is a considerable contributor) exhibited similar relationships (dissolved oxygen, salinity).

Unlike dam sites, water level or macrophytes in creeks showed no relationships with taxa richness but taxa richness and percent chironomid abundance varied significantly with several phys/chemical parameters. Family richness and chironomid abundance varied significantly (negatively and positively) with conductivity and salinity in creeks. This suggests that slightly saline values at most creeks prove unfavourable to some invertebrate families but chironomids are more tolerant of these conditions. Furthermore, chironomid relative abundance drops significantly in summer as shown by the negative relationship between temperature and percent chironomids.

6.0 Discussion

Relationships in dams and creeks

Past reports found that dam communities were different to creeks in terms of macroinvertebrate assemblages. This was further tested by exploring relationships between water quality, macrophytes, macroinvertebrate abundance and richness separately for creeks and dams. When examining the results of this test it was obvious that many significant ($p<0.05$ or $p<0.001$) interactions were habitat specific. The differences in relationships between habitat types further highlight the inadequacy of directly comparing results between creek sites and dam sites.

Interpretation

Relationships that were significant in both habitats were pH and DO%, submerged macrophytes and pH, conductivity and salinity, conductivity and family richness and salinity and family richness.

Disparate relationships with conductivity exist for each habitat type. Conductivity increased with water level in dams signifying that conductivity is related to an increase of ions (nutrients, chlorides) associated with water runoff. In creeks conductivity was inversely related to temperature, suggesting that in summer months conductivity was lower than in winter months and vice versa. In view of the increased rainfall generally associated with summer, it is likely that creeks are susceptible to groundwater intrusion that is diluted by rainfall or runoff in summer months and concentrated in colder, dryer seasons. With this knowledge in mind, increases in conductivity can be interpreted two ways; for dams' periods of rain result in increased runoff containing ions (chloride, phosphate and nitrate) which are detected as high conductivity values (Waterwatch Australia 2002). For creeks, increases in conductivity may relate to extended dry periods, water evaporation and resultant increased concentration of ground water ions in the water body (Williams 1973).

A significant positive relationship between submerged macrophytes and pH was consistent for both habitats and may be explained by the process of photosynthesis (during daily photosynthesis plants absorb carbon dioxide from the water causing water to become more alkaline and increasing water pH (Raven and Johnson 1992)). Large differences in pH would influence presence of submerged macrophytes but changes over this survey were minimal and therefore more representative of photosynthetic processes. Therefore, pH was also highly significantly related to the amount of dissolved oxygen present. The significant relationship between pH and conductivity in creek sites is harder to explain. This relationship is relatively weak ($p<0.05$ $r^2= 0.15$) and most likely reflects the influence of other variables.

Significant relationships between conductivity, salinity and family richness contrast across habitats and require further investigation. These significant associations are stronger ($p<0.001$) and positive in dams (taxa increase with salinity) and weaker ($p<0.05$) and negative in creeks (taxa decrease with salinity). This result is thought to be due to the much higher conductivity levels in creeks exceeding threshold levels of tolerance by infauna.

The relative importance of macrophytes for taxa richness in dams and creeks varied. For example in dams the relationship between macrophytes and taxa richness was significant at a high level (<0.01), but no such relationship existed in creeks. Studies elsewhere have found presence of macrophytes to significantly influence invertebrate community structure (Gregg and Rose 1985).

Individual site assessment

Creek sites showed the greatest incidence of biotic decline and Boat and Humpy creeks fared worst with scores of 5 and 6 consecutively. The decline in invertebrate families at these sites, including the decline in taxa of sensitive species, may be due to high conductivity values (confirmed by the negative richness*conductivity relationship within creeks) at these sites and, perhaps more influentially, the very low dissolved oxygen content. In previous years low oxygen content at these sites corresponds with decreased taxa (winter99 winter00 at HumpyCk1 and spring97, summer98 at Boat CK1).

Dam sites with highest values of biotic decline include R3 and R4 (scores of 5). The reasons for these declines are obvious when examining site photos. R3 exists as merely a springfed puddle in 2003, with water levels too low for water quality measurements and almost a complete lack of aquatic macrophytes. Astoundingly, (given the conductivity values in the past) some sensitive invertebrate taxa were still present at this site in 2002 (richness in dams was significantly related to water level and total macrophytes). Water levels at R4 would also influence presence of macroinvertebrate taxa and the large decrease in aquatic vegetation is also thought to be an important contributing factor.

Despite common fluctuations in physico/chemical parameters, values were generally within ranges shown in the past and generally indicative of healthy water bodies. Conductivity generally increased across sites and the increases at Scrubby and Teningie Creeks were beyond the NWQMS guideline (<500uS increase). Increases at creeks were thought to be the result of concentration of ions due to evaporation due to extremely low water levels. This theory is supported by the negative relationship between conductivity and temperature, indicating that conductivity is highest in winter, (a time of low rainfall) due to concentration of ions. Ground water intrusion could negate the relationship between water levels and conductivity in creeks, as evaporation combined with groundwater intrusion would not affect water levels but would increase conductivity concentrations.

Conductivity at dam sites S2 and S3 were the highest ever recorded. These two sites receive water released into Gully C from the mine water management system and S2 was the only site where water level actually increased in 2002. The increase in conductivity at these sites from winter 2001 is suggestive of a decline in the quality (increase in ions) of water released from the mine management system. Alternatively, increased flow into these water bodies may cause resuspension of benthic sediments and associated conductivity flux. The decrease in sensitive taxa from nine to three species at Site 2 was possibly related to the conductivity increase, however, general family richness was maintained most likely due to a comparatively stable water level.

The seasonal and site differences in macroinvertebrate abundance were strongly influenced by the numbers of chironomids. Chironomids dominated both dam and creek invertebrate assemblages in the 2002 winter survey.

General

The decreases in some health parameters measured within this survey are thought to be a result of the ongoing drought. Another study in the region investigating macroinvertebrates families in farm dams (The Yarwun Targinnie Sustainability Project) yielded similar results (low species diversity) when water levels in dams and creeks were low. Effects from lowered water levels appear to be more concentrated in creeks (as apparent from water quality and invertebrate results) than in dams. The possible negative influence of water released from the mine site into dams S2 and S3 (apparent as increased conductivity levels) appears to be offset by the maintenance of a relatively stable water level in comparison with other dam sites, although sensitive taxa declined at this site. These results are suggestive of caution and further monitoring of these water bodies in the future is recommended.

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Table 1. Water level index (vertical distance from a reference point to a water body surface) and change in water level index in the water body (cm): a plus sign indicates water level rise, a minus sign indicates a fall.

Site	Spring 97	Summer 98	Winter 98	Summer99	Winter99	Winter00	Winter 01	Winter 02	Water level
Dam Sites									
S1	400	300	400	230	335	315	415	965	-550
S2	280	265	295	127	124	111	135	87	+24
S3	270	307	320	105	79	105	128	190	-85
S4	180	155	200	100	108	88	128	226	-138
S5	340	340	400	248	284	260	387	570	-310
S6	ns	ns	ns	ns	ns	183	245	1000	-817
Creek Sites									
R1	310	304	345	193	160	175	205	960	-785
R2	450	402	497	264	320	343	445	1755	-1412
R3	145	143	145	148	150	155	170	900	-745
R4	455	475	725	343	270	384	475	890	-506
Boat Ck1	280	292	275	270	265	250	272	630	-380
Larcom Ck1	ns	250	270	235	240	262	367	1790	-1528
Humpy Ck1	nr	ns	ns	nr	330	312	275	354	-42
Scrubby Ck1	ns	ns	ns	ns	ns	245	248	625	-380
Teningie Ck1	ns	ns	ns	ns	ns	325	522	1090	-765
Average	311	294	352	206	222	234	294	802	-561

Table 2: Seasonal change in water quality parameters from 1997 to 2002. Each value represents an average of five readings for each of the 15 sites.

Parameter	Survey	S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	Boat Ck1	Larcom Ck1	Humpy Ck1	Scrubby Ck1	Teningie Ck1
pH	Audit 97	9.2	7.0	5.9	8.9	6.2	ns	7.3	9.6	8.0	9.1	8.4	ns	7.4	ns	ns
	Summer 98	6.8	6.6	6.8	9.0	6.6	ns	7.2	9.4	8.1	7.3	7.1	7.1	ns	ns	ns
(NWQMS guideline = 6.6-8.0 #)	Winter 98	9.7	7.8	6.8	9.0	8.1	ns	8.0	9.7	8.9	8.9	7.4	7.0	ns	ns	ns
	Summer 99	6.4	7.1	7.1	6.9	6.5	ns	7.9	8.9	7.3	8.7	6.9	6.8	ns	ns	ns
	Winter 99	6.4	7.2	7.1	7.8	6.3	ns	6.6	6.8	6.9	6.9	7.2	7.1	6.6	ns	ns
	Winter 00	7.2	7.8	7.6	9.7	6.9	9.3	7.7	7.4	8.1	8.3	7.8	8.2	7.8	8.0	7.9
	Winter 01	6.9	7.0	7.1	9.1	7.8	9.6	7.7	7.3	8.2	7.3	7.3	7.3	7.1	7.8	7.9
	Winter 02	7.7	7.6	7.3	8.8	7.2	8.4	7.9	8.1	nr	8.2	7.1	8.1	7.3	10.5	7.6
Change from previous season		0.8	0.6	0.2	-0.3	-0.6	-1.2	0.3	0.8	-	0.9	-0.2	0.8	0.2	2.8	-0.3
Conductivity (uS/cm)	Audit 97	250.0	1268.8	1292.6	348.5	234.0	ns	1379.0	310.5	1946.5	266.8	3797.5	ns	7705.0	ns	ns
	Summer 98	260.8	1082.6	1254.0	517.4	226.2	ns	1041.6	262.8	2522.0	255.0	3218.0	416.2	ns	ns	ns
(NWQMS guideline = 500 increase #)	Winter 98	221.0	858.0	989.6	492.4	198.8	ns	980.6	240.0	2194.0	258.0	2920.0	343.6	ns	ns	ns
	Summer 99	149.2	250.2	356.8	162.8	125.2	ns	1276.0	140.0	2566.0	192.4	2144.0	450.8	ns	ns	ns
	Winter 99	159.0	592.8	541.6	114.6	115.2	ns	575.6	152.0	2370.0	160.6	3014.0	2042.0	6526.0	ns	ns
	Winter 00	175.5	1130.0	1084.0	153.5	96.3	1323.33	423.0	141.0	3338.3	173.7	3256.7	2256.7	6436.7	6402.9	11933.3
	Winter 01	175.3	1306.4	1436.8	267.4	210.9	1686.40	481.8	205.3	3208.0	205.0	2756.0	988.6	6046.0	6730.0	6478.0
	Winter 02	245.0	1672.6	1673.0	222.5	147.7	1114.50	756.0	158.6	nr	195.0	3152.0	588.2	6078.0	8468.0	7152.0
Change from previous season		69.7	366.2	236.2	-44.9	-63.2	-571.9	274.2	-46.7	-	-10.1	396.0	-400.4	32.0	1738.0	674.0
DO (%)	Audit 97	94.5	55.7	54.9	98.2	40.5	ns	48.6	108.9	44.4	78.8	138.0	ns	20.1	ns	ns
	Summer 98	107.2	9.3	55.5	160.2	45.6	ns	99.4	182.8	118.9	88.5	29.2	52.9	ns	ns	ns
(NWQMS guideline = 90%)	Winter 98	182.7	121.3	51.0	140.2	135.6	ns	97.4	86.9	169.5	105.0	72.4	40.7	ns	ns	ns
	Summer 99	51.6	97.3	73.4	101.8	-7.2	ns	177.1	117.6	5.9	162.6	57.3	51.3	ns	ns	ns
	Winter 99	80.7	88.9	90.5	127.0	77.6	ns	36.3	66.1	105.0	98.0	93.9	61.4	6.0	ns	ns
	Winter 00	53.2	104.4	64.5	172.4	53.7	107.6	51.0	71.5	55.5	97.3	51.6	53.4	13.7	69.7	74.5
	Winter 01	104.8	39.9	38.7	138.8	122.4	183.6	137.3	85.6	97.3	272.7	123.2	49.4	30.7	111.4	92.8
	Winter 02	85.8	90.7	72.5	98.1	83.2	39.6	99.7	97.9	nr	102.5	68.4	85.5	19.8	106.8	68.1
Change from Previous season		-19.0	50.8	33.7	-40.7	-39.2	-144.0	-37.7	12.3	-	-170.2	-54.8	36.0	-10.9	-4.7	-24.7

Table 2 cont. Each value represents an average of five readings for each of the five sites.

Parameter	Survey	S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	Boat Ck1	Larcom Ck1	Humpy Ck1	Scrubby Ck1	Teningie Ck1
Temperature (C)	Audit 97	25.7	27.4	29.9	26.8	25.3	ns	27.2	27.9	26.5	25.7	25.7	ns	23.5	ns	ns
	Summer 98	28.0	23.7	28.9	32.8	26.9	ns	26.6	27.8	28.8	25.4	27.9	26.5	ns	ns	ns
	Winter 98	26.0	28.0	24.0	27.8	28.0	ns	26.0	19.8	26.5	24.2	20.0	20.0	ns	ns	ns
	Summer 99	26.1	32.0	31.5	34.7	26.5	ns	29.1	28.2	25.8	31.9	26.8	27.6	ns	ns	ns
	Winter 99	17.1	18.2	18.6	22.1	20.9	ns	16.8	16.7	18.7	19.4	15.9	18.4	15.6	ns	ns
	Winter 00	15.7	16.4	16.2	18.2	16.5	17.6	15.3	13.3	15.0	16.9	14.7	15.2	12.3	16.4	16.0
	Winter 01	21.8	16.0	17.3	19.5	18.1	18.4	16.5	15.1	15.3	18.1	14.7	15.8	14.8	15.4	13.3
	Winter 02	17.9	19.0	17.3	20.4	22.9	15.1	16.3	17.5	nr	22.0	16.8	18.6	15.0	18.2	15.4
Change from Previous season		-3.9	3.0	0.0	0.8	4.9	-3.3	-0.2	2.4	-	3.9	2.1	2.7	0.2	2.8	2.1
Salinity (%)	Summer 99	0.0	0.0	0.0	0.0	0.0	ns	0.1	0.0	0.1	0.0	0.1	0.0	ns	ns	ns
	Winter 99	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0	0.1	0.0	0.1	0.1	0.3	ns	ns
	Winter 00	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.2	0.1	0.3	0.4	0.7
	Winter 01	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.2	0.1	0.3	0.4	0.7
	Winter 02	0.0	0.1	0.0	0.0	0.0	nr	0.0	0.0	nr	0.0	nr	0.1	nr	nr	nr
Change from Previous season		0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	-	0.0	-	0.0	-	-	-
Secchi Depth (cm)	Audit 97	29.5	53.1	61.4	52.5	73.5	ns	67.5	39.0	66.0	105.0	>100	ns	92.8	nr	nr
	Summer 98	58.0	34.0	38.0	27.0	nr	ns	nr	31.0	24.5	71.0	>60	75.0	nr	nr	nr
	Winter 98	93.0	66.0	43.0	23.0	73.0	ns	68.0	35.0	52.0	71.0	>60	102.0	nr	nr	nr
	Summer 99	nr	nr	nr	nr	nr	ns	nr	nr	nr	nr	nr	nr	nr	nr	nr
	Winter 99	85.0	125.0	110.0	nr	nr	ns	nr	70.0	nr	>90	85.0	160.0	50.0	nr	nr
	Winter 00	97.0	140.0	nr	65.0	54.0	140.0	130.0	67.0	170.0	111.0	60.0	170.0	130.0	110.0	110.0
	Winter 01	60.0	110.0	120.0	120.0	80.0	nr	55.0	60.0	40.0	70.0	80.0	95.0	80.0	>150	>110
	Winter 02	>200	>100	>100	>60	100.0	nr	>120	40.0	nr	>120	>60	>100	>120	>100	>114
Change from Previous season		140.0	-10.0	-20	-60.0	20.0	-	65.0	-20.0	-	50.0	-20.0	5.0	40.0	-50.0	4.0

*=dam sites, Prefix Ck1=creek sites, ns = not sampled, nr = not recorded, #=applies only to lowland creeks (NWQMS)

Table 3: Macrophyte species composition including mean percent cover and guild structure at 15 freshwater sites in Targinnie, Gladstone. Means are derived from the percent cover recorded for six 1m^2 quadrats in the invertebrate sampling area during Winter 2002. A tick indicates presence at the site

Species	Distribution Frequency	S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	Boat Ck1	Larcom Ck1	Humpy Ck1	Scrubby Ck1	Teningie Ck1
Acrostichum speciosum	2											✔		3.3		
Bucopa sp.	1							✔								
Cyperus sp.	3		✔	✔												✔
Cyperus javanicus	0															
Cyperus exaltatus	1						✔									
Cyperus polystachyos	1								✔							
Eleocharis dulcis	4		31.8	0.5		1.2										2.3
Juncus usitatus	3		✔	✔												✔
Paspalum distichum	1												✔			
Persicaria decipiens	8	0.8		0.8	2.0	✔	9.5	1.8			0.2		✔			
Triglochin procera	1															✔
Typha domingensis	5		✔	✔		✔									0.2	✔
Urochloa mutica	2			✔	4.2											
Emergent		0.8	31.8	1.3	6.2	1.2	9.5	1.8	0.0	0.0	0.2	0.0	0.0	3.3	0.2	2.3
Ludwigia peploides	5	1.2			26.8	3.6		0.4			0.8					
Marsilea mutica	2				✔	7.5										
Nymphaea violacea	8	2.5	✔	✔	✔	1.7		11.7			3.4	✔				
Nymphoides indica	8	1.3	8.5	0.3	0.6	3.8		2.0			15.0	4.2				
Ottelia ovalifolia	1														2.5	
Potamogeton javanicus	3	2.6			4.2						0.2					
Potamogeton tricarinatus	2									1.3	0.8					
Floating Attached		7.6	8.5	0.3	31.6	16.6	0.0	32.8	0.0	1.3	18.8	4.2	0.0	0.0	2.5	0.0
Azolla pinnata	0															
Lemna sp.	1														✔	
Spirodela sp.	1													11.2		
Free-Floating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0
Chara vulgaris	4	✔				5.8									✔	✔
Ceratophyllum demersum	0															
Hydrilla sp.	0															
Myriophyllum	2		0.2	✔												
Najas tenuifolia	5				0.3	0.2	0.2	✔			✔					
Nitella sp	2			✔											4.3	
Ottelia alismoides	2				✔						0.8					
Potamogeton crispus	7				6.8			4.9	0.3	0.3	✔		1.0	2.2		
Potamogeton pectinatus	6				0.3	✔	64.3	✔					✔		31.0	
Utricularia gibba	4	0.7	0.2	✔		0.5										
Vallesnaria gigantea	2					0.3		0.8								
Submergent		0.7	0.3	0.0	7.3	6.8	64.5	5.0	0.3	0.3-	0.8	0.0	1.0	2.2	35.3	0.0
Species Richness	30	7	8	11	11	12	4	9	2	2	9	3	4	3	6	6

Table 4: Seasonal comparisons of the mean percent cover of each macrophyte guild at 15 freshwater sites in Targinnie, Gladstone. Means are derived from the percent cover recorded for six 1 m^2 quadrats in the invertebrate sampling area.

Site	Guild	Spring 1997	Summer 1998	Winter 1998	Summer 1999	Winter 1999	Winter 2000	Winter 2001	Winter 2002
S1*	Total Vegetation Cover	10.0	29.1	29.5	10.3	26.5	20.5	2.0	9.1
	Emergent	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.8
	Floating-attached	10.0	25.3	3.7	10.3	26.5	20.3	1.0	7.6
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	0.0	3.8	25.8	0.0	0.0	0.0	1.0	0.7
S2*	Total Vegetation Cover	100.0	100.0	29.1	0.0	16.0	85.8	52.5	40.7
	Emergent	0.0	0.0	0.8	0.0	15.0	83.3	45.0	31.8
	Floating-attached	42.8	95.5	25.8	0.0	1.0	2.5	3.7	8.5
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	57.2	4.5	2.5	0.0	0.0	0.0	3.8	0.3
S3*	Total Vegetation Cover	53.1	75.4	29.1	0.0	51.3	43.3	51.2	1.7
	Emergent	2.6	0.0	0.0	0.0	50.0	27.5	16.2	1.3
	Floating-attached	37.5	37.7	24.2	0.0	1.3	15.8	21.0	0.3
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	13.0	37.7	4.9	0.0	0.0	0.0	14.0	0.0
S4*	Total Vegetation Cover	57.0	63.0	0.5	66.1	58.9	38.9	37.3	45.1
	Emergent	0.0	0.0	0.0	0.0	21.7	29.2	2.5	6.2
	Floating-attached	57.0	3.0	0.0	66.1	37.2	9.7	18.3	31.6
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
	Submergent	0.0	60.0	0.5	0.0	0.0	0.0	15.7	7.3
S5*	Total Vegetation Cover	48.1	50.4	49.2	82.4	63.8	74.0	22.7	24.6
	Emergent	0.1	0.2	0.8	12.2	20.0	23.5	2.0	1.2
	Floating-attached	48.0	47.7	34.7	70.2	43.8	50.5	14.8	16.6
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	0.0	2.5	13.7	0.0	0.0	0.0	5.8	6.8
S6*	Total Vegetation Cover	ns	ns	ns	ns	ns	20.8	14.5	74.0
	Emergent	-	-	-	-	-	18.8	7.5	9.5
	Floating-attached	-	-	-	-	-	0.0	0.3	0.0
	Floating	-	-	-	-	-	0.0	0.0	0.0
	Submergent	-	-	-	-	-	2.0	6.7	64.5
R1*	Total Vegetation Cover	60.0	80.0	95.9	12.1	7.3	58.1	26.8	39.7
	Emergent	0.0	0.0	0.0	0.0	0.0	0.2	23.3	1.8
	Floating-attached	57.5	80.0	95.9	11.8	7.0	55.8	3.5	32.8
	Floating	2.5	0.0	0.0	0.3	0.3	1.3	0.0	0.0
	Submergent	0.0	0.0	0.0	0.0	0.0	0.8	0.0	5.0
R2*	Total Vegetation Cover	100.0	100.0	95.2	0.2	0.2	0.0	0.0	0.3
	Emergent	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
	Floating-attached	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	100.0	100.0	95.2	0.0	0.0	0.0	0.0	0.3
R3*	Total Vegetation Cover	80.0	73.3	65.3	42.1	89.7	75.8	14.3	1.7
	Emergent	0.0	11.7	0.0	9.3	0.2	0.0	0.0	0.0
	Floating-attached	0.0	0.8	0.0	8.5	7.2	75.8	12.5	1.3
	Floating	80.0	60.8	51.7	24.3	82.3	0.0	1.5	0.0
	Submergent	0.0	0.0	13.6	0.0	0.0	0.0	0.3	0.3

Table 4 cont.

Site	Guild	Spring 1997	Summer 1998	Winter 1998	Summer 1999	Winter 1999	Winter 2000	Winter 2001	Winter 2002
R4*	Total Vegetation Cover	87.1	45.0	27.6	52.7	59.2	56.0	52.2	19.8
	Emergent	0.0	0.0	0.0	6.7	0.2	0.2	6.3	0.2
	Floating-attached	58.6	0.0	0.0	46.0	54.0	50.0	41.2	18.8
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	28.5	45.0	27.6	0.0	5.0	5.8	4.7	0.8
Boat	Total Vegetation Cover	93.0	34.2	42.3	32.6	0.3	22.5	43.3	4.2
Ck1	Emergent	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	Floating-attached	2.5	8.7	0.3	15.8	0.0	22.5	43.3	4.2
	Floating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Submergent	90.5	25.5	42.0	16.8	0.0	0.0	0.0	0.0
Larcom	Total Vegetation Cover	ns	5.1	8.5	28.0	10.7	22.1	24.3	1.0
Ck1	Emergent	-	1.8	0.5	0.5	0.7	3.8	3.5	0.0
	Floating-attached	-	0.0	0.2	3.3	0.0	0.0	0.0	0.0
	Floating	-	0.0	0.0	6.5	6.3	6.5	20.8	0.0
	Submergent	-	3.3	7.8	17.7	3.7	11.8	0.0	1.0
Humpy	Total Vegetation Cover	0.0	ns	ns	ns	1.5	0.5	13.8	16.7
Ck1	Emergent	0.0	-	-	-	0.0	0.0	2.5	3.3
	Floating-attached	0.0	-	-	-	0.0	0.0	0.0	0.0
	Floating	0.0	-	-	-	1.5	0.5	10.8	11.2
	Submergent	0.0	-	-	-	0.0	0.0	0.5	2.2
Scrubby	Total Vegetation Cover	ns	ns	ns	ns	ns	63.7	63.5	38.0
Ck1	Emergent	-	-	-	-	-	6.0	1.2	0.2
	Floating-attached	-	-	-	-	-	0.0	12.5	2.5
	Floating	-	-	-	-	-	0.0	0.0	0.0
	Submergent	-	-	-	-	-	57.7	49.8	35.3
Teningie	Total Vegetation Cover	ns	ns	ns	ns	ns	41.8	57.8	2.3
Ck1	Emergent	-	-	-	-	-	8.3	0.0	2.3
	Floating-attached	-	-	-	-	-	0.0	0.0	0.0
	Floating	-	-	-	-	-	0.0	0.0	0.0
	Submergent	-	-	-	-	-	33.5	57.8	0.0

*= dam sites, prefix Ck1 = Creek sites

Table 5: Mean macroinvertebrate family abundance at 15 freshwater aquatic sites in Targinnie, Gladstone. Bold numbers represent mean abundance for that order. Means are derived from three replicate kick-net samples collected in Winter 2002.

Taxa	S1*	S2*	S3*	S4*	S5*	S6*	R1*	R2*	R3*	R4*	Boat Ckl	Humpy Ckl	Larcom Ckl	Tenginie Ckl	Scrubby Ckl	Abundance %
Bivalvia	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**18.6**	**0.0**	**0.0**	**0.07**
Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.07
Gastropoda	**137.3**	**31.7**	**93.3**	**50.0**	**16.7**	**286.7**	**251.1**	**365.0**	**635.0**	**60.0**	**126.7**	**27.8**	**39.7**	**0.0**	**88.2**	**8.55**
Hydrobiidae	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	103.3	4.4	1.7	0.0	0.0	0.44
Lymnaeidae	1.3	0.0	66.7	6.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.33
Planorbidae	110.9	31.7	26.7	40.0	15.6	260.0	251.1	271.7	525.0	0.0	23.3	23.3	38.1	0.0	13.0	6.31
Thiaridae	25.1	0.0	0.0	0.0	0.0	26.7	0.0	93.3	110.0	60.0	0.0	0.0	0.0	0.0	65.2	1.47
Platyhelminthes	**0.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.2**	**0.0**	**0.0**	**0.01**
Platyhelminthes	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.01
Oligochaetae	**13.2**	**3.3**	**0.0**	**3.3**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.7**	**0.0**	**0.09**
Oligochaetae	13.2	3.3	0.0	3.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.09
Hirudinea	**0.0**	**1.7**	**0.0**	**21.7**	**0.0**	**0.0**	**1.1**	**1.7**	**0.0**	**0.0**	**0.0**	**0.0**	**1.1**	**0.0**	**0.0**	**0.11**
Glossiphonidae	0.0	1.7	0.0	21.7	0.0	0.0	1.1	1.7	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.11
Acarina	**0.0**	**0.0**	**1.7**	**0.0**	**13.3**	**80.0**	**1.1**	**13.3**	**0.0**	**68.3**	**0.0**	**0.0**	**0.8**	**0.0**	**0.0**	**0.69**
Hydracarina	0.0	0.0	1.7	0.0	13.3	80.0	1.1	13.3	0.0	68.3	0.0	0.0	0.8	0.0	0.0	0.69
Decapoda	**15.3**	**14.2**	**15.0**	**20.0**	**3.3**	**6.7**	**12.2**	**0.0**	**0.0**	**16.7**	**16.7**	**2.5**	**7.5**	**27.8**	**22.6**	**0.70**
Atyidae	7.0	14.2	15.0	20.0	3.3	6.7	12.2	0.0	0.0	13.3	16.7	2.5	7.5	27.8	22.6	0.65
Palaemonidae	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.05
Ephemeroptera	**0.0**	**158.3**	**105.0**	**5.0**	**21.1**	**463.3**	**35.6**	**13.3**	**10.0**	**3.3**	**6.7**	**0.0**	**10.0**	**3.3**	**1.3**	**3.23**
Caenidae	0.0	0.0	0.0	0.0	0.0	20.0	0.0	8.3	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13
Baetidae	0.0	158.3	105.0	5.0	21.1	443.3	35.6	5.0	5.0	3.3	6.7	0.0	10.0	3.3	1.3	3.11
Odonata	**5.8**	**153.3**	**23.3**	**20.0**	**48.9**	**653.3**	**83.3**	**8.3**	**10.0**	**28.3**	**0.0**	**6.1**	**15.8**	**13.9**	**72.0**	**4.42**
Aeshnidae	0.0	12.5	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07
Coenagrionidae	0.7	125.0	13.3	15.0	33.3	233.3	72.2	0.0	0.0	25.0	0.0	5.6	3.3	6.1	8.0	2.09
Corduliidae	0.0	8.3	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.6	3.3	1.7	6.7	0.09
Gomphidae	4.6	0.0	0.0	3.3	2.2	0.0	3.3	8.3	10.0	1.7	0.0	0.0	1.7	4.4	1.1	0.16
Libellulidae	0.6	7.5	10.0	0.0	13.3	403.3	3.3	0.0	0.0	1.7	0.0	0.0	3.3	0.0	5.6	1.74
Protoneuridae	0.0	0.0	0.0	1.7	0.0	6.7	4.4	0.0	0.0	0.0	0.0	0.0	4.2	1.7	50.7	0.27

Taxa	S1*	S2*	S3*	S4*	S5*	S6*	R1*	R2*	R3*	R4*	Boat Ck1	Humpy Ck1	Larcom Ck1	Teningie Ck1	Scrubby Ck1	Abundance %
Hemiptera	**38.4**	**165.8**	**18.3**	**495.0**	**98.9**	**30.0**	**5.6**	**458.3**	**480.0**	**5.0**	**10.0**	**3.3**	**49.4**	**0.0**	**6.7**	**7.21**
Corixidae	37.3	1.7	3.3	483.3	54.4	0.0	3.3	448.3	465.0	1.7	0.0	0.0	0.0	0.0	1.1	5.80
Hebridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.03
Mesovelidae	0.0	3.3	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03
Naucoridae	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	3.3	0.0	0.0	2.8	0.03
Notonectidae	1.1	147.5	11.7	1.7	7.8	16.7	0.0	8.3	15.0	0.0	3.3	0.0	0.0	0.0	0.0	0.82
Pleidae	0.0	13.3	3.3	10.0	36.7	10.0	1.1	1.7	0.0	3.3	0.0	0.0	49.4	0.0	2.8	0.51
Diptera	**515.7**	**576.7**	**948.3**	**2213.3**	**897.8**	**2933.3**	**431.1**	**530.0**	**1240.0**	**585.0**	**3193.3**	**1293.9**	**819.2**	**1591.1**	**721.7**	**71.52**
Ceratopogonidae	1.3	38.3	6.7	145.0	1.1	26.7	75.6	31.7	10.0	1.7	200.0	11.4	2.2	498.9	39.1	4.21
Culicidae	0.7	9.2	3.3	0.0	6.7	60.0	0.0	1.7	0.0	0.0	23.3	0.0	0.0	1.1	0.0	0.41
Chironomidae	513.7	407.5	676.7	2068.3	890.0	2846.7	353.3	496.7	1230.0	583.3	2970.0	1282.5	816.9	1091.1	681.9	65.40
Dolichopodidae	0.0	120.0	260.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.47
Ephyridae	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.01
Tabanidae	0.0	1.7	1.7	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.02
Lepidoptera	**0.0**	**0.0**	**3.3**	**3.3**	**1.1**	**3.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.0**	**0.05**
Pyralidae	0.0	0.0	3.3	3.3	1.1	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.05
Trichoptera	**1.7**	**0.0**	**5.0**	**25.0**	**0.0**	**16.7**	**0.0**	**48.3**	**0.0**	**40.0**	**3.3**	**0.0**	**2.8**	**0.0**	**31.4**	**0.67**
Hydroptilidae	0.0	0.0	0.0	6.7	0.0	6.7	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	3.7	0.19
Leptoceridae	1.7	0.0	5.0	18.3	0.0	10.0	0.0	48.3	0.0	6.7	3.3	0.0	2.8	0.0	27.8	0.48
Coleoptera	**17.9**	**15.8**	**73.3**	**128.3**	**104.4**	**16.7**	**97.8**	**10.0**	**110.0**	**23.3**	**13.3**	**33.1**	**38.1**	**5.0**	**4.9**	**2.68**
Dytiscidae	0.0	10.0	30.0	10.0	104.4	10.0	96.7	5.0	110.0	15.0	10.0	26.4	36.1	3.9	3.6	1.82
Grinidae	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06
Helminthidae	0.0	1.7	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.02
Haliplidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	<0.01
Helolidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.01
Hydraenidae	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	1.7	3.3	0.0	0.0	1.1	0.0	0.04
Hydrophilidae	0.0	4.2	43.3	118.3	0.0	0.0	1.1	5.0	0.0	6.7	0.0	3.3	1.9	0.0	0.0	0.71
Hygrobiidae	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Average Abundance	**745.9**	**1120.8**	**1286.7**	**2985.0**	**1206.7**	**4490.0**	**918.9**	**1448.3**	**2485.0**	**830.0**	**3370.0**	**1366.7**	**1005.3**	**1642.8**	**950.8**	**100.00**
Taxa Richness (pooled by site)	**18.0**	**21.0**	**19.0**	**20.0**	**17.0**	**23.0**	**18.0**	**16.0**	**10.0**	**17.0**	**12.0**	**11.0**	**19.0**	**12.0**	**22.0**	

* = dam sites, prefix Ck1 = creeks sites

Table 6: Seasonal macroinvertebrate abundance by order at 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002. Abundance values are means obtained from three replicate kick-net samples.

Site	Survey	Bivalvia	Gastropoda	Platyhelmithes	Oligochaetae	Hirudinea	Acarina	Isopoda	Decapoda	Collembola	Ephemeroptera	Odonata	Hemiptera	Neuroptera	Megaloptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Total abundance	Net Change
S1*	Audit 97	0.0	56.4	0.0	0.0	0.0	2.1	0.0	82.3	0.0	18.5	98.5	29.8	0.0	0.0	432.3	26.0	17.0	96.1	858.9	
	Summer 98	0.0	124.4	113.8	0.9	0.0	0.9	0.0	12.4	0.0	5.3	170.7	27.1	0.0	0.0	430.2	13.8	0.0	61.8	961.3	102.4
	Winter 98	0.0	685.3	0.0	0.0	0.0	1.0	0.0	17.7	0.0	0.3	41.3	17.7	0.0	0.0	1738.7	0.0	1.0	66.7	2569.7	1608.4
	Summer 99	0.0	33.7	0.0	0.0	0.0	0.0	0.0	29.0	0.0	1.0	39.0	2.0	0.0	0.0	51.3	1.7	0.7	24.0	182.3	-2387.3
	Winter 99	0.0	130.8	0.0	0.0	0.0	2.5	0.0	45.5	0.0	0.0	23.1	43.4	0.5	0.0	224.3	0.0	0.0	19.7	489.8	307.4
	Winter 00	0.0	9.9	0.0	0.0	0.0	6.5	0.0	140.3	0.0	6.4	14.0	10.0	0.0	0.0	224.2	1.5	0.4	84.7	498.0	8.2
	Winter 01	0.0	94.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	31.3	0.0	25.3	0.0	0.0	1058.0	0.0	14.7	60.7	1317.3	819.3
	Winter 02	0.0	137.3	0.6	13.2	0.0	0.0	0.0	15.3	0.0	0.0	5.8	38.4	0.0	0.0	515.7	0.0	1.7	17.9	745.89	-571.4
S2*	Audit 97	0.0	8.9	0.0	0.0	0.0	0.0	0.0	139.5	0.0	5.6	80.1	19.1	0.0	0.0	115.9	13.0	0.0	37.3	419.2	
	Summer 98	0.0	179.6	0.0	1.3	10.1	0.0	0.0	6.8	0.0	40.4	214.7	119.9	0.0	0.0	478.5	25.0	0.0	32.6	1108.9	689.7
	Winter 98	0.0	20.0	0.0	0.0	36.7	16.7	0.0	270.0	0.0	446.7	296.7	293.3	0.0	0.0	5623.3	3.3	0.0	430.0	7436.7	6327.8
	Summer 99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	174.0	0.0	18.7	70.3	8.0	0.0	0.0	1.7	0.0	72.3	12.3	357.3	-7079.3
	Winter 99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.7	0.0	43.7	9.7	47.7	0.0	0.0	196.0	0.0	21.3	9.7	356.7	-0.7
	Winter 00	0.0	30.7	0.0	0.0	0.0	1.3	0.0	785.3	0.0	667.3	58.0	12.0	0.0	0.0	168.7	0.0	0.0	8.7	1732.0	1375.3
	Winter 01	0.0	846.7	0.0	0.0	0.0	3.3	0.0	156.7	0.0	1463.3	140.0	403.3	0.0	0.0	3773.3	0.0	20.0	60.0	6866.7	5134.7
	Winter 02	0.0	31.7	0.0	3.3	1.7	0.0	0.0	14.2	0.0	158.3	153.3	165.8	0.0	0.0	576.7	0.0	0.0	15.8	1120.8	-5745.8
S3*	Audit 97	0.0	18.7	0.0	1.0	0.0	0.0	0.0	214.3	0.0	51.7	74.3	15.0	0.0	0.0	18.4	2.3	0.0	9.7	405.4	
	Summer 98	0.0	369.3	0.0	4.0	0.0	2.7	0.0	8.0	0.0	318.7	256.0	406.7	0.0	0.0	330.7	22.7	0.0	26.7	1745.3	1339.9
	Winter 98	0.0	13.3	0.0	0.0	5.0	36.7	0.0	63.3	0.0	123.3	78.3	98.3	0.0	0.0	6578.3	0.0	0.0	318.3	7315.0	5569.7
	Summer 99	0.0	1.0	0.0	0.0	0.3	0.0	0.0	645.7	0.0	14.3	55.3	4.7	0.0	0.0	419.0	0.0	46.3	16.0	1202.7	-6112.3
	Winter 99	0.0	67.1	0.0	0.0	0.0	0.0	0.0	185.4	0.0	111.7	148.5	24.6	0.0	0.0	1038.1	0.0	29.7	49.5	1654.7	452.0
	Winter 00	0.0	16.7	0.0	0.0	0.0	3.3	0.0	206.7	0.0	1388.0	132.7	8.0	0.0	0.0	526.7	0.0	0.0	10.0	2292.0	637.3
	Winter 01	0.0	69.2	0.0	0.0	10.8	0.0	0.0	11.7	0.0	2932.5	21.7	390.0	0.0	0.0	1833.3	0.0	0.0	55.0	5324.2	3032.2
	Winter 02	0.0	93.3	0.0	0.0	0.0	1.7	0.0	15.0	0.0	105.0	23.3	18.3	0.0	0.0	948.3	3.3	5.0	73.3	1286.7	-4037.5

Table 6 cont.

Site	Survey	Bivalvia	Gastropoda	Platyhelmithes	Oligochaetae	Hirudinea	Acarina	Isopoda	Decapoda	Collembola	Ephemeroptera	Odonata	Hemiptera	Neuroptera	Megaloptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Total abundance	Net Change
S4*	Audit 97	0.0	94.7	0.0	0.0	5.3	10.7	0.0	28.0	0.0	149.3	450.7	54.7	0.0	0.0	1889.3	6.7	6.7	58.7	2754.7	
	Summer 98	0.0	70.2	0.0	6.2	0.0	87.1	0.0	11.6	0.0	71.6	79.6	1000.9	0.0	0.0	622.2	5.3	0.0	107.1	2061.8	-692.9
	Winter 98	0.0	1.7	0.0	0.0	0.0	121.7	0.0	0.0	0.0	1.7	0.0	516.7	0.0	0.0	1818.3	0.0	0.0	16.7	2476.7	414.9
	Summer 99	0.0	3.7	0.0	0.0	0.3	18.3	0.0	3.0	0.0	53.7	79.0	35.0	0.0	0.0	571.7	2.7	5.3	36.0	808.7	-1668.0
	Winter 99	0.0	128.3	0.0	0.0	28.3	86.7	0.0	38.3	0.0	66.7	136.7	458.3	0.0	0.0	1543.3	11.7	56.7	446.7	3001.7	2193.0
	Winter 00	0.0	53.9	0.0	0.0	0.0	154.4	0.0	60.6	0.0	12.8	151.7	42.8	0.0	0.0	1781.1	0.0	162.2	131.1	2550.6	-451.1
	Winter 01	0.0	366.2	0.0	0.0	0.0	6.8	0.0	28.5	0.0	10.3	140.2	168.0	0.0	0.0	789.0	1.7	25.0	141.0	1676.7	-873.9
	Winter 02	0.0	50.0	0.0	3.3	21.7	0.0	0.0	20.0	0.0	5.0	20.0	495.0	0.0	0.0	2213.3	3.3	25.0	128.3	2985.0	1308.3
S5*	Audit 97	0.0	7.4	0.0	0.3	0.3	1.3	0.0	13.0	0.0	0.0	88.2	7.1	0.0	0.0	84.8	16.9	0.8	29.8	249.9	
	Summer 98	0.0	80.3	10.7	3.7	0.0	12.3	0.0	18.9	0.0	70.7	166.9	11.5	0.0	0.0	346.9	21.6	0.0	46.7	790.1	540.2
	Winter 98	0.0	361.0	0.0	0.0	0.0	21.9	0.0	0.0	0.0	13.6	95.9	32.1	0.0	0.0	1287.7	19.2	26.7	47.2	1905.2	1115.1
	Summer 99	0.0	5.0	0.0	0.0	0.0	1.0	0.0	74.3	0.0	6.3	184.0	14.3	0.0	0.0	71.7	8.0	4.0	33.3	402.0	-1503.2
	Winter 99	0.0	1.7	0.0	0.0	1.1	6.7	0.0	22.2	0.0	27.2	100.0	116.7	0.0	0.0	1417.2	17.8	16.1	65.6	1792.2	1390.2
	Winter 00	0.0	26.0	0.0	0.0	3.3	15.3	0.0	34.7	0.0	0.0	176.0	50.0	2.7	0.0	2824.0	39.3	15.3	256.7	3443.3	1651.1
	Winter 01	0.0	80.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	53.3	0.0	78.3	0.0	0.0	2680.0	6.7	71.7	76.7	3056.7	-386.6
	Winter 02	0.0	16.7	0.0	1.1	0.0	13.3	0.0	3.3	0.0	21.1	48.9	98.9	0.0	0.0	897.8	1.1	0.0	104.4	1206.7	-1850.0
S6*		Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																			
	Winter 00	0.0	57.3	0.0	0.0	0.0	88.0	0.0	0.0	0.0	76.0	95.6	5.8	0.0	0.0	451.8	2.2	46.9	32.0	855.6	
	Winter 01	0.0	970.0	0.0	0.0	0.0	123.3	0.0	6.7	0.0	96.7	946.7	16.7	0.0	0.0	6780.0	0.0	86.7	16.7	9043.3	8187.7
	Winter 02	0.0	286.7	0.0	0.0	0.0	80.0	0.0	6.7	0.0	463.3	653.3	30.0	0.0	0.0	2933.3	3.3	16.7	16.7	4490.0	-4553.3
R1*	Audit 97	38.2	469.9	0.0	0.0	5.9	0.0	0.0	56.4	0.0	21.3	101.5	18.6	0.0	0.0	265.3	43.6	4.8	83.0	1108.5	
	Summer 98	0.0	9.4	6.7	0.0	4.4	16.0	0.0	6.9	0.0	148.6	223.9	392.4	0.0	0.0	549.4	10.4	0.0	75.2	1443.4	334.9
	Winter 98	3.3	0.0	0.0	0.0	11.7	3.3	0.0	1.7	0.0	40.0	65.0	391.7	0.0	0.0	4473.3	6.7	0.0	325.0	5321.7	3878.3
	Summer 99	0.0	1.3	0.0	0.0	9.3	29.3	0.0	38.7	0.0	16.0	68.0	9.3	0.0	0.0	6.7	0.0	76.0	126.7	381.3	-4940.3
	Winter 99	0.0	1.1	0.0	0.0	0.0	5.3	0.0	2.8	0.0	23.9	12.1	205.6	0.0	0.0	308.7	0.0	28.8	13.9	602.1	220.8
	Winter 00	0.0	730.0	0.0	83.3	6.7	100.0	0.0	16.7	0.0	13.3	170.0	53.3	0.0	0.0	5356.7	26.7	36.7	43.3	6553.3	5951.2
	Winter 01	0.0	93.3	0.0	0.0	0.0	0.0	0.0	22.0	0.0	13.0	18.0	349.0	0.0	0.0	2002.3	0.0	26.0	73.0	2596.7	-3956.6
	Winter 02	0.0	251.1	0.0	0.0	1.1	1.1	0.0	12.2	0.0	35.6	83.3	5.6	0.0	0.0	431.1	0.0	0.0	97.8	918.9	-1677.8

Table 6 cont.

Site	Survey	Bivalvia	Gastropoda	Platyhelmithes	Oligochaetae	Hirudinea	Acarina	Isopoda	Decapoda	Collembola	Ephemeroptera	Odonata	Hemiptera	Neuroptera	Megaloptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Total abundance	Net Change
R2*	Audit 97	0.0	348.0	0.0	0.0	0.0	29.3	0.0	108.0	0.0	64.0	32.0	857.3	0.0	0.0	189.3	2.7	48.0	8.0	1686.7	
	Summer 98	0.0	494.2	0.0	0.0	0.0	516.4	0.0	0.0	0.0	148.4	40.9	2639.1	0.0	0.0	164.4	5.3	0.0	31.1	4040.0	2353.3
	Winter 98	0.0	502.0	0.0	0.0	0.0	45.7	0.0	1.7	0.0	52.0	56.7	264.7	0.0	0.0	998.3	0.3	5.7	18.0	1945.0	-2095.0
	Summer 99	0.0	2.0	0.0	0.0	4.7	31.3	0.0	0.7	0.0	185.3	9.3	29.3	0.0	0.0	318.7	0.0	372.0	18.7	972.0	-973.0
	Winter 99	0.0	130.0	0.0	0.0	53.3	193.3	0.0	3.3	0.0	500.0	16.7	156.7	0.0	0.0	5993.3	0.0	380.0	70.0	7496.7	6524.7
	Winter 00	0.0	491.7	0.0	3.3	3.3	5.0	0.0	0.0	0.0	791.7	20.0	285.0	0.0	0.0	316.7	0.0	555.0	10.0	2478.3	-5018.3
	Winter 01	0.0	115.0	0.0	0.0	20.0	10.7	0.0	0.0	0.0	43.0	6.7	1789.3	0.0	0.0	762.7	0.0	59.3	60.3	2867.0	388.7
	Winter 02	0.0	365.0	0.0	0.0	1.7	13.3	0.0	0.0		13.3	8.3	458.3	0.0		530.0	0.0	48.3	10.0	1448.3	-1418.6
R3*	Audit 97	0.0	2864.0	0.0	0.0	6.7	8.0	0.0	30.7	0.0	38.7	106.7	78.7	0.0	0.0	330.9	6.7	4.0	48.0	3522.9	
	Summer 98	0.0	477.3	0.0	2.7	0.0	13.3	0.0	880.0	0.0	744.0	1672.0	178.7	0.0	0.0	2648.0	96.0	0.0	61.3	6773.3	3250.5
	Winter 98	0.0	565.0	0.0	0.0	0.0	30.0	0.0	185.0	0.0	55.0	205.0	106.7	0.0	0.0	3911.7	10.0	0.0	133.3	5201.7	-1571.7
	Summer 99	0.0	328.7	0.0	0.0	0.0	4.7	0.0	6.0	0.0	38.0	35.3	133.3	0.0	0.0	238.0	12.0	0.0	122.0	918.0	-4283.7
	Winter 99	0.0	449.9	0.0	0.0	1.7	11.1	0.0	63.6	0.0	8.6	108.3	134.0	0.0	0.0	571.9	60.7	79.0	42.7	1531.3	613.3
	Winter 00	0.0	542.7	0.0	95.3	0.0	0.0	0.0	48.0	0.0	16.7	22.7	50.0	0.0	0.0	3646.0	2.7	0.0	33.3	4362.0	2830.7
	Winter 01	0.0	1396.7	0.0	0.0	0.0	93.3	0.0	56.7	0.0	243.3	50.0	2053.3	0.0	0.0	5546.7	0.0	16.7	190.0	9646.7	5284.7
	Winter 02	0.0	635.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	480.0	0.0	0.0	1240.0	0.0	0.0	110.0	2485.0	-7161.7
R4*	Audit 97	0.0	306.7	0.0	0.0	1.1	6.9	0.0	345.1	0.0	111.5	29.3	6.4	0.0	0.0	562.2	2.1	18.7	15.5	1405.4	
	Summer 98	0.0	978.9	68.4	1.8	0.0	261.8	0.0	12.8	0.0	48.0	16.6	22.2	0.0	0.0	322.8	0.0	193.6	24.7	1951.4	546.0
	Winter 98	0.0	160.0	0.0	0.0	0.0	413.3	0.0	36.7	0.0	13.3	83.3	5.0	0.0	0.0	1790.0	0.0	15.0	46.7	2563.3	611.9
	Summer 99	0.0	106.7	0.0	0.0	0.0	28.0	0.0	10.0	0.0	12.0	43.3	13.3	0.0	0.0	187.3	2.0	12.0	62.7	477.3	-2086.0
	Winter 99	0.0	286.8	0.0	0.0	0.0	132.6	0.0	5.4	0.0	1.8	34.1	51.3	0.0	0.0	655.9	1.7	31.2	72.4	1273.2	795.9
	Winter 00	0.0	146.7	0.0	6.7	0.0	250.0	0.0	236.7	0.0	283.3	253.3	286.7	0.0	0.0	4980.0	0.0	3.3	40.0	6480.0	5206.8
	Winter 01	0.0	49.2	0.0	0.0	0.0	0.0	0.0	27.8	0.0	19.3	1.3	13.4	0.0	0.0	380.7	0.4	0.0	17.1	509.1	-5970.9
		0.0	50.0	0.0	3.3	21.7	0.0	0.0	20.0		5.0	20.0	495.0	0.0		2213.3	3.3	25.0	128.3	830.0	320.9
Boat Ck1	Audit 97	0.0	1624.4	0.0	0.0	0.0	0.0	0.0	140.4	0.0	35.6	35.6	6.2	0.0	0.0	77.3	0.0	40.0	3.6	1963.1	
	Summer 98	0.0	2516.0	0.0	2.7	0.0	0.0	0.0	54.7	0.0	112.7	49.3	0.0	0.0	0.0	687.3	0.0	10.7	13.3	3446.7	1483.6
	Winter 98	1.0	1959.3	0.0	0.0	0.0	0.0	0.0	4.0	0.0	72.0	10.3	1.0	0.0	0.0	1380.3	0.0	32.0	35.3	3495.3	48.7
	Summer 99	7.0	3.0	0.0	0.0	0.0	0.0	0.0	97.7	0.0	8.7	20.7	1.0	0.0	1.0	172.3	1.0	37.3	14.7	364.3	-3131.0
	Winter 99	9.3	298.2	0.0	0.0	0.0	0.0	0.0	73.1	0.0	298.0	58.0	49.8	2.2	0.0	3348.9	0.0	216.4	61.6	4415.6	4051.2

Table 6 cont.

Site	Survey	Bivalvia	Gastropoda	Platyhelminthes	Oligochaetae	Hirudinea	Acarina	Isopoda	Decapoda	Collembola	Ephemeroptera	Odonata	Hemiptera	Neuroptera	Megaloptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Total abundance	Net Change
Boat	Winter 00	0.0	660.0	0.0	2.7	0.0	0.0	0.0	10.7	2.7	232.0	34.7	46.7	1.3	0.0	1680.0	0.0	94.7	41.3	2804.0	-1611.6
Ck1 cont.	Winter 01	5.3	54.4	0.0	0.0	0.0	1.1	0.0	18.2	0.0	258.9	12.9	25.6	0.0	0.0	819.1	0.0	53.1	28.2	1276.9	-1527.1
	Winter 02	0.0	126.7	0.0	0.0	0.0	0.0	0.0	16.7		6.7	0.0	10.0	0.0		3193.3	0.0	3.3	13.3	3370.0	2093.1
Humpy	Audit 97	0.0	32.0	0.0	0.7	0.0	0.0	0.0	240.3	0.0	44.7	82.3	20.7	0.0	0.0	13.0	2.3	0.0	9.0	445.0	-
Ck1		Summer 98, Winter 98, Summer 99 - ns																			
	Winter 99	0.0	22.2	0.0	0.0	0.0	0.0	1.7	10.0	0.0	0.0	25.0	9.4	0.0	0.0	1351.4	0.0	15.6	11.7	1446.9	-
	Winter 00	0.0	19.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.8	0.0	0.0	1346.5	0.0	0.0	25.3	1400.0	-46.9
	Winter 01	0.0	54.7	0.0	0.0	0.0	0.0	0.0	3.6	0.0	3.0	11.2	4.3	0.0	0.0	305.2	0.0	3.0	12.1	395.1	-1004.9
	Winter 02	0.0	27.8	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	6.1	3.3	0.0	0.0	1293.9	0.0	0.0	33.1	1366.7	971.6
Larcom		Audit 97 - ns																			
Ck1	Summer 98	0.0	197.8	0.0	2.2	1.3	9.8	0.0	51.1	0.0	253.8	220.4	46.7	0.0	0.0	344.9	0.0	4.0	123.6	1255.5	-
	Winter 98	11.0	237.0	0.0	0.0	1.7	6.3	0.0	66.3	0.0	31.3	20.7	16.3	1.7	0.0	1568.0	0.0	10.0	48.0	2018.3	762.8
	Summer 99	5.0	260.0	0.0	0.0	3.7	1.7	0.0	301.7	0.0	12.3	85.0	3.0	2.7	0.0	162.3	0.7	14.0	2.0	854.0	-1164.3
	Winter 99	15.0	280.0	0.0	0.0	3.3	0.0	0.0	258.3	0.0	23.3	213.3	203.3	0.0	0.0	2233.3	0.0	520.0	248.3	3998.3	3144.3
	Winter 00	50.0	651.3	0.0	0.0	6.0	2.7	0.0	81.3	0.0	100.0	184.0	164.7	0.0	0.0	3564.7	2.7	96.7	190.7	5094.7	1096.3
	Winter 01	0.0	583.3	0.0	0.0	13.3	0.0	0.0	6.7	0.0	120.0	246.7	286.7	33.3	0.0	2833.3	0.0	263.3	1586.7	5973.3	878.6
	Winter 02	18.6	39.7	0.0	0.0	1.1	0.8	0.0	7.5	0.0	10.0	15.8	49.4	0.0	0.0	819.2	0.0	2.8	38.1	1005.3	-4968.1
Scrubby		Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																			
Ck1	Winter 00	0.0	378.0	0.0	0.0	0.0	24.7	0.0	39.3	0.0	0.0	106.7	2.7	0.0	0.0	5164.7	3.3	56.7	9.3	5785.3	
	Winter 01	0.0	24.1	0.0	0.0	0.0	0.0	0.0	123.0	0.0	0.7	46.0	9.7	0.0	0.0	650.8	0.4	47.0	7.3	908.8	-4876.5
	Winter 02	0.0	88.2	0.0	0.0	0.0	0.0	0.0	22.6	0.0	1.3	72.0	6.7	0.0	0.0	721.7	2.0	31.4	4.9	950.8	42.0
Teningie		Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																			
Ck1	Winter 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.3	0.0	0.0	138.0	28.3	0.0	0.0	2417.7	3.3	4.0	49.7	2751.3	
	Winter 01	0.0	0.0	0.0	0.0	0.0	3.3	0.0	100.0	0.0	372.7	0.0	37.3	0.0	0.0	4222.7	0.0	114.7	26.0	4876.7	2125.4
	Winter 02	0.0	0.0	0.0	1.7	0.0	0.0	0.0	27.8	0.0	3.3	13.9	0.0	0.0	0.0	1591.1	0.0	0.0	5.0	1642.8	-3233.9

* = dam sites, prefix Ck1 = creeks sites

Table 7: Change in macroinvertebrate taxa richness at 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002. Richness values are totals obtained from three replicate kick-net samples.

	Survey	Bivalvia	Gastropoda	Platyhelminthes	Oligochaetae	Hirudinea	Acarina	Decapoda	Colembolla	Ephemeroptera	Odonata	Hemiptera	Megaloptera	Neuroptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Average abundance	Number of Taxa	Net change of taxa richness	Number of 5 taxa	Net change of 5 taxa*
S1*	Audit 97	0	2	0	0	0	0	2	0	2	4	6	0	0	3	1	3	4	860	27		9	
	Summer 98	0	1	1	1	0	1	2	0	1	4	6	0	0	3	1	0	3	961	24	-3	4	-5
	Winter 98	0	1	0	0	0	1	2	0	1	5	6	0	0	3	0	2	5	2570	26	2	6	2
	Summer 99	0	1	0	0	0	0	2	0	1	4	2	0	0	3	1	1	2	182	17	-9	5	-1
	Winter 99	0	1	0	0	0	1	2	0	0	2	4	0	1	4	0	0	3	490	18	1	3	-2
	Winter 00	0	3	0	0	0	1	2	0	1	5	4	0	0	3	1	1	5	498	26	8	7	4
	Winter 01	0	3	0	0	0	0	2	0	2	0	4	0	0	4	0	2	4	1317	21	-5	9	2
	Winter 02	0	3	1	1	0	0	0	2	0	3	2	0	0	3	0	1	2	746	18	-3	4	-5
																					-14%		
S2*	Audit 97	0	1	1	1	0	0	2	0	1	2	6	0	0	3	1	0	3	423	21		4	
	Summer 98	0	2	0	1	1	0	1	0	1	4	5	0	0	5	1	0	2	1109	23	2	4	0
	Winter 98	0	1	0	0	1	1	1	0	1	3	4	0	0	2	1	0	3	7437	18	-5	3	-1
	Summer 99	0	0	0	0	0	0	2	0	2	3	3	0	0	1	0	2	3	357	16	-2	6	3
	Winter 99	0	0	0	0	0	0	2	0	2	3	1	0	0	2	0	1	3	357	14	-2	5	-1
	Winter 00	0	3	0	0	0	1	2	0	1	3	4	0	0	3	0	0	4	1732	21	7	6	1
	Winter 01	0	4	0	0	0	1	2	0	1	4	4	0	0	6	0	2	4	6867	28	9	9	3
	Winter 02	0	1	0	1	1	0	1	0	1	4	4	0	0	5	0	0	3	1121	21	-7	3	-6
																					-25%		
S3*	Audit 97	0	2	0	0	0	0	2	0	1	2	6	0	0	7	1	0	6	406	27		5	
	Summer 98	0	1	0	1	0	1	1	0	1	4	6	0	0	4	1	0	3	1745	23	-4	3	-2
	Winter 98	0	1	0	0	1	1	1	0	2	2	3	0	0	3	0	0	4	7315	18	-5	4	1
	Summer 99	0	1	0	0	1	0	2	0	2	5	5	0	0	1	0	1	4	1203	22	4	6	2
	Winter 99	0	1	0	0	0	0	2	0	2	4	7	0	0	4	0	2	5	1655	27	5	7	1
	Winter 00	0	2	0	0	0	1	2	0	1	4	2	0	0	4	0	0	1	2292	17	-10	5	-2
	Winter 01	0	3	0	0	1	0	1	0	1	6	4	0	0	4	0	0	3	5324	23	6	5	0
	Winter 02	0	2	0	0	0	1	1	0	1	2	3	0	0	5	1	1	2	1287	19	-4	5	0
																					17%		
S4*	Audit 97	0	2	0	0	0	1	1	0	1	2	7	0	0	3	1	2	2	2754	22		6	
	Summer 98	0	2	0	1	0	1	1	0	1	3	4	0	0	2	1	0	2	2062	18	-4	4	-2
	Winter 98	0	1	0	0	0	1	0	0	1	0	1	0	0	3	0	0	2	2477	9	-9	2	-2
	Summer 99	0	1	0	0	1	1	1	0	1	3	5	0	0	5	1	2	5	809	26	17	5	3
	Winter 99	0	2	0	0	1	1	1	0	2	2	4	0	0	2	1	2	4	3002	22	-4	7	2
	Winter 00	0	1	0	0	0	1	1	0	1	6	5	0	0	3	0	3	3	2551	24	2	6	-1
	Winter 01	0	2	0	0	0	1	1	0	1	4	2	0	0	4	1	1	3	1677	20	-4	5	-1
	Winter 02	0	3	0	1	1	0	1	0	1	3	3	0	0	2	1	2	2	2985	20	0	7	2
																					0%		
S5*	Audit 97	0	1	0	1	1	1	1	0	0	4	6	0	0	4	1	1	3	250	24		3	
	Summer 98	0	2	1	1	0	1	1	0	1	4	2	0	0	4	1	0	3	790	21	-3	4	1
	Winter 98	0	1	0	0	0	1	0	0	1	5	4	0	0	3	1	1	3	1905	20	-1	3	-1
	Summer 99	0	2	0	0	0	1	1	0	1	3	2	0	0	2	0	1	4	402	17	-3	5	2
	Winter 99	0	1	0	0	0	1	0	0	1	2	3	0	0	2	1	2	5	1792	18	1	4	-1
	Winter 00	0	2	0	0	1	1	1	0	0	6	3	0	1	4	1	2	4	3443	26	8	5	1
	Winter 01	0	1	0	0	0	0	1	0	1	0	2	0	0	2	1	2	3	3057	13	-12	5	0
	Winter 02	0	2	0	1	0	1	1	0	1	3	3	0	0	3	1	0	1	1207	17	4	4	-1
																					31%		
S6*	Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																						
	Winter 00	0	4	0	0	0	1	0	0	2	5	2	0	0	4	1	2	4	856	25		8	
	Winter 01	0	3	0	0	0	1	1	0	2	4	2	0	0	3	0	2	2	9043	20	-4	8	0
	Winter 02	0	2	0	0	0	1	1	0	2	5	3	0	0	3	1	2	3	4490	23	3	7	-1
																					15%		

Table 7 cont.

	Survey	Bivalvia	Gastropoda	Platyhelminthes	Oligochaetae	Hirudinea	Acarina	Decapoda	Colembolla	Ephemeroptera	Odonata	Hemiptera	Megaloptera	Neuroptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Average abundance	Number of Taxa	Net change of taxa richness	Number of 5 taxa	Net change of 5 taxa*
R1*	Audit 97	1	3	0	0	1	0	1	0	1	5	4	0	0	3	1	2	4	1108	26		8	
	Summer 98	0	2	1	0	1	1	1	0	1	4	5	0	0	4	1	0	2	1443	23	-3	4	-4
	Winter 98	1	0	0	0	1	1	1	0	1	1	6	0	0	4	1	0	3	5322	20	-3	3	-1
	Summer 99	0	1	0	0	1	1	1	0	1	3	4	0	0	2	1	2	4	381	21	1	5	2
	Winter 99	0	1	0	0	0	1	1	0	1	2	4	0	0	5	0	2	3	602	20	-1	5	0
	Winter 00	0	4	0	1	1	1	1	0	1	5	4	0	0	5	1	1	3	6553	28	8	7	2
	Winter 01	0	1	0	0	0	0	1	0	1	3	3	0	0	2	0	3	2	2597	16	-12	6	-1
	Winter 02	0	1	0	0	1	1	1	0	1	4	3	0	0	4	0	0	2	919	18	2	3	-3
																					12.5%		
R2*	Audit 97	0	2	0	0	0	1	1	0	2	1	5	0	0	2	1	1	2	1687	18		6	
	Summer 98	0	1	0	0	0	1	0	0	2	3	3	0	0	2	1	0	3	4040	16	-2	3	-3
	Winter 98	0	3	0	0	0	1	1	0	2	3	6	0	0	5	1	1	2	1945	25	9	7	4
	Summer 99	0	1	0	0	1	1	1	0	2	3	5	0	0	2	0	2	4	972	22	-3	6	-1
	Winter 99	0	2	0	0	1	1	1	0	2	2	2	0	0	2	0	2	1	7497	16	-6	7	1
	Winter 00	0	3	0	1	1	1	0	0	2	3	2	0	0	2	0	2	2	2478	19	3	7	0
	Winter 01	0	2	0	0	1	1	0	0	2	2	4	0	0	4	0	2	5	2867	23	4	6	-1
	Winter 02	0	2	0	0	1	1	0	0	2	1	3	0	0	3	0	1	2	1448	16	-7	5	-1
																					-30.4%		
R3*	Audit 97	0	3	0	0	1	1	1	0	1	2	3	0	0	4	1	1	2	3523	20		6	
	Summer 98	0	4	0	1	0	1	1	0	1	3	6	0	0	4	1	0	2	6773	24	4	6	0
	Winter 98	0	4	0	0	0	1	1	0	1	2	5	0	0	3	1	0	2	5202	20	-4	6	0
	Summer 99	0	4	0	0	0	1	1	0	1	4	6	0	0	6	1	0	4	918	28	8	6	0
	Winter 99	0	3	0	0	1	1	1	0	1	4	6	0	0	4	1	2	6	1531	30	2	7	1
	Winter 00	0	3	0	1	0	0	1	0	1	4	5	0	0	5	1	0	5	4362	26	-4	5	-2
	Winter 01	0	4	0	0	0	1	1	0	1	3	4	0	0	3	0	1	5	9647	23	-3	7	2
	Winter 02	0	2	0	0	0	0	0	0	2	1	2	0	0	2	0	0	1	2485	10	-13	4	-3
																					-56.5%		
R4*	Audit 97	0	2	0	0	1	1	2	0	2	3	3	0	0	4	1	2	3	1405	24		8	
	Summer 98	0	2	1	1	0	1	1	0	1	2	1	0	0	3	0	3	1	1951	17	-7	7	-1
	Winter 98	0	2	0	0	0	1	1	0	1	2	2	0	0	3	0	1	1	2563	14	-3	5	-2
	Summer 99	0	3	0	0	0	1	2	0	1	4	5	0	0	4	1	2	3	477	26	12	8	3
	Winter 99	0	3	0	0	0	1	1	0	1	2	5	0	0	3	1	2	4	1273	23	-3	7	-1
	Winter 00	0	2	0	0	0	1	2	0	2	3	3	0	0	6	0	1	2	6480	22	-1	7	0
	Winter 01	0	3	0	0	0	0	2	0	2	2	3	0	0	5	1	0	2	509	20	-2	7	0
	Winter 02	0	1	0	0	0	1	2	0	1	3	2	0	0	2	0	2	3	830	17	-3	6	-1
																					-15.0%		
Boat Ck1	Audit 97	0	4	0	0	0	0	1	0	2	3	2	0	0	2	0	3	1	1973	18		10	
	Summer 98	0	3	0	1	0	0	1	0	2	3	0	0	0	2	0	2	2	3447	16	-2	8	-2
	Winter 98	1	5	0	0	0	0	2	0	2	5	1	0	0	2	0	3	2	3495	23	7	13	5
	Summer 99	1	2	0	0	0	0	2	0	2	4	1	0	0	4	1	4	3	364	24	1	11	-2
	Winter 99	1	4	0	0	0	0	2	0	2	3	4	0	1	5	0	4	6	4416	32	8	13	2
	Winter 00	0	5	0	0	0	0	2	1	2	5	5	1	0	4	0	3	5	2804	32	0	12	-1
	Winter 01	1	3	0	0	0	1	1	0	2	2	4	0	0	5	0	4	6	1277	29	-3	11	-1
	Winter 02	0	2	0	0	0	0	1	0	1	0	2	0	0	3	0	1	2	3370	12	-17	5	-6
																					-58.6%		
Humpy Ck1	Audit 97	0	2	0	1	0	0	2	0	1	2	6	0	0	4	1	0	5	445	24		5	
	Summer 98, Winter 98, Summer 99 - ns																				-	0	
	Winter 99	0	2	0	0	0	0	1	0	0	4	2	0	0	3	0	1	2	1447	15	-	4	-1
	Winter 00	0	2	0	0	0	0	0	0	0	3	1	0	0	6	0	0	4	1400	16	1	2	-2
	Winter 01	0	5	0	0	0	0	1	0	2	3	3	0	0	6	0	2	6	395	28	12	10	10
	Winter 02	0	2	0	0	0	0	1	0	0	2	1	0	0	2	0	0	3	1367	11	-17	3	-7
																					-60.7%		

Table 7 cont.

	Survey	Bivalvia	Gastropoda	Platyhelminthes	Oligochaetae	Hirudinea	Acarina	Decapoda	Colembolla	Ephemeroptera	Odonata	Hemiptera	Megaloptera	Neuroptera	Diptera	Lepidoptera	Trichoptera	Coleoptera	Average abundance	Number of Taxa	Net change of taxa richness	Number of 5 taxa	Net change of 5 taxa*
Larcom		Audit 97 - ns																					
Ck1	Summer 98	0	2	0	1	1	1	1	0	1	5	7	0	0	2	0	3	4	1256	28	-	7	
	Winter 98	1	2	0	0	1	1	1	0	1	4	4	0	1	3	0	2	7	2018	28	0	7	0
	Summer 99	1	4	0	0	1	1	2	0	2	4	2	0	1	2	1	1	2	854	24	-4	10	3
	Winter 99	1	3	0	0	1	0	1	0	2	5	7	0	0	5	0	1	8	3998	34	10	8	-2
	Winter 00	1	5	0	0	1	1	2	0	2	4	7	0	0	7	1	2	6	5095	39	5	12	4
	Winter 01	0	3	0	0	1	0	1	0	1	2	9	0	1	6	0	1	6	5973	31	-8	6	-6
	Winter 02	1	2	1	0	1	1	1	0	1	5	1	0	0	2	0	1	2	1005	19	-12	6	0
																					-38.7%		
Scrubby		Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																					
Ck1	Winter 00	0	3	0	0	0	1	1	0	0	4	2	0	0	4	1	2	2	5785	20		6	
	Winter 01	0	2	0	0	0	0	1	0	1	4	3	0	0	5	1	2	5	909	24	4	6	0
	Winter 02	0	3	0	0	0	0	1	0	1	5	3	0	0	3	1	2	3	951	22	-2	7	1
																					-8.3%		
Teningie		Audit 97, Summer 98, Winter 98, Summer 99, Winter 99 - ns																					
Ck1	Winter 00	0	0	0	0	0	0	1	0	0	5	3	0	0	5	1	1	2	2751	18		2	
	Winter 01	0	0	0	0	0	1	1	0	2	0	3	0	0	4	0	3	2	4877	16	-1	6	4
	Winter 02	0	0	0	1	0	0	1	0	1	4	0	0	0	3	0	0	2	1643	12	-4	2	-4
																					-25.0%		

* = dam sites, prefix Ck1 = creeks sites

Table 8: Change in mean relative abundance of Chironomid Dipterans at 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002. Mean abundance values are obtained from three replicate kick-net samples.

Season	S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	BCk1	HCk1	LCk1	SCk1	TCk1
Autumn 98	42.7	25.4	8.5	29.4	42.4		34.9	3.9	37.2	16.2	19.9		27.3		
Winter 98	66.1	75.4	88.9	71.1	66.4		79.9	32.3	74.5	69.7	38.6		77.3		
Summer 99	12.2	0.5	34.8	68.4	16.2		1.4	30.8	19.7	31.6	46.3		18.9		
Winter 99	42.4	48.4	48.4	42.9	76.5		36.3	77.4	21.1	43.8	75.2	93.1	52.7		
Winter 00	34.3	3.5	14.8	64.7	80.6	48.4	78.4	9.9	39.5	67.6	58.6	91.8	66.1	88.9	86.2
Winter 01	79.5	45.3	34.4	45.4	87.1	65.2	77.1	21.1	35.7	38.1	62	66.1	42.4	71	84.5
Winter 02	68.9	36.4	52.6	69.3	73.8	63.4	38.5	34.3	49.5	70.3	88.1	93.8	81.3	66.4	71.7

Table 9a: Results of two-way ANOVA on differences in the total macroinvertebrate abundance of 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002.

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Observed*
Corrected Model	1332413753.920(b)	98	13596058.713	6.694	.000	1.000
Intercept	1527246055.824	1	1527246055.824	751.987	.000	1.000
DATE	311035878.084	7	44433696.869	21.878	.000	1.000
SITE	220278424.623	14	15734173.187	7.747	.000	1.000
DATE * SITE	767475439.851	77	9967213.505	4.908	.000	1.000
Error	398065792.918	196	2030947.923			
Total	3583158868.113	295				
Corrected Total	1730479546.837	294				

a Computed using alpha = .05
b R Squared = .770 (Adjusted R Squared = .655)

Table 9b. Results of the Student-Newman-Keuls post-hoc multiple comparison test for differences in the mean abundance between the 15 SPP freshwater sites.

	Site	*N*	*Subset*			
			1	2	3	4
Student-Newman-Keuls	S1	24	953.364108			
	Humpy	12	1151.76388	1151.763889		
	S5	24	1605.95807	1605.958076	1605.958076	
	R4	24	1938.15491	1938.154913	1938.154913	
	S4	24	2290.79132	2290.791328	2290.791328	
	R1	24		2367.066079	2367.066079	
	S2	24		2425.715329	2425.715329	
	Scrubby	9		2548.306878	2548.306878	
	Boat	24		2643.651876	2643.651876	
	R2	24			2858.832862	
	Larcom	21			2885.640425	
	S3	21			2974.357143	
	Teningie	9			3090.259259	
	R3	22				4476.54545
	S6	9				4796.29629
	Sig.		.054	.054	.096	.516

Table 9c. Results of the Student-Newman-Keuls post-hoc multiple comparison test for differences in the mean abundance between the eight sampling dates.

	Date	*N*	*Subset*		
			1	2	3
Student-Newman-Keuls	Summer-1999	33	629.090909		
	Spring-1997	27		1563.972056	
	Winter-2002	43		1688.100775	
	Autumn-1998	33		2325.259358	
	Winter-1999	36		2332.845442	
	Winter-2000	45			3272.026781
	Winter-2001	45			3755.672487
	Winter-1998	33			3840.777778
	Sig.		1.000	.106	.212

Table 10a: Results of two-way ANOVA on differences in the total macroinvertebrate family richness of 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002.

Source	Type III Sum of	df	Mean Square	F	Sig.	Observed
Corrected Model	4704.169(b)	98	48.002	7.491	.000	1.000
Intercept	58359.417	1	58359.417	9107.043	.000	1.000
DATE	995.296	7	142.185	22.188	.000	1.000
SITE	1146.017	14	81.858	12.774	.000	1.000
DATE * SITE	2412.485	77	31.331	4.889	.000	1.000
Error	1256.000	196	6.408			
Total	75830.000	295				
Corrected Total	5960.169	294				

a Computed using alpha = .05
b R Squared = .789 (Adjusted R Squared = .684)

Table 10b. Results of the Student-Newman-Keuls post-hoc multiple comparison test for differences in the mean family richness between the 15 SPP freshwater sites.

	Site	*N*	*Subset*					
			1	2	3	4	5	6
Student-Newman-Keuls	Teningie	9	10.11					
	Humpy	12	10.83					
	Scrubby	9		13.56				
	R2	24		14.33	14.33			
	R4	24		14.46	14.46			
	S2	24		14.67	14.67			
	S5	24		14.71	14.71			
	S3	21		14.86	14.86			
	S4	24		15.00	15.00			
	R1	24		15.38	15.38	15.38		
	S1	24		15.92	15.92	15.92		
	Boat	24			16.71	16.71	16.71	
	S6	9				17.44	17.44	
	R3	22					18.32	18.32
	Larcom	21						19.86
	Sig.		.409	.152	.147	.086	.158	.079

Table 10c. Results of the Student-Newman-Keuls post-hoc multiple comparison test for differences in the mean family richness between the eight sampling dates.

	Date	*N*	*Subset*		
			1	2	3
Student-Newman-Keuls	Winter-2002	43	11.09		
	Winter-1998	33		14.42	
	Autumn-1998	33			15.64
	Spring-1997	27			15.96
	Winter-2001	45			16.24
	Winter-1999	36			16.39
	Winter-2000	45			16.69
	Summer-1999	33			17.21
	Sig.		1.000	1.000	.094

Table 11a. Seasonal changes in fish species composition at ten freshwater dams in Targinnie, Gladstone surveyed from spring 1997 to winter 2002. Values are totals from eight baited trap catches over a two hour sample period for each site.

Site	Survey	*Ambassis agassizii*	*Amniataba percoides*	*Anguilla reinhardtii*	*Craterocephalus stercusmuscarum*	*Gambuisa holbrooki*	*Glossamia aprion gillii*	*Hypseleotris compressus*	*Hypseleotris spA*	*Leiopotherapon unicolor*	*Melanotaenia splendida splendida*	*Mogurnda adspersa*	*Mugilidae* sp.	*Pseudomugil signifer*	Abundance	No. of species/survey	Cumulative species/site
S1	Audit 97										13				13	1	
	Summer 98										22				22	1	
	Winter 98									*O*	6				6	2	
	Summer 99*										6				6	1	
	Winter 99														0	0	
	Winter 00	1									S				1	2	
	Winter 01*										S				0	1	
	Winter 02														0	0	**3**
S2	Audit 97			*T*							129				129	2	
	Summer 98*										1				1	1	
	Winter 98										S				0	1	
	Summer 99*										78				78	1	
	Winter 99										*S*				0	1	
	Winter 00			*S*						*S*	*S*				0	3	
	Winter 01*														0	0	**3**
	Winter 02														0	0	
S3	Audit 97*										88				88	1	
	Summer 98*										167				167	1	
	Winter 98*										51				51	1	
	Summer 99*										153				153	1	
	Winter 99										162				162	1	
	Winter 00*										1				1	1	
	Winter 01*														0	0	
	Winter 02										34				34	1	1
S4	Audit 97	55								*S*	*S*				55	3	
	Summer 98	118								*S*	46				164	3	
	Winter 98	9								*S*	4				13	3	
	Summer 99*	75								1					76	2	
	Winter 99	53						4		*S*	1				58	4	
	Winter 00	2						*S*			*S*				2	3	
	Winter 01*	17						14							31	2	
	Winter 02	S													0	1	4
S5	Audit 97	118							*S*		55				173	3	
	Summer 98	752									110				862	2	
	Winter 98*	99									11				110	2	
	Summer 99*	84									6				90	2	
	Winter 99*	14						2			5				21	3	
	Winter 00*	2													2	1	
	Winter 01*	2													2	1	
	Winter 02*	134									7				141	2	4
S6	**Site not sampled in previous surveys**																
	Winter 00	3									*S*				3	2	
	Winter 01*	50													50	1	
	Winter 02*	1													1	1	**2**

Table 11a cont.

Site	Survey	*Ambassis agassizii*	*Amniataba percoides*	*Anguilla reinhardtii*	*Craterocephalus stercusmuscarum*	*Gambuisa holbrooki*	*Glossamia aprion gillii*	*Hypseleotris compressus*	*Hypseleotris spA*	*Leiopotherapon unicolor*	*Melanotaenia splendida splendida*	*Mogurnda adspersa*	*Mugilidae sp.*	*Pseudomugil signifer*	Abundance	No. of species/survey	Cumulative species/site
R1	Audit 97	*S*				137									137	2	
	Summer 98*	59				43									102	2	
	Winter 98*	67				9				*O*					76	3	
	Summer 99*	20				47			17			6			90	4	
	Winter 99*	7						1							8	2	
	Winter 00	83				1									84	2	
	Winter 01	54								*S*					54	2	
	Winter 02	11				1									12	2	6
R2	Audit 97								2397						2397	1	
	Summer 98								203						203	1	
	Winter 98								204						204	1	
	Summer 99								186						186	1	
	Winter 99*							9	271						280	2	
	Winter 00								226						226	1	
	Winter 01								45						45	1	
	Winter 02								43						43	1	2
R3	Audit 97*	6						*T*			*T*	12			18	4	
	Summer 98*	524									8	1			533	3	
	Winter 98*	234									23	9			266	3	
	Summer 99*	6										18			24	2	
	Winter 99*	2													2	1	
	Winter 00	6							18			4			28	3	
	Winter 01*														0	0	5
	Winter 02														0	0	5
R4	Audit 97									*S*	11	41			52	3	
	Summer 98										1				1	1	
	Winter 98*										7				7	1	
	Summer 99*										1				1	1	
	Winter 99										23	3			26	2	
	Winter 00										15				15	1	
	Winter 01*										338				338	1	
	Winter 02										1	28			29	2	3

*=seine net not taken at site; *S*=captured in seine net; *O*=observed only; *T*=captured in turtle trap (used in spring 1997 only).

Table 11b. Seasonal changes in fish species composition at five freshwater creeks in Targinnie, Gladstone surveyed from spring 1997 to winter 2002. Values are totals from eight baited trap baited trap catches over a two-hour sample period for each site.

Site	Survey	*Ambassis agassizii*	*Amniataba percoides*	*Anguilla reinhardtii*	*Craterocephalus stercusmuscarum*	*Gambusia holbrooki*	*Glossamia aprion gillii*	*Hypseleotris compressus*	*Hypseleotris spA*	*Leiopotherapon unicolor*	*Melanotaenia splendida splendida*	*Mogurnda adspersa*	*Mugilidae* sp.	*Pseudomugil signifer*	Abundance	No. of species/survey	Cumulative species/site
Boat	Audit 97	*T*			1		3	56		*O*	2		*O*	*S*	62	8	
Ck1	Summer 98				11		2	2			*S*		*O*		15	5	
	Winter 98						2	7	*S*				*O*		9	4	
	Summer 99*	*O*	*O*		2		1	3			*O*		*O*		6	7	
	Winter 99	2			2		3	65							72	4	
	Winter 00	*S*			S			61	*S*	1					62	5	
	Winter 01*						1	9							10	2	
	Winter 02							18	16						34	2	10
Larcom	Audit 97														ns	ns	
Ck1	Summer 98*						5	3	11						19	3	
	Winter 98*								27						27	1	
	Summer 99*	10			1				6		1				18	4	
	Winter 99*				1	16		4	4						25	4	
	Winter 00								1						1	1	
	Winter 01*							1							1	1	
	Winter 02*							21	18			1			40	3	8
Humpy	Audit 97*					2		16		*O*		5			23	4	
Ck1	Summer 98														ns	ns	
	Winter 98														ns	ns	
	Summer 99														ns	ns	
	Winter 99*					33		1				4			38	3	
	Winter 00*					1		6				2			9	3	
	Winter 01*							1				6	*O*		7	3	
	Winter 02*												*O*		0	1	5
Scrubby	Site not sampled in previous years																
Ck1	Winter 00								5						5	1	
	Winter 01*	9			29			19	5				*O*		62	5	
	Winter 02*				85	15		29	33						162	4	6
Teningie	Site not sampled in previous years																
Ck1	Winter 00							14							14	1	
	Winter 01*	89			3	20		27							139	4	
	Winter 02	5							7						12	2	5

*=seine net not taken at site; *S*=captured in seine net; *O*=observed only; *T*=captured in turtle trap (used in spring 1997 only)

Table 12. Seasonal observations of waterbirds at 15 freshwater sites in Targinnie, Gladstone surveyed from spring 1997 to winter 2002.

Sites		S1							S2							S3							S4							S5							S6		
Common Name	Scientific Name	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Winter 00	Winter 01	Winter 02
Black duck	*Anas superciliosa*	+		+	+				+	+	+	+	+	+	+			+			+	+	+	+	+	+		+	+	+	+	+	+		+				+
Wood duck	*Chenonetta jubata*	+								+																			+										
White-eyed duck/Hardhead	*Aythya australis*														+														+	+						+			
Plumed Whistling-Duck	*Dendrocygna eytoni*																																						
Grey Teal	*Anas gibberifrons*																																						
Green Pigmy Goose	*Nettapus pulchellus*																													+									
Brolga	*Grus rubicundus*																																		+				
Australian White Ibis	*Threskiornis molucca*																			+								+											
Straw-necked Ibis	*Threskiornis spinicollis*											+																											
Black-Fronted Dotterel	*Elseyornis melanops*																																						
Banded Lapwing	*Vanellus tricolor*																																						
Masked Plover	*Vanellus miles*											+																											
Eastern Swamp Hen	*Porphyrio porphyrio melanotus*																+	+															+	+					
Dusky Moorhen	*Gallinula tenebrosa*													+	+						+																+	+	+
White-faced Heron	*Ardea novaehollandiae*							+				+			+									+	+			+	+										+
Royal Spoonbill	*Platalea regia*																								+														
Yellow-billed Spoonbill	*Platalea flavipes*																																						
Pelican	*Pelecanus conspicillatus*																																						
Black Cormorant	*Phalacrocorax carbo*						+										+																			+			
Pied Cormorant	*Phalacrocorax varius*						+																					+								+			+
Little Pied Cormorant	*Phalacrocorax melanoleucos*		+							+		+																			+		+	+					
White Egret	*Egretta alba*							+															+					+	+							+			+
Little Australian Grebe	*Podiceps novaehollandiae*																									+							+						
Comb-Crested Jacana	*Irediparra gallinacea*																													+	+	+	+	+		+			
Darter	*Anhinga rufa*														+				+																	+			
Number of Species per Site		2	1	1	1	0	2	2	1	3	1	5	1	2	5	0	2	2	1	1	2	1	2	2	3	2	0	5	5	4	3	2	5	3	2	6	1	1	5
Total Number of Species		7							9							6							9							12							5		

Table 12 cont.

Sites		R1							R2							R3							R4						
Common Name	Scientific Name	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02
Black duck	*Anas superciliosa*		+				+	+	+					+							+		+	+	+	+		+	
Wood duck	*Chenonetta jubata*																							+	+				
White-eyed duck/Hardhead	*Aythya australis*																												
Plumed Whistling-Duck	*Dendrocygna eytoni*	+																											
Grey Teal	*Anas gibberifrons*																												
Green Pigmy Goose	*Nettapus pulchellus*																												
Brolga	*Grus rubicundus*																												
Australian White Ibis	*Threskiornis molucca*																												
Straw-necked Ibis	*Threskiornis spinicollis*																												
Black-Fronted Dotterel	*Elseyornis melanops*																						+						
Banded Lapwing	*Vanellus tricolor*																							+					
Masked Plover	*Vanellus miles*																							+	+				
Eastern Swamp Hen	*Porphyrio porphyrio melanotus*	+						+																+	+		+	+	
Dusky Moorhen	*Gallinula tenebrosa*																				+								
White-faced Heron	*Ardea novaehollandiae*				+						+	+												+			+		
Royal Spoonbill	*Platalea regia*																												
Yellow-billed Spoonbill	*Platalea flavipes*																												+
Pelican	*Pelecanus conspicillatus*																												+
Black Cormorant	*Phalacrocorax carbo*																										+		
Pied Cormorant	*Phalacrocorax varius*						+																				+		
Little Pied Cormorant	*Phalacrocorax melanoleucos*											+			+	+	+							+					
White Egret	*Egretta alba*																												
Little Australian Grebe	*Podiceps novaehollandiae*																												
Comb-Crested Jacana	*Irediparra gallinacea*																												
Darter	*Anhinga rufa*							+							+														
Number of Species per Site		2	1	0	1	0	2	3	1	0	1	2	0	1	2	1	1	0	0	0	2	0	2	7	4	1	4	2	2
Total Number of Species		6							4							3							12						

Sites		Boat Ck1							Larcom Ck1							Humpy Ck1				Scrubby Ck1			Teningie Ck1		
Common Name	Scientific Name	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Summer 98	Winter 98	Summer 99	Winter 99	Winter 00	Winter 01	Winter 02	Winter 99	Winter 00	Winter 01	Winter 02	Winter 00	Winter 01	Winter 02	Winter 00	Winter 01	Winter 02
Black duck	*Anas superciliosa*									+					+										
Wood duck	*Chenonetta jubata*																								
White-eyed duck/Hardhead	*Aythya australis*																								
Plumed Whistling-Duck	*Dendrocygna eytoni*																								
Grey Teal	*Anas gibberifrons*										+														
Green Pigmy Goose	*Nettapus pulchellus*																								
Brolga	*Grus rubicundus*																								
Australian White Ibis	*Threskiornis molucca*																								
Straw-necked Ibis	*Threskiornis spinicollis*																								
Black-Fronted Dotterel	*Elseyornis melanops*																								
Banded Lapwing	*Vanellus tricolor*																								
Masked Plover	*Vanellus miles*																								
Eastern Swamp Hen	*Porphyrio porphyrio melanotus*									+															
Dusky Moorhen	*Gallinula tenebrosa*																			+					
White-faced Heron	*Ardea novaehollandiae*																								
Royal Spoonbill	*Platalea regia*																								
Yellow-billed Spoonbill	*Platalea flavipes*																								
Pelican	*Pelecanus conspicillatus*																								
Black Cormorant	*Phalacrocorax carbo*									+															
Pied Cormorant	*Phalacrocorax varius*																					+			
Little Pied Cormorant	*Phalacrocorax melanoleucos*																								
White Egret	*Egretta alba*																								
Little Australian Grebe	*Podiceps novaehollandiae*																								
Comb-Crested Jacana	*Irediparra gallinacea*																								
Darter	*Anhinga rufa*																								
Number of Species per Site		0	0	0	0	0	0	0	0	3	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0
Total Number of Species		0							4							0				2			0		

Table 13: Assessment of change from the previous season. A tick indicates decline in the relevant biotic index at that site between 2001 and 2002. These declines are combined to give a biotic decline score for each site.

Site	Marked decline in plant cover	Decline in macroinvertebrate family richness	Decline in sensitive taxa: Gastropoda	Decapoda	Ephemeroptera	Trichoptera	Bivalvia	Decline in fish species	Biotic Decline Score
S1		✓				✓		✓	3
S2	✓	✓	✓			✓			4
S3	✓		✓			✓			3
S4			✓					✓	2
S5						✓			1
S6			✓						1
R1						✓			1
R2		✓				✓			2
R3	✓	✓	✓	✓		✓			5
R4	✓	✓	✓		✓	✓			5
Boat Ck1	✓	✓	✓		✓	✓	✓		6
Humpy Ck1		✓	✓		✓	✓		✓	5
Larcom Ck1	✓	✓							3
Scrubby Ck1	✓	✓						✓	3
Teningie Ck1	✓	✓	✓		✓	✓		✓	5

Table 14: Correlation results (r) of water quality parameters, macroinvertebrate indices and macrophyte indices at SPP dam sites. Significant values are in bold (*= p<0.05 ** =p<0.001).

Water quality Indices	pH	conductivity	temperature	percent dissolved oxygen	salinity	**Macroinvertebrate Indices**	familiy richness	abundance	percent chironomidae	**Macrophyte Indices**	total macrophytes	submerged macrophytes
water level	0.130	**0.228***	0.157	-0.023	0.285		**0.258***	0.116	-0.135		0.140	-0.198
pH		0.005	0.045	**0.559****	0.136		-0.059	0.230*	0.134		0.059	**0.408****
conductivity			-0.087	-0.148	**0.985****		**0.308****	0.377**	-0.168		0.218	-0.097
temperature				0.135	-0.193		-0.019	**(-)0.255****	-0.143		**0.189**	0.198
percent dissolved oxygen					-0.153		-0.190	0.660	0.106		-0.113	0.130
salinity							**0.410****	**0.355***	-0.278		0.210	-0.910
mg/L dissolved oxygen							-0.22	-0.89	-0.21		-0.14	-0.43
Macroinvertebrate Indices												
familiy richness								0.014	-0.132		**0.353****	-0.710
abundance									**0.374****		0.047	0.012
percent chironomidae											-0.112	-0.171

Table 15: Correlation results (r) of water quality parameters, macroinvertebrate indices and macrophyte indices at SPP creek sites. Significant values are in bold (*= p<0.05 **= p<0.001).

Water quality Indices	pH	conductivity	temperature	percent dissolved oxygen	salinity	**Macroinvertebrate Indices**	familiy richness	abundance	percent chironomidae	**Macrophyte Indices**	total macrophytes	submerged macrophytes
water level	-0.263	0.020	0.122	-0.168	0.094		0.364	0.181	-0.258		0.292	0.175
pH		**0.391***	-0.174	**0.488****	0.36		-0.037	0.021	0.205		0.377	**0.439***
conductivity			**(-)0.402***	-0.001	**0.916****		**(-)0.464***	-0.134	**0.553****		0.191	0.259
temperature				-0.023	-0.494		0.007	-0.284	**(-)0.772****		0.129	0.199
percent dissolved oxygen					0.108		0.089	0.094	0.014		**0.641****	**0.577****
salinity							**(-)0.620***	0.108	**0.675****		**0.498***	**0.666****
mg/L dissolved oxygen							0.107	0.147	0.090		**0.609****	**0.525****
Macroinvertebrate Indices												
familiy richness								0.239	-0.395		-0.081	-0.223
abundance									0.031		0.192	0.196
percent chironomidae											-0.104	0.007

Figure 1: Map of the Yarwun Targinie area showing the locations of fifteen freshwater monitoring sites sampled from spring 1997 to winter 2002.

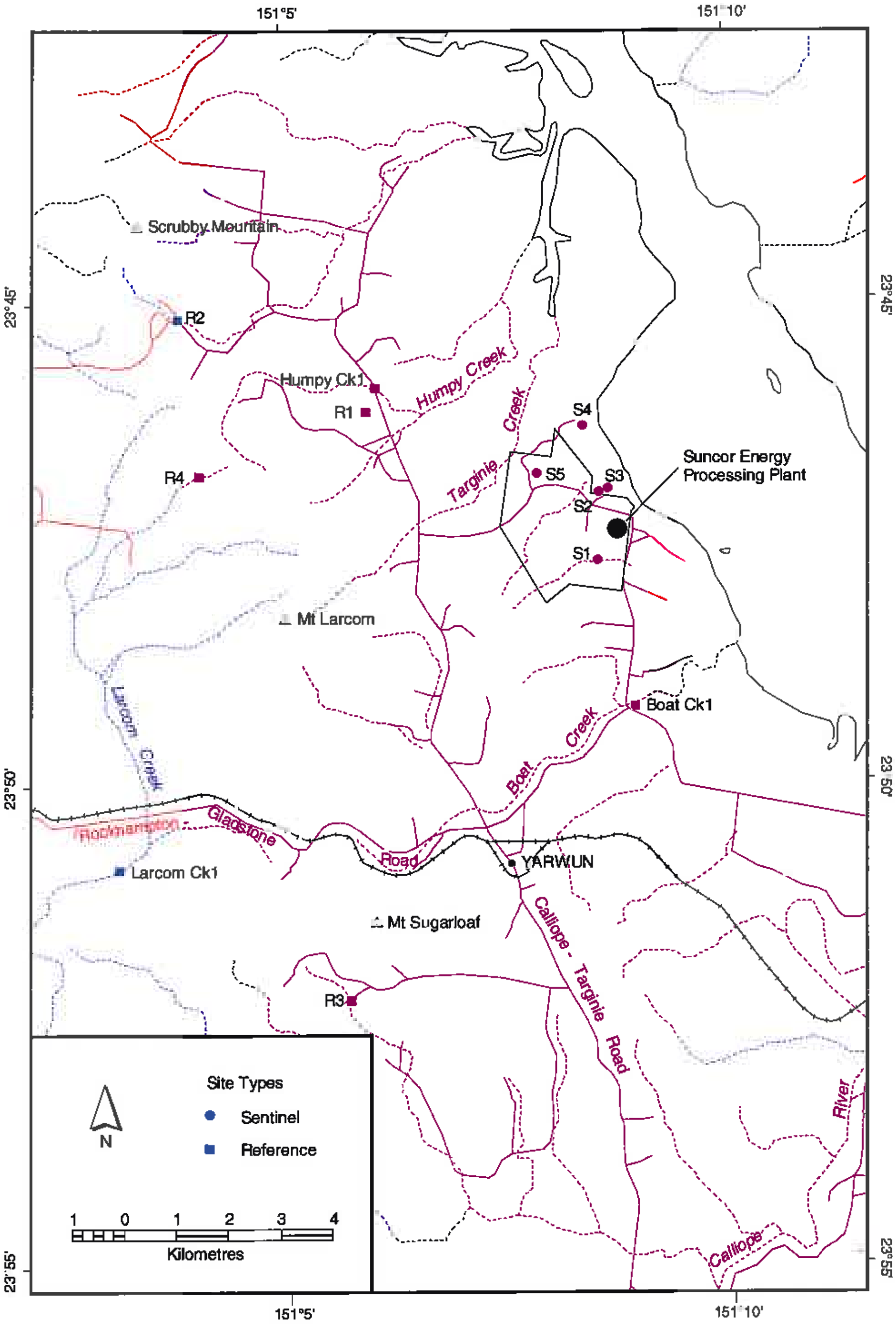
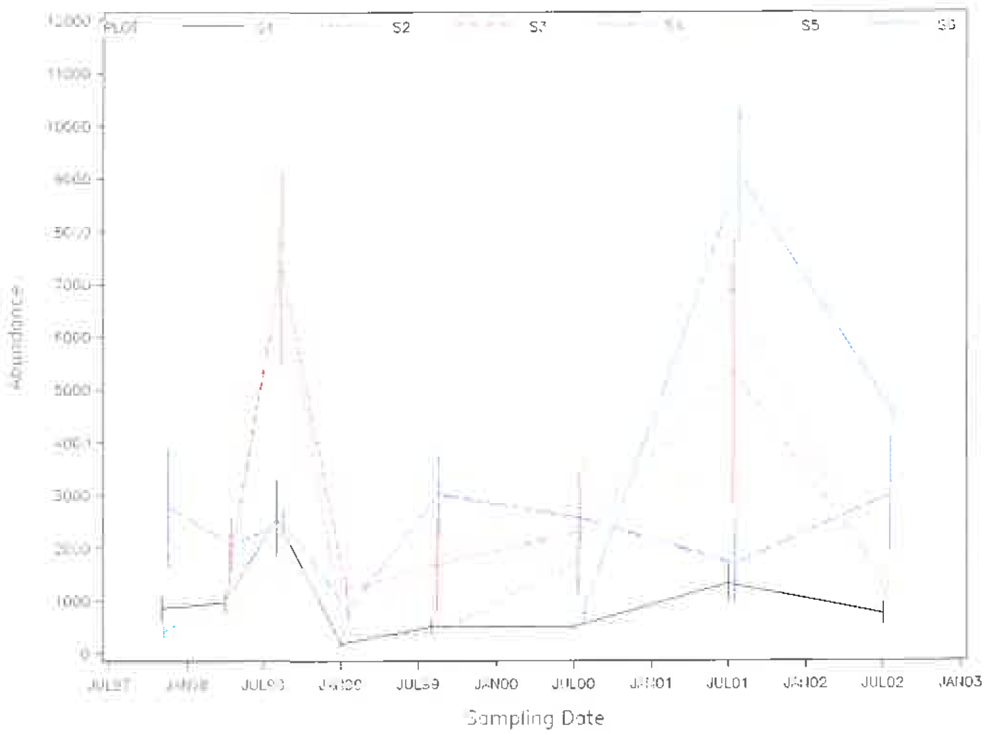


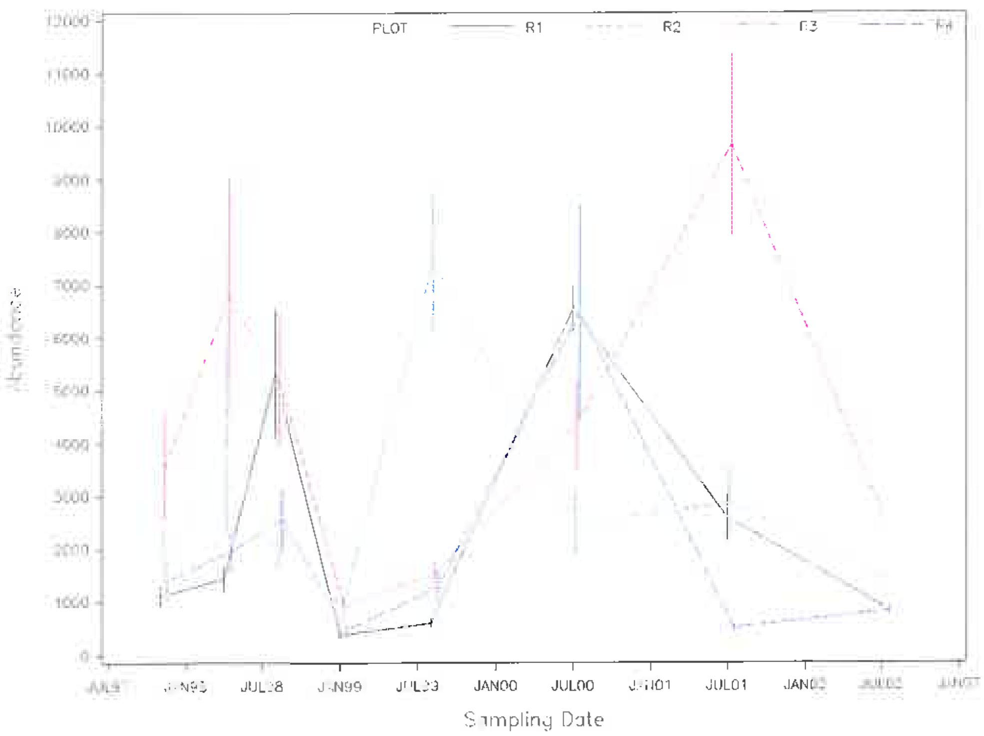
Figure 1: Targinie - Yarwun area showing Aquatic Monitoring Sites for the Stage 1- Stuart Project.

Figure 2. Changes in mean abundance of invertebrate fauna at (a) dam sites S1-S6, (b) dam sites R1-R4 and (c) creek sites from spring 1997 to winter 2002. Means and associated standard errors are derived from 3 replicate net samples.

(a)



(b)



(c)

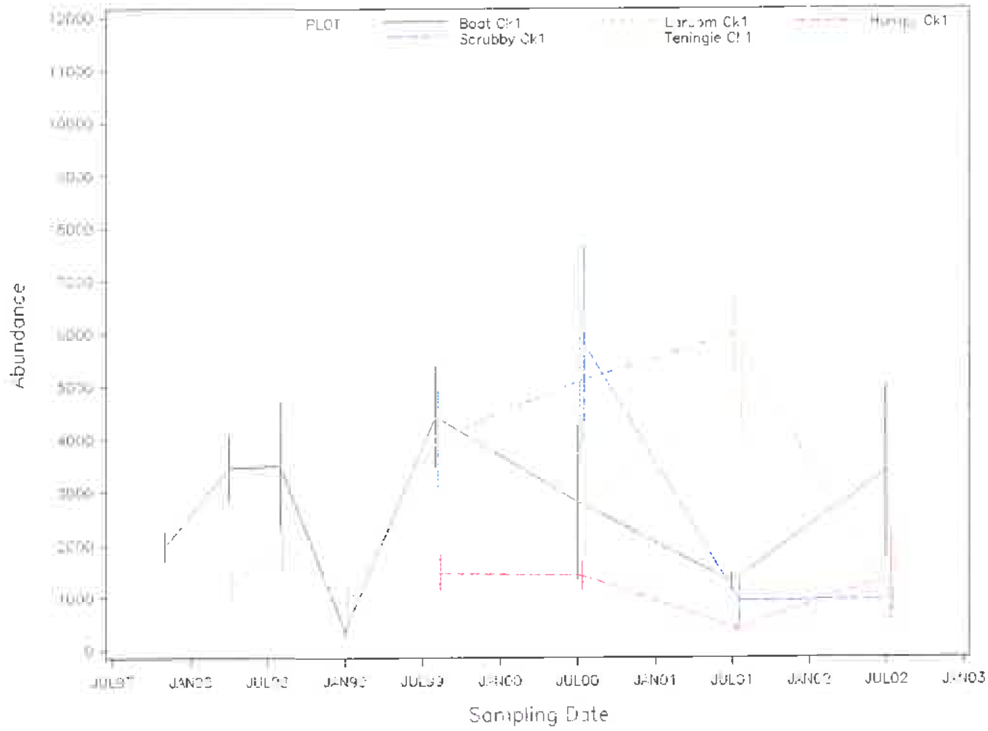
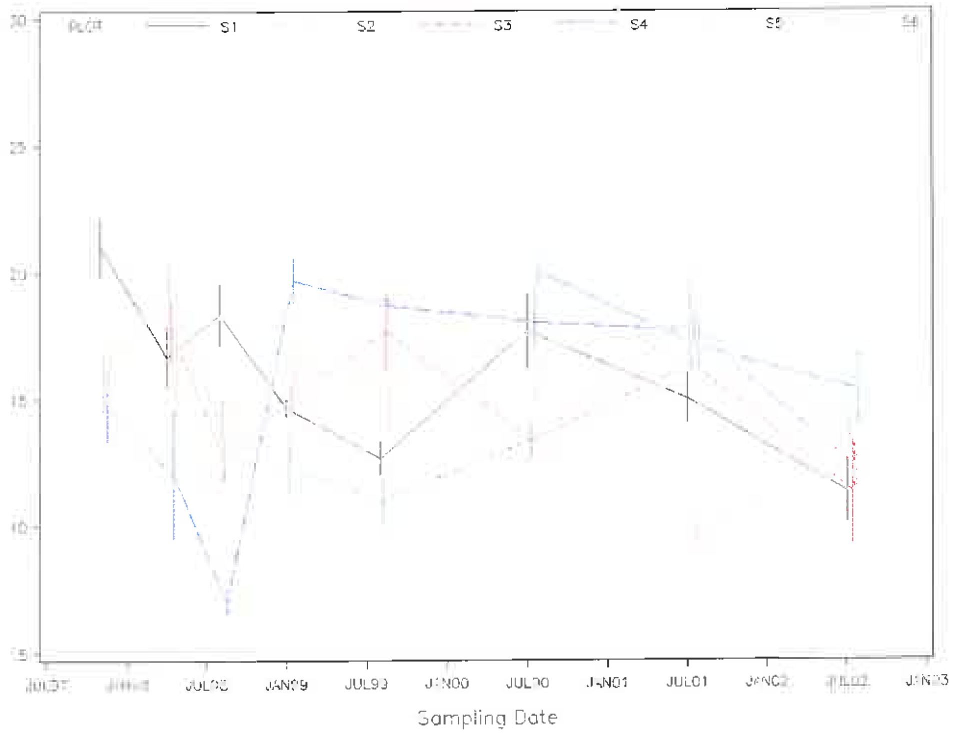
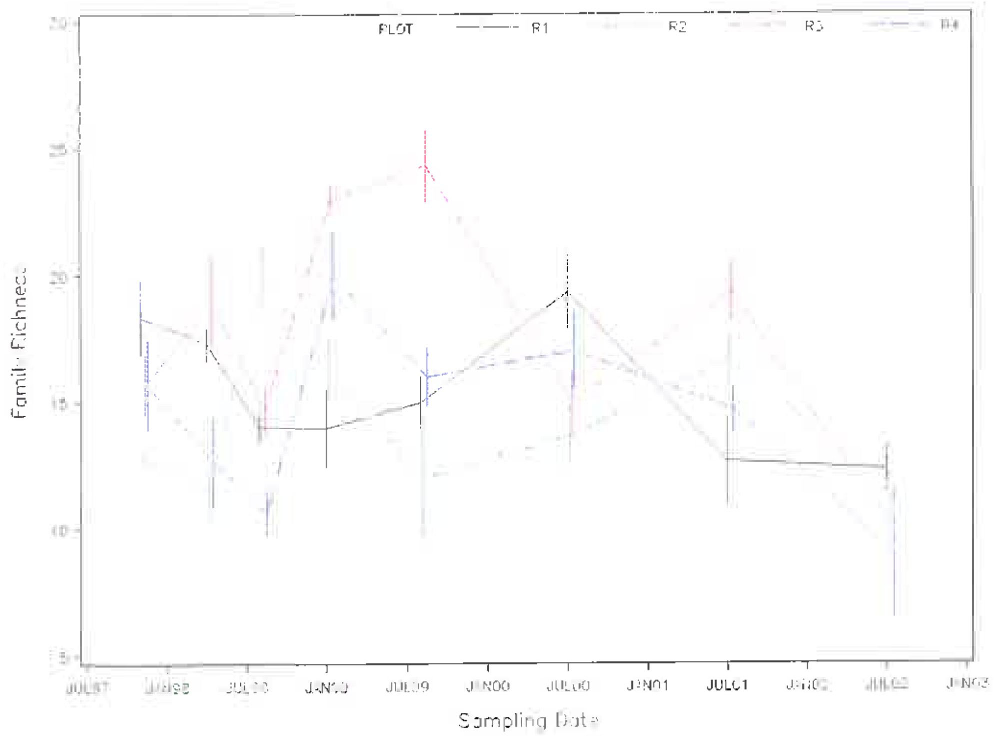

PLOT
Boat Ck1
Scrubby Ck1
Teningie Ck1
Abundance
Sampling Date
JAN00
JUL00
JAN01
JUL02
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000

Figure 3. Changes in mean famly richness of invertebrate fauna at (a) dam sites S1-S6, (b) dam sites R1-R4 and (c) creek sites from spring 1997 to winter 2002. Means and associated standard errors are derived from 3 replicate net samples.

(a)



(b)



(c)

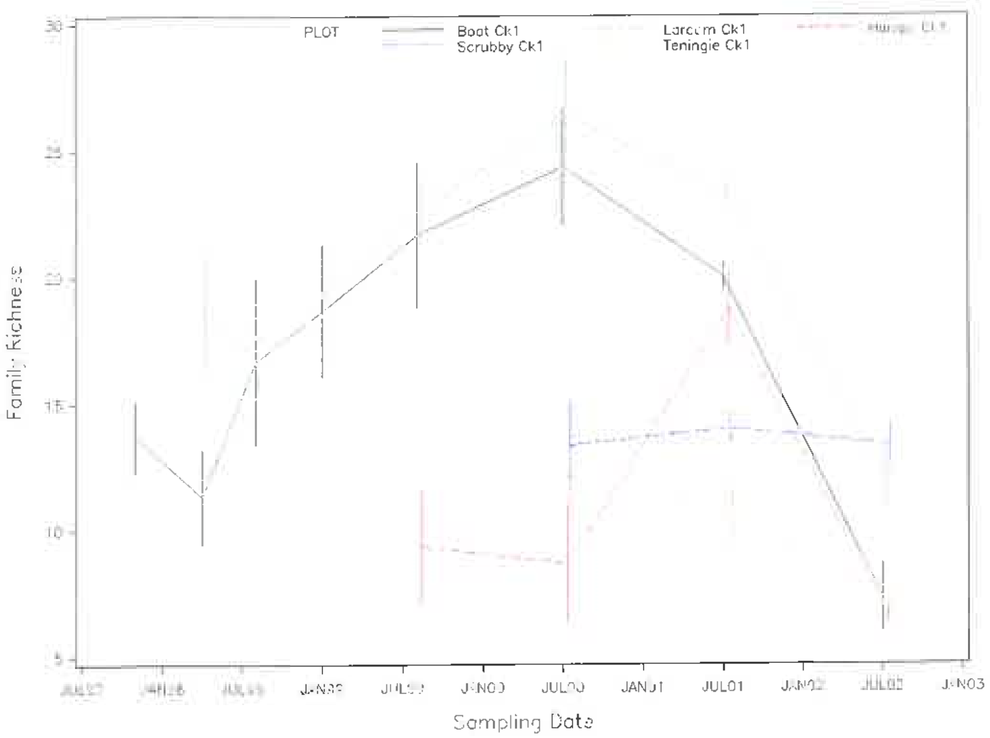

PLOT
Boot Ck1
Scrubby Ck1
Teningie Ck1
Family Richness
JAN03
JUL01
Sampling Date

Figure 4: Plot of habitat types superimposed onto MDS ordination of aquatic macroinvertebrate families found at SPP freshwater sites during summer 1998, winter 1998, summer 1999, winter 1999, winter 2000, winter 2001 and winter 2002.

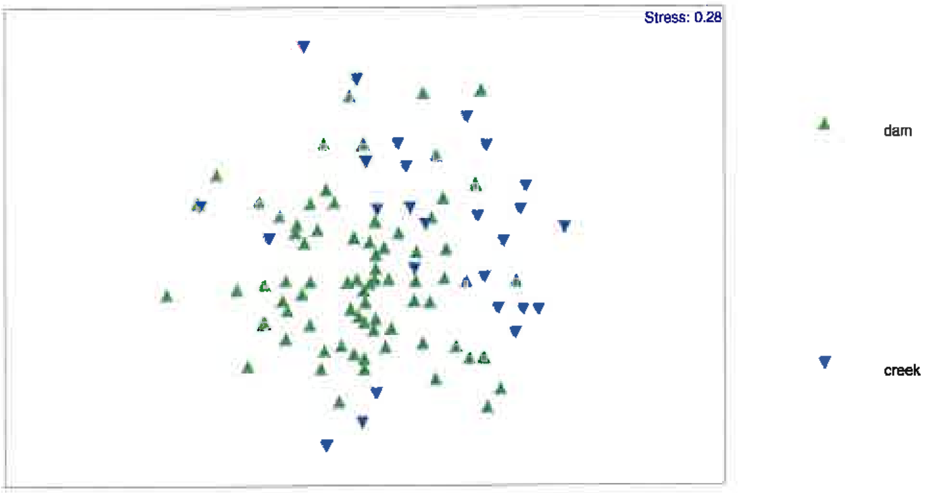


Figure 5: Plot of seasons superimposed onto MDS ordination of aquatic macroinvertebrate famlies found at SPP freshwater sites during summer 1998, winter 1998, summer 1999, winter 1999, winter 2000, winter 2001 and winter 2002.

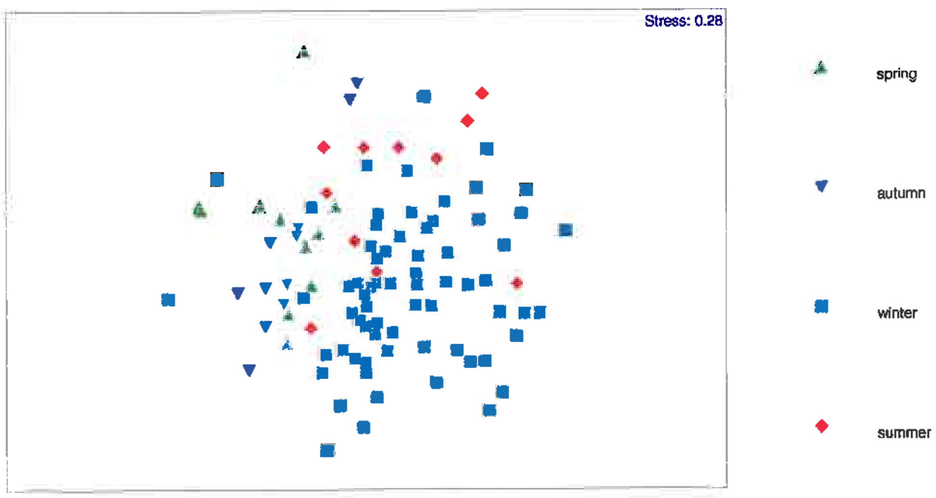


Figure 6: MDS ordination of Bray Curtis dissimilarity measures for aquactic macroinvertebrates observed at SPP freshwater dam sites sampled during winter 1998, winter 1999, winter 2000, winter 2001 and winter 2002.

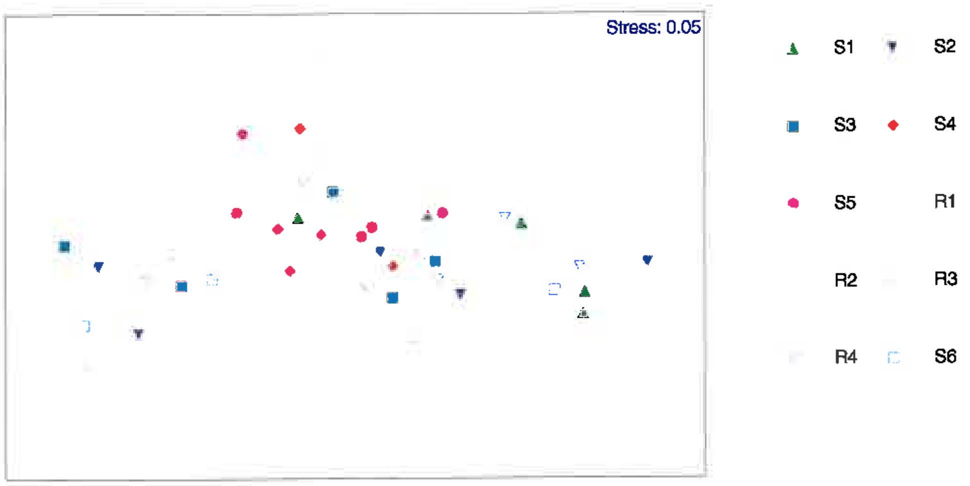
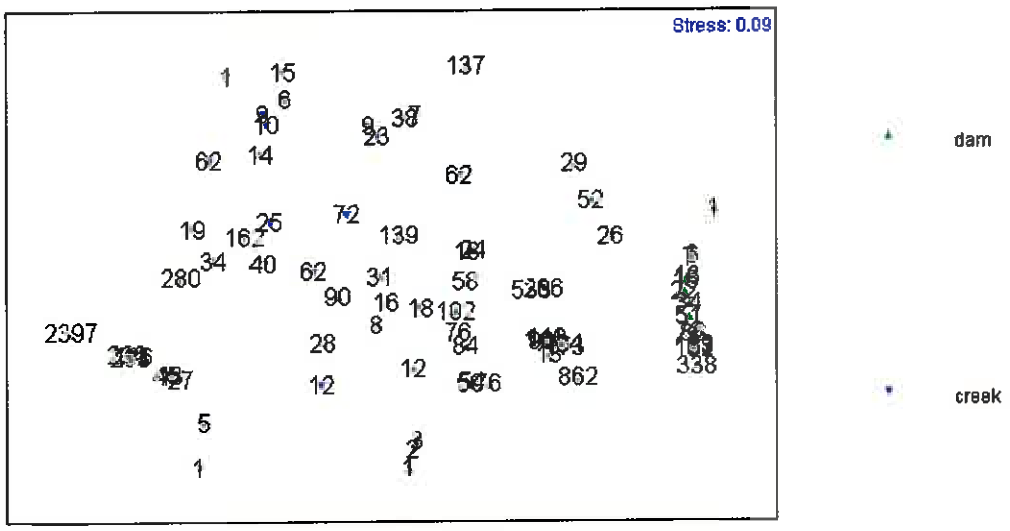


Figure 7: Plots of fish habitat type and (a) abundance and (b) species richness superimposed onto MDS ordination of SPP freshwater sites sampled during spring 1997, summer 1998, winter 1998, summer 1999, winter 1999, winter 2000, winter 2001 and winter 2002.

(a)



(b)

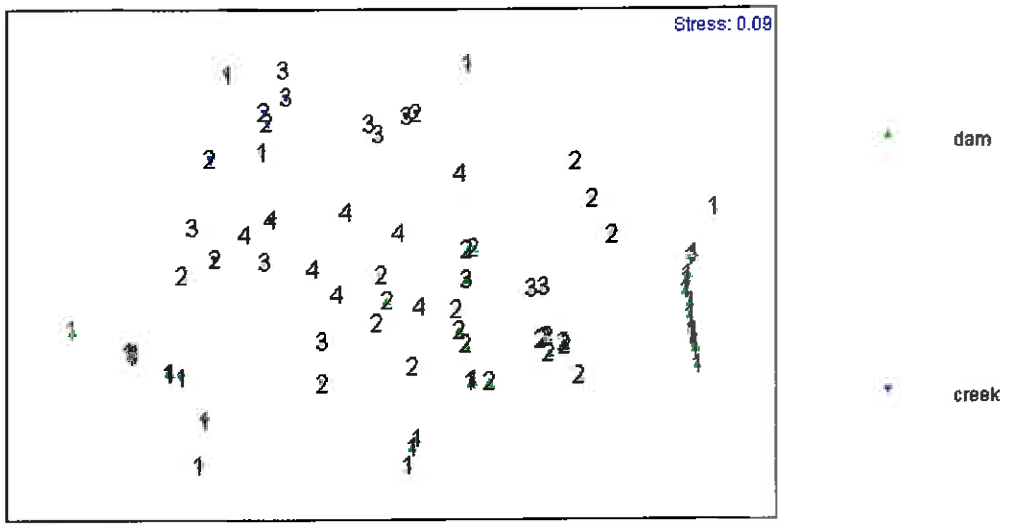


Figure 8: MDS ordination of Bray Curtis dissimilarity measures for fish observed at SPP freshwater sites sampled during spring 1997, autumn 1998, winter 1998, summer 1999, winter 1999, winter 2000, winter 2001 and winter 2002.

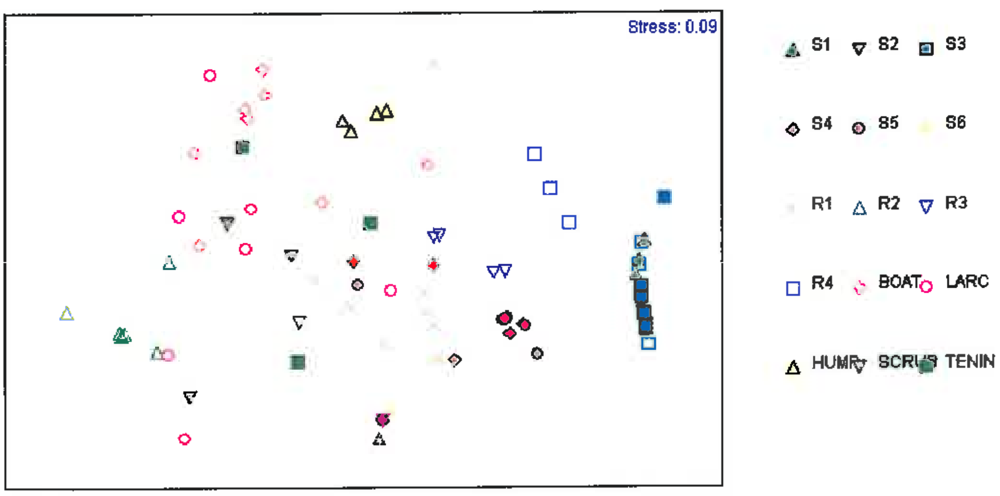
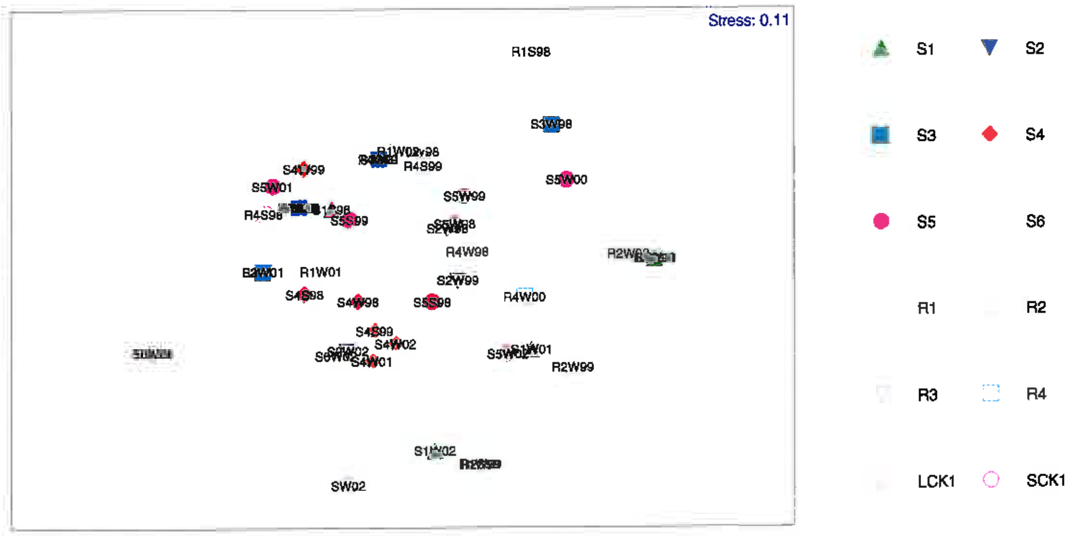


Figure 9: MDS ordination of Bray Curtis dissimilarity measures for the birds observed at SPP freshwater sites sampled during summer 1998, winter 1998, summer 1999, winter 1999, winter 2000, winter 2001 and winter 2002.



Appendix 1: SPP winter 2002 aquatic monitoring site locations and details

Site Name	Site Habit	Lat. & Long.	Lot Description	Catchment	Habitat
S1	dam	S 23 47'38.2" E 151 08'35.6"	SGP 502	Southern Pacific Petroleum Lease, Gully B	Dam
S2	dam	S 23 46'55.3" E 151 08'37.2"	Lot 32 on DS469	Southern Pacific Petroleum Lease, Gully C	Dam
S3	dam	S 23 46'52.5" E 151 08'43.2"	Lot 32 on DS469	Southern Pacific Petroleum Lease, Gully C	Dam
S4	dam	S 23 46'14.3" E 151 08'26.4"	Lot 92 on DS654	Gladstone Port Authority, Gully D	Dam
S5	dam	S 23 46'42.6" E 151 07'55.0"	SGP 502	Southern Pacific Petroleum Lease, Gully E	Dam
S6	dam	S 23 47'27.2" E 151 06'26.5"	Lot 90 MPH 33801	Targinie Amphitheatre	Dam
R1	dam	S 23 46'03.3" E 151 06'00.5"	Lot 1 on MPH30866	Humpy Creek	Dam
R2	dam	S 23 45'04.7" E 151 03'56.3"	Lot 75 on DS670	Scrubby Creek	Dam
R3	dam	S 23 52'10.0" E 151 05'45.9"	Lot 1 on RP611963	Spring Valley Region	Dam
R4	dam	S 23 46'42.2" E 151 04'08.3"	Lot 45 on RP894241	Larcom Creek	Dam
Larcom Ck1	creek	S 23 50'47.2" E 151 03'10.8"	Lot 267 on L4093 Lot 268 on L4094 Lot 1 on P619803 Lot 2 on P619805	Larcom Creek	Creek
Boat Ck1	creek	S 23 49'07.7" E 151 09'00.7"	Lot 130 on CTN1912	Boat Creek	Creek
Humpy Ck1	creek	S 23 45'49.1" E 151 06'04.8"	Lot 94 on DS677	Humpy Creek	Creek
Scrubby Ck1	creek	S 23 43'42.2" E 151 06'18.5"	Lot 37 DS288	Scrubby Creek	Creek
Teningie Ck1	creek	S 23 43'16.8" E 151 06'08.6"	Lot 36 DS288	Teningie Creek	Creek