Current Status of the Macroinvertebrate Communities in Lakes Sorell and Crescent

Inland Fisheries SERVICE

Rehabilitation of Lakes Sorell and Crescent Report Series

Number 7/2

February 2003

Natural Heritage Trust

Helping Communities Helping Australia

A Commonwealth Government Initiative

Current Status of the Macroinvertebrate Communities in Lakes Crescent and Sorell

Integrated and multi-disciplinary approach to the rehabilitation of Lakes Sorell and Crescent

Scott A. Hardie

Inland Fisheries Service
February 2003

Inland Fisheries Service

Natural Heritage Trust
Helping Communities
Helping Australia

For further information contact:

Inland Fisheries Service
PO Box 288
Moonah Tas 7009
Telephone: (03) 6233 4140
Facsimile: (03) 6233 4141
Email: infish@ifs.tas.gov.au

Find further information about IFS on the internet site http://www.ifs.tas.gov.au

This report is part of a series of documents, which provide management recommendations for the environmental requirements of lakes Sorell and Crescent as part of the Lakes Sorell and Crescent Rehabilitation Project.

The aim of the rehabilitation project is to obtain an understanding of the systems, identify the needs of the users of the lakes and subsequently provide recommendations for the future management and protection of these important ecosystems.

Financial support contributed by the Natural Heritage Trust and the Tasmanian State Government via the Inland Fisheries Service is gratefully acknowledged.

Citation: Hardie, S. A. (2003). Current Status of the Macroinvertebrate Communities in Lakes Crescent and Sorell. Inland Fisheries Service, Hobart.

Executive Summary

A decline in the trout fishery, water quality and ecological values of lakes Sorell and Crescent has occurred over the past few years. In light of these problems, the Inland Fisheries Service (IFS) secured State and Commonwealth (Natural Heritage Trust) funding to implement on-ground works and formulate management options to address the recent environmental decline. The key problem associated with the lakes is low water levels due primarily to drought conditions and competition for water by various users. A multi-disciplinary project was adopted to address the situation – the *Lakes Sorell and Crescent Rehabilitation Project*. This project was comprised of ten sub-projects targeting key areas of physical and biological importance to the functioning and management of lakes Crescent and Sorell. The ten sub-projects were:

- Lake Crescent Outflow Screen Duplication
- Mountain Creek Rehabilitation
- Catchment Management Plan
- Water Management Plan
- Water Quality
- Wetlands
- Aquatic Fauna
- Recreational Fisheries
- Carp Management
- Ecological Modelling

This report outlines some of the findings and management recommendations for the *Aquatic Fauna Sub-project*.

The aquatic fauna of lakes Crescent and Sorell thought to be of particular importance, in terms of the health of the aquatic eco-systems and conservation value, were populations of the 'rare' and endemic freshwater fish, golden galaxias (*Galaxias auratus*), and the macroinvertebrate communities of both lakes. It was suspected prior to the project that the recent decline in the environmental condition of lakes Crescent and Sorell had adversely impacted on these faunal components of the lakes.

The *Aquatic Fauna Sub-project* of the *Lakes Sorell and Crescent Rehabilitation Project* involved studying the ecology and current status of populations of *G. auratus* and also the current status of macroinvertebrate communities in lakes Crescent and Sorell. The project also focused on defining the threatening processes which these fauna are facing.

This report, 'Current Status of the Macroinvertebrate Communities in Lakes Crescent and Sorell', documents the results of the work that was undertaken on the invertebrate communities during the *Aquatic Fauna Sub-project* and details recommendations for the future management of lakes Crescent and Sorell. The results of the *G. auratus* study are documented in a separate report (Hardie 2003).

The **macroinvertebrate fauna of lakes Crescent and Sorell was surveyed** to:

- determine the current status of macroinvertebrate communities,
- determine the effect of lake level on macroinvertebrate communities,
- identify threatening processes to macroinvertebrates and
- produce a report detailing the current status of the macroinvertebrate communities and recommendations for maintaining and enhancing the distribution, abundance and diversity of these communities.

The macroinvertebrate communities of lakes Crescent and Sorell are a critical component of the ecosystem associated with these lakes. Invertebrates are at the lower end of the food chain providing valuable food resources for fish, waterbirds platypus and other animals. In the case of lakes Crescent and Sorell, populations of the endemic gastropod *Austropyrus* sp. also hold significant conservation value.

During the 12-month study period (July 2000 – July 2001), lakes Crescent and Sorell were in a very degraded state in terms of water quality as well as habitat diversity and availability. The lakes were experiencing record low water levels resulting in loss and degradation of available habitat and high to extremely high water turbidity. These alterations to the Crescent-Sorell system were thought to be threatening the invertebrate communities present in the system.

A total of 47 species were collected in lakes Crescent and Sorell during the recent study. Forty species were recorded in both Lake Crescent and Lake Sorell and 33 of these species were found to be common to both lakes.

The composition of the invertebrate communities in both lakes was found to be very similar. The dominant groups were turbellaria (3 unidentified species), nematod (1 unidentified species), oligochaete (1 unidentified species), gastropod (3 species in each lake), crustacea (11 species in each lake) and insect (17 and 19 species in Lake Crescent and Lake Sorell, respectively).

During the study period the wetlands associated with lakes Crescent and Sorell remained relatively dry and did not become inundated from the main lakes. Therefore, sampling was not undertaken on a major scale in the wetlands. Kemps Marsh did however, hold a significant volume of water over a period of approximately 5 months during spring/summer 2001/02, which allowed macrophytes to germinate and grow and invertebrate communities to establish.

A total of 50 macroinvertebrate species (and 1 vertebrate species) were recorded in Kemps Marsh. The species composition of the wetland fauna was dominated by acarina (5 species), micro-crustacea (8 species) and insects (27 species).

The invertebrate fauna of Kemps Marsh was found to vary greatly from that of lakes Crescent and Sorell. Significant differences were found in both the composition and abundance of fauna in general and the diversity of some fauna groups. Of the 50 invertebrate species recorded in Kemps Marsh, 32 (64%) were not currently present in lakes Crescent and Sorell. A further 6 species had been recorded in lakes Crescent and Sorell during previous studies but were not found during the current study.

It was found to be difficult to draw any significant conclusions in regard to changes in the invertebrate fauna of lakes Crescent and Sorell in recent years. Previous studies have focused on specific aspects of the communities (ie certain habitats or specific species) and have used different sampling methodologies to that employed during this study. In addition, variation in accuracy and level of the taxonomy undertaken by the different studies has made it difficult to draw direct comparisons between the findings of past studies and those of the current study.

It would appear that the structure of the invertebrate communities of lakes Crescent and Sorell has remained reasonably stable despite alterations to in-lake habitats in recent years. However due to the reduction in the diversity and amount of habitat(s) that are available (eg. de-watered rocky shorelines) it is thought that the abundance and population size of certain species has significantly decreased.

The **main threats** to the invertebrate communities of lakes Crescent and Sorell are associated with low water levels. These threats include:

- decrease in the diversity of in-lake habitat
    - loss of rocky shore habitat, particularly Lake Crescent
    - loss of in-lake macrophyte habitat, particularly Lake Sorell
    - loss of sandy shore habitat
- reduction in available habitat
    - disconnection and de-watering of adjacent wetlands
    - reduction of lake volume
- decrease in water quality
    - high to very high water turbidity
    - siltation of rock and sand shores
    - limitation of the growth and survival of in-lake macrophytes

Other general threats to macroinvertebrates include:

- competition and predation from introduced fauna
- draining and grazing of adjacent and associated wetlands
    - restrict distribution and abundance of some species by decreasing and/or disturbing available habitat
    - alter flooding regimes and water levels
- recreational use of lakes
    - potential for introduction of flora and fauna

In light of the findings of the survey that has been undertaken on the macroinvertebrate communities of lakes Crescent and Sorell and the threatening processes that have been identified, several management issues have been highlighted. A brief summary (see section 5 for more detail) containing **6 key recommendations** for the management and protection of macroinvertebrate communities follows:

1 Historical seasonal cycles in water level regimes should be retained and altered as little as possible.

2 Lakes Crescent and Sorell should be managed at mid to high water levels to protect habitat diversity and ensure good water quality. Water levels in Lake Crescent should be managed above 802.20 m AHD, the level above which rocky shore habitat becomes inundated.

3 Educate users of lakes Crescent and Sorell about the risks associated with introducing flora and fauna into the system and procedures that can be adopted to prevent it happening.

4 Develop partnership approaches with landholders for managing the wetlands as sensitive aquatic habitats.

5 Replicate the in-lake invertebrate survey undertaken in the current study during an extended period of high water levels (possibly levels > 803.20 m AHD and 804.20 m AHD in Crescent and Sorell respectively). Sample in-lake macrophyte beds (if/when present) for invertebrates during the survey. Compare the diversity and abundance of the invertebrate communities to the results obtained for in-lake habitats during the current study to examine the effect of water level variation on invertebrate communities on in-lake habitats.

6 Replicate the wetland invertebrate survey undertaken in the current study in Kemps Marsh (Lake Sorell) and also conduct a survey in Interlaken Lakeside Reserve (Lake Crescent), during an extended period of high water levels. Compare diversity and abundance of invertebrate communities to the results obtained for Kemps Marsh during the current study to examine the effect of water level variation on invertebrate communities of the wetlands.

Acknowledgments

Many people provided valuable support and advice during the *Aquatic Fauna Sub-project* and made significant contributions towards the work undertaken on the invertebrate communities in lakes Crescent and Sorell and this report.

Several people from the Inland Fisheries Service (IFS) are thanked. John Diggle managed the project and gave valuable advice that helped direct the project. Jenny Deakin provided water level and metrological data at regular intervals during the study and also helped direct the project. Adam Uytendaal and Danielle Heffer were fantastic Project Officers to work with and gave valuable support and encouragement in the areas of project management, fieldwork, data analysis and reporting of results. Brett Mawbey assisted in a large proportion of the field and laboratory work. Brett also gave technical support and advice in regard to the historical status of invertebrate communities in lakes Crescent and Sorell and methods used for field work. Brett's guidance based on his extensive knowledge of the Interlaken area was also much appreciated. Keith Breheny helped with both field and laboratory work and also analysed the invertebrate data to a preliminary level. Helen Mulcahy also provided technical support. Members of the IFS Carp Management and Recreational Fisheries teams also gave support in the field.

Ron Mawbey (Aquenal) provided inspiration and useful information from his extensive knowledge of the Interlaken area.

Tom Sloane (SSS Wildlife Services) undertook all invertebrate identifications and provided insight into the distribution of invertebrates in the Crescent-Sorell system.

The work that is documented in this report was conducted in accordance with the terms of an Inland Fisheries Service Exemption Permit (IFS Permit Number 2000/31 and PWS Permit Number TFA00022) and conditions of the Department of Primary Industries Water and Environment Animal Ethics Committee (DPIWE AEC certificate number 20/2001-2002). This work was funded by the Inland Fisheries Service and the Natural Heritage Trust.

Abbreviations

Acronyms

AEC	Animal Ethics Committee
AHD	Australian Height Datum
DPIWE	Department of Primary Industries, Water and Environment
FBA	Freshwater Biological Association
IFS	Inland Fisheries Service
NTU	Nephelometric Turbidity Units
PWS	Parks and Wildlife Service

Terminology

Integrated and multi-disciplinary approach to the rehabilitation of Lakes Sorell and Crescent
Lakes Sorell and Crescent Rehabilitation Project

The 'Aquatic Fauna Sub-project' of the Lakes Crescent and Sorell Rehabilitation Project
Aquatic Fauna Sub-Project

The 'Water Quality Sub-project' of the Lakes Crescent and Sorell Rehabilitation Project
Water Quality Sub-Project

The 'Wetlands Sub-project' of the Lakes Crescent and Sorell Rehabilitation Project
Wetlands Sub-Project

Contents

Figures

Tables

1. Introduction

1.1 Lakes Crescent and Sorell

Lakes Crescent and Sorell lie approximately 1 km apart and are situated at approximately 800 m AHD on the south-eastern corner of the Tasmanian Central Plateau (Figure 1). In comparison to most lakes in Tasmania, lakes Crescent and Sorell are quite large (surface areas of 23 and 50 km^2, respectively), relatively shallow (average depths of 1.5 and 2.5 m at full supply levels, respectively) and are exposed to strong wind action and are turbid. Lakes Crescent and Sorell are very similar, physically and chemically and are located in an area of uniform geology, climate, soils and vegetation (Cheng & Tyler 1976b). The lakes are located on an extensive plateau of Jurassic dolerite with areas of Tertiary basalt and sandstone around both lakes. There are also sandy dunes and beaches on the eastern shores (Cheng & Tyler 1973b). Dry sclerophyll forests dominate the Crescent-Sorell catchment although there is some forestry and grazing of sheep and cattle in semi-cleared farmland areas.

The physico-chemical properties, nutrient and trophic status, plankton populations and primary productivity of lakes Crescent and Sorell have previously been described in detail (Buckney 1976; Cheng & Tyler 1973a, b, 1976a, b). Despite physical and chemical similarities, plankton communities were found to vary markedly between the two lakes (Cheng & Tyler 1973b). The trophic status of these lakes also differs with Lake Sorell being regarded as mesotrophic and Lake Crescent moderately eutrophic (Cheng & Tyler 1976b). Uytendaal (2003) has monitored and investigated processes that influence water quality in lakes Crescent and Sorell during 2000-2002 as a part of the *Water Quality Sub-project* of the *Lakes Sorell and Crescent Rehabilitation Project*.

Extensive adjacent marsh areas connect to the main body of lakes Crescent and Sorell during periods of moderate to high water levels (Figures 2 and 3). These wetlands are some of the largest areas of shallow freshwater marsh in Tasmania (Kirkpatrick & Tyler 1988). The wetlands account for 7.8% (385 ha) and 17% (415 ha) of the surface area of lakes Crescent and Sorell, respectively (Heffer 2003). These wetlands provide important habitat for invertebrates as well as a diverse range of animals such as the endemic and 'rare' golden galaxias (*Galaxias auratus*), frogs (with populations of the threatened southern bell frog (*Litoria raniformis*) previously recorded), snakes, water birds, platypus and water rats. The aquatic vegetation of these wetlands has previously been briefly surveyed as a part of a large-scale study of macrophyte communities in wetlands across Tasmania (Kirkpatrick & Harwood 1981, 1983). The *Wetlands Sub-project* of the *Lakes Sorell and Crescent Rehabilitation Project* has surveyed the aquatic vegetation of the Crescent-Sorell wetlands in more detail during 2000-2002 (Heffer 2003).

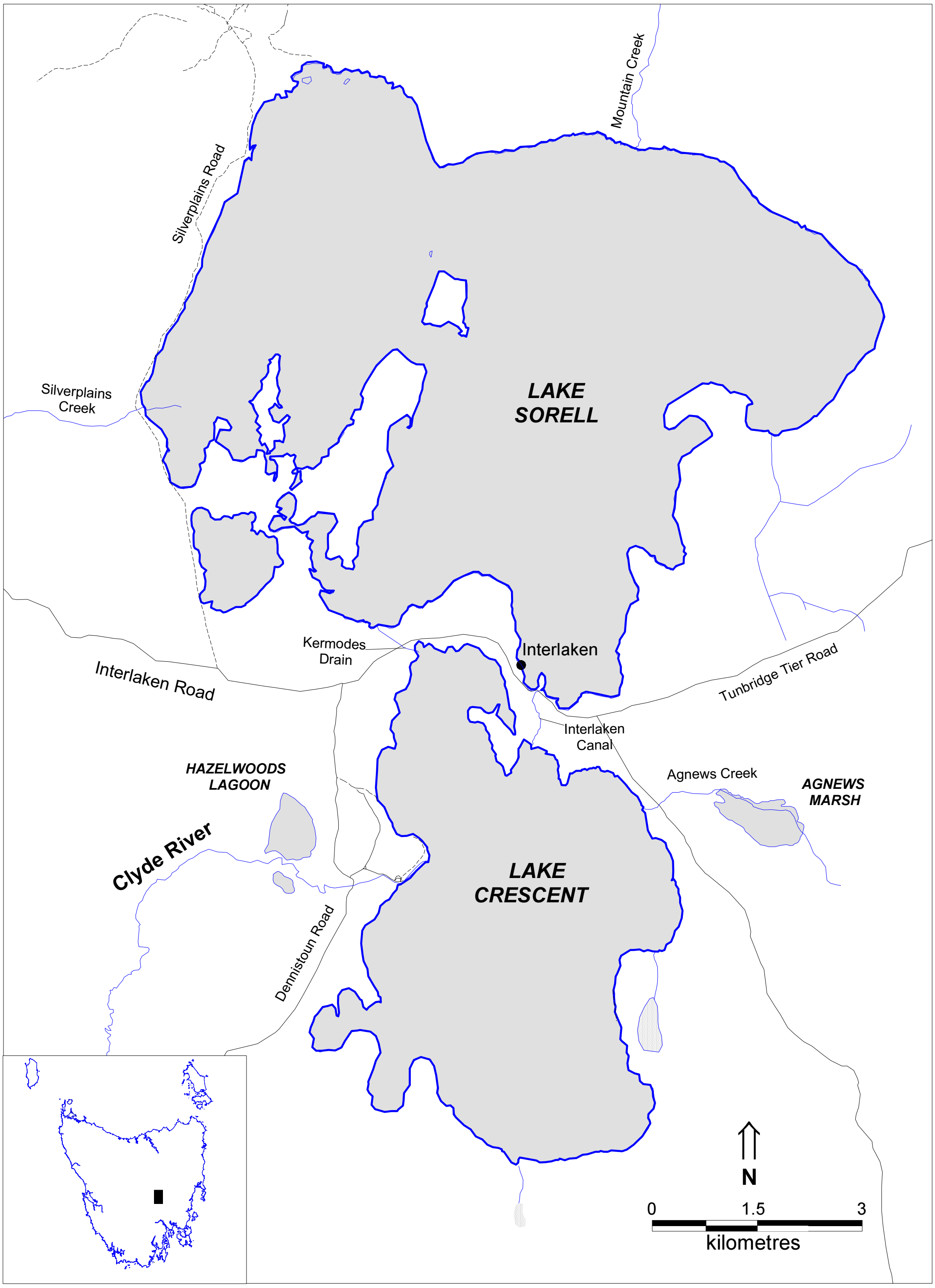

Figure 1. Map of the location of lakes Crescent and Sorell.

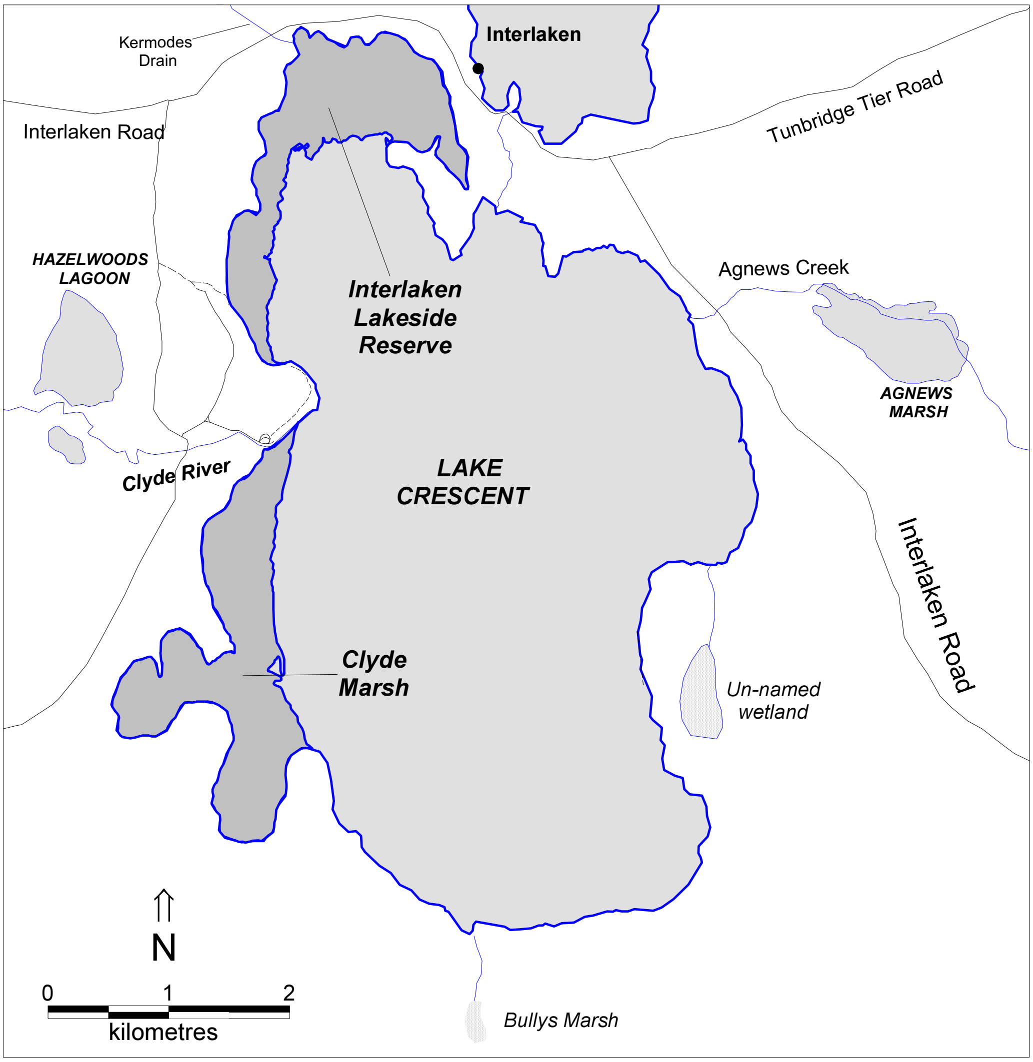

Figure 2. Map of Lake Crescent wetlands.

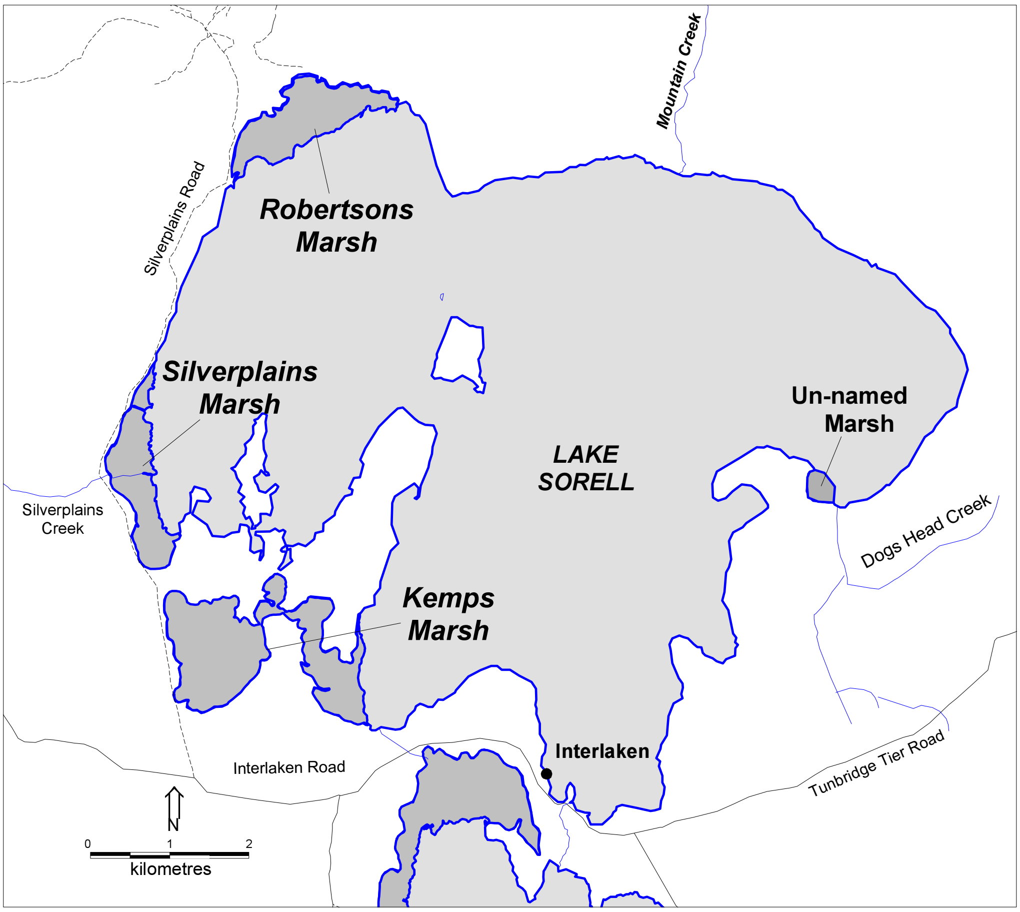

Figure 3. Map of Lake Sorell wetlands.

For the purpose of this study, the Lake Crescent and Lake Sorell areas were defined as all lands and waters contained within the full supply levels of the lakes and all lands and waters within 100 m of the full supply levels. Wetlands of note within the Lake Crescent area are Clyde Marsh and the Ramsar listed Interlaken Lakeside Reserve (Figure 2). These wetlands connect to the main body of Lake Crescent at lake levels above 802.7 and 802.8 m AHD, respectively (Heffer 2003). Other creeks and wetlands associated with Lake Crescent which provide habitat for aquatic invertebrates (particularly during wet years) include Agnews Creek and Agnews Marsh on the eastern shore of Lake Crescent, the creek flowing out of Bullys Marsh (southern shore) and the unnamed wetland and its out-flowing creek (eastern shore).

Wetlands of note within the Lake Sorell area are Kemps/Kermodes Marsh, Silver Plains Marsh and Robertsons Marsh (Figure 3). These wetlands connect to the main body of Lake Sorell at lake levels above 803.6 m AHD (Heffer 2003). Another smaller unnamed wetland exists in Powells Bay near the mouth of Dogs Head Creek (locally known as Powells Marsh). The three main in-flowing creeks of Lake Sorell are Mountain Creek (northern shore), Silver Plains Creek (western shore) and Dogs Head Creek (eastern shore).

During this study, lakes Sorell and Crescent were in a state of severe environmental degradation. Since 1997, the lakes have experienced near record-low water levels causing a significant deterioration in water quality (particularly very high water turbidity) and also a decrease in habitat diversity. Low lake levels have caused all of the wetland areas to be de-watered and disconnected from the main body of the lakes for an extended period. Consequently, the habitat provided by the extensive marsh areas have essentially been removed from the Crescent-Sorell system. Likewise, low water levels have caused a decrease in the amount of rocky littoral habitat in the main body of both lakes. It also appears that in-lake macrophytes have decreased in abundance due to the high turbidity levels and severe wind action that have persisted in both lakes in recent years. In general, habitats that have been lost or significantly reduced include in-lake macrophyte beds, adjacent wetlands and rocky and sandy shorelines.

1.2 Invertebrate Fauna

1.2.1 Previous Studies

The invertebrate fauna of lakes Crescent and Sorell has previously been the subject of several studies ((Borrows 1968; Chilcott 1986; Cleary 1997; Fulton 1983a; Leonard & Timms 1974; Roberts 1973; Timms 1978)) (Table 1). Previous studies have focused on specific aspects of the invertebrate fauna of Lake Crescent and/or Lake Sorell over a small period of time (often only one sampling occasion). Several studies have focused on the invertebrate fauna of specific habitats (Chilcott 1986; Fulton 1983a; Leonard & Timms 1974; Timms 1978). Other previous studies have focused on specific fauna (Burrows & Timms 1968; Cleary 1997; Roberts 1973).

Table 1. Summary of previous studies on the invertebrate fauna of lakes Crescent and Sorell.

Study	Crescent	Sorell	Focus of Work
Burrows (1968)	X	X	Zooplankton communities
Roberts (1973)	X		Isopod (*Heterias* sp.) taxonomy and ecology
Leonard and Timms (1974)	X	X	Littoral rocky habitat fauna
Timms (1978)	X	X	In-lake benthic habitat fauna
Fulton (1983)		X	In-lake benthic habitat fauna
Chilcott (1986)	X		In-lake benthic and littoral macrophyte habitat fauna
Cleary (1997)	X	X	Habitat preference of gastropods

Prior to this study, knowledge of the aquatic macroinvertebrate fauna currently inhabiting lakes Crescent and Sorell was limited. No assessments of species diversity and abundance have taken place in either Lake Sorell or Lake Crescent since 1983 and 1986 respectively.

1.2.2 Description and Distribution of Communities

Previous studies have identified a total 24 orders/classes of macroinvertebrates in lakes Crescent and Sorell, dominated by small crustacea and insects. The level and accuracy of taxonomy employed by previous studies has varied greatly. Also, given the changes that have occurred in the nomenclature of invertebrates in lakes Crescent and Sorell it is difficult to assess the total number of species identified by previous studies.

The invertebrate fauna of the macrophyte dominated wetland habitats associated with lakes Crescent and Sorell has not been previously examined.

1.2.3 Significant Fauna

Several species of fauna that have high conservation value inhabit lakes Crescent and Sorell, including an endemic gastropod species (*Austropyrgus sp*). Aquatic vertebrates of significant conservation value that inhabit the Crescent-Sorell system include the ‘rare’ and endemic golden galaxias (*Galaxias auratus*). The ’vulnerable’ southern bell frog (*Litoria raniformis*) has previously been recorded in the area, but has not been sited in recent years (B. Mawbey pers. comm.).

1.3 Threats

Alterations to the water level regime of lakes Crescent and Sorell are thought to be a significant threat facing the macroinvertebrate communities in these lakes. The loss of habitat and decrease in water quality associated with low water levels are thought to influence the composition of the invertebrate communities. The presence of the introduced 'pest' fish, European carp (*Cyprinus carpio*) is also a concern. *C. carpio* populations may have a negative impact of invertebrate communities, particularly through habitat alteration associated with their bottom feeding behaviour (Fletcher *et al.* 1985), as well as direct predation on certain invertebrate species (Tatrai *et al.* 1994). Alterations to wetland habitats such as variation in flooding regime (Neckles *et al.* 1990; Boulton & Jenkins 1997) may also impact on invertebrate communities.

1.4 Objectives

The *Aquatic Fauna Sub-project* has examined the current status of macroinvertebrate communities in lakes Crescent and Sorell. The project has also focused on defining the threatening processes currently facing invertebrates in Lake Crescent and Lake Sorell. This report documents all of the work that has been undertaken on the invertebrate communities of lakes Crescent and Sorell during the *Aquatic Fauna Sub-project* and details recommendations for the future management of the lakes.

The macroinvertebrate fauna of lakes Crescent and Sorell was surveyed to:

- determine the current status of macroinvertebrate communities,
- determine the effect of lake level on macroinvertebrate communities,
- identify threatening processes to macroinvertebrates and
- produce a report detailing the current status of the macroinvertebrate communities and recommendations for maintaining and enhancing the distribution, abundance and diversity of these communities.

2. Methodology

2.1 Climatic Conditions

J. Deakin (Inland Fisheries Service (IFS)) provided rainfall data for the Interlaken area. Data was collated from several sources including the IFS, Hydro Tasmania, Bureau of Meteorology, Department of Primary Industry, Water and Environment and private landowners, R. Bowden (Cluny, Bothwell) and A. Jarvis (Interlaken Estate, Interlaken).

2.2 Water Levels

J. Deakin (Inland Fisheries Service (IFS)) provided water level data for lakes Crescent and Sorell. Data was collated from the IFS and R. Bowden (Clyde Trust).

2.3 Physico-chemical Water Parameters

In-lake water temperatures in both Lake Crescent and Lake Sorell were measured using Optic StowAway Temperature loggers (Model WTA). Temperature loggers were deployed at the mid-water water sampling sites in each lake (Uytendaal 2003) and data was down-loaded at bi-monthly intervals.

Turbidity data was provided by Uytendaal (2003). See Uytendaal (2003) for methodology.

2.4 Invertebrate Sampling Regimes

2.4.1 In-Lake Sampling

Macroinvertebrate sampling was undertaken bi-monthly over a 12 month period, between July 2000 and July 2001. Samples were collected at 4 sites in each lake on each sampling occasion. Sampling sites were spatially distributed across each lake and represented the 4 major habitat types that were present in both lakes at the time of the study (Figure 4 and 5). In both lakes, 3 sites were located in littoral areas (<20 m from shore and <1.0 m in depth) and 1 in-lake benthic site (>100 m from shore and > 1.5 m in depth) was also sampled. Each of the 4 sites consisted of a 500 m transect along the given habitat.

Lake Crescent sampling sites and the habitats they represented were:

1. sandy shore near Agnews Creek mouth = fine sand
2. Boathouse Shore = cobble rock
3. Jacks Point = degraded marsh area that was dominated by muddy sediment
4. mid site = benthic soft sediment

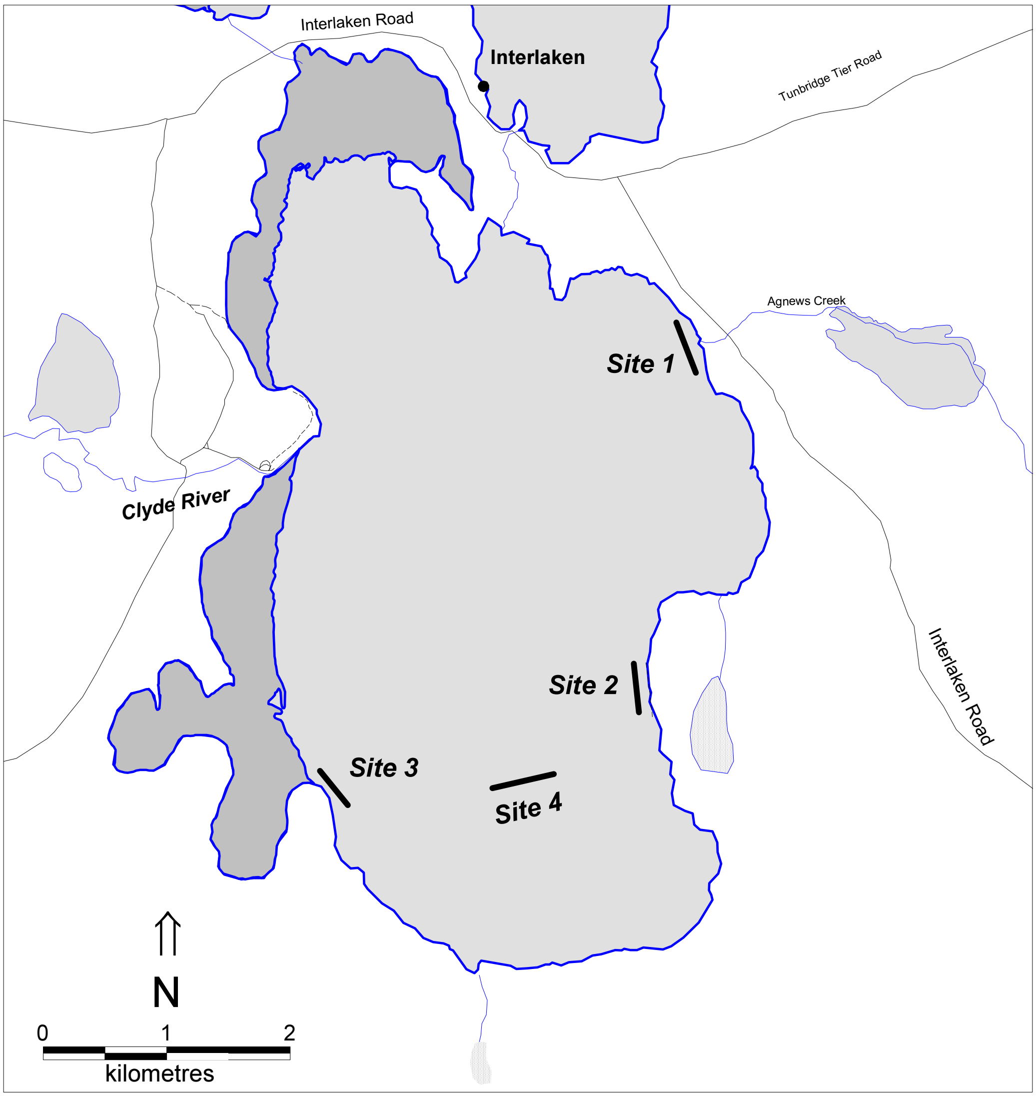

Figure 4. Map of Lake Crescent invertebrate sampling sites.

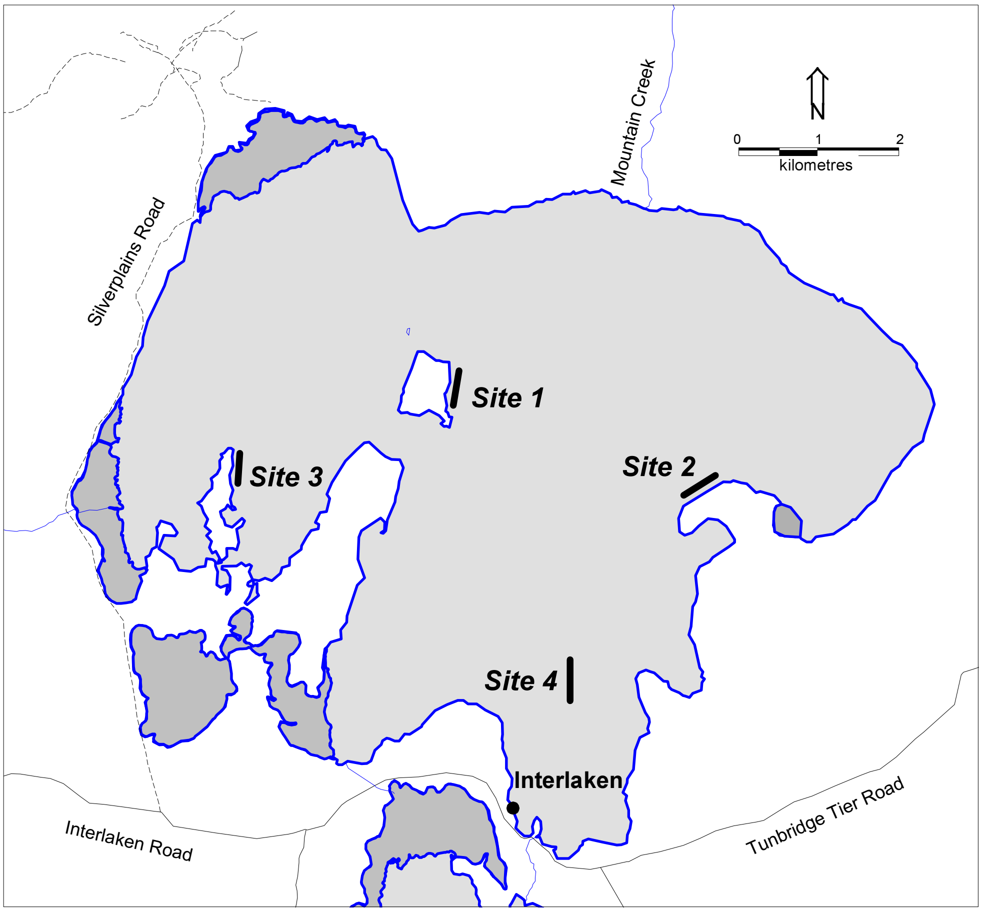

Figure 5. Map of Lake Sorell invertebrate sampling sites.

Lake Sorell sampling sites and the habitats they represented were:

1. St Georges Island = fine sand
2. Dogs Head = cobble rock
3. Grassy Point = mixture of sediment and some cobble rock
4. mid site = benthic soft sediment

Samples were collected using the same procedure on each sampling occasion. An area of approximately 20 m^2 was randomly selected along each site transect. Five replicate samples were taken randomly within the sample area. Two sampling methods were employed, one at the littoral sites and one at the benthic sites. A Freshwater Biological Association (FBA) net with dimensions of 220 mm x 220 mm x 250 mm and 250 µm mesh was swept for 1 minute through open water and disturbed substrate at littoral sites. An Ekman grab of 232 cm^2 gape was used to sample benthic sites.

In summary the number of samples that were collected from within each lake was:

12 months of sampling => 7 sampling occasions x 4 sites x 5 replicates

= 140 samples (from each lake)

2.4.2 Wetland Sampling

Macroinvertebrate samples were collected from Kemps Marsh on a single occasion in January 2002. Three replicate samples were collected from 3 sites (Figure 6) within the marsh. Sampling was conducted using the same sampling technique that was used for littoral in-lake sites (see section 2.4.1).

2.5 Processing and Analysis

All invertebrate samples were processed in the same manner. Samples were sieved through 250 µm mesh in the field and retained animals were preserved in 70% ethanol. Animals were sorted from raw samples using both naked eye and dissecting microscopes in the laboratory. Where samples contained a highly abundant species, not all of the individuals of that species were sorted. Instead a representative number of the taxa's abundance (several hundred) were retained and the remainder were discarded.

All taxa were counted and identified to the lowest possible level, usually to species.

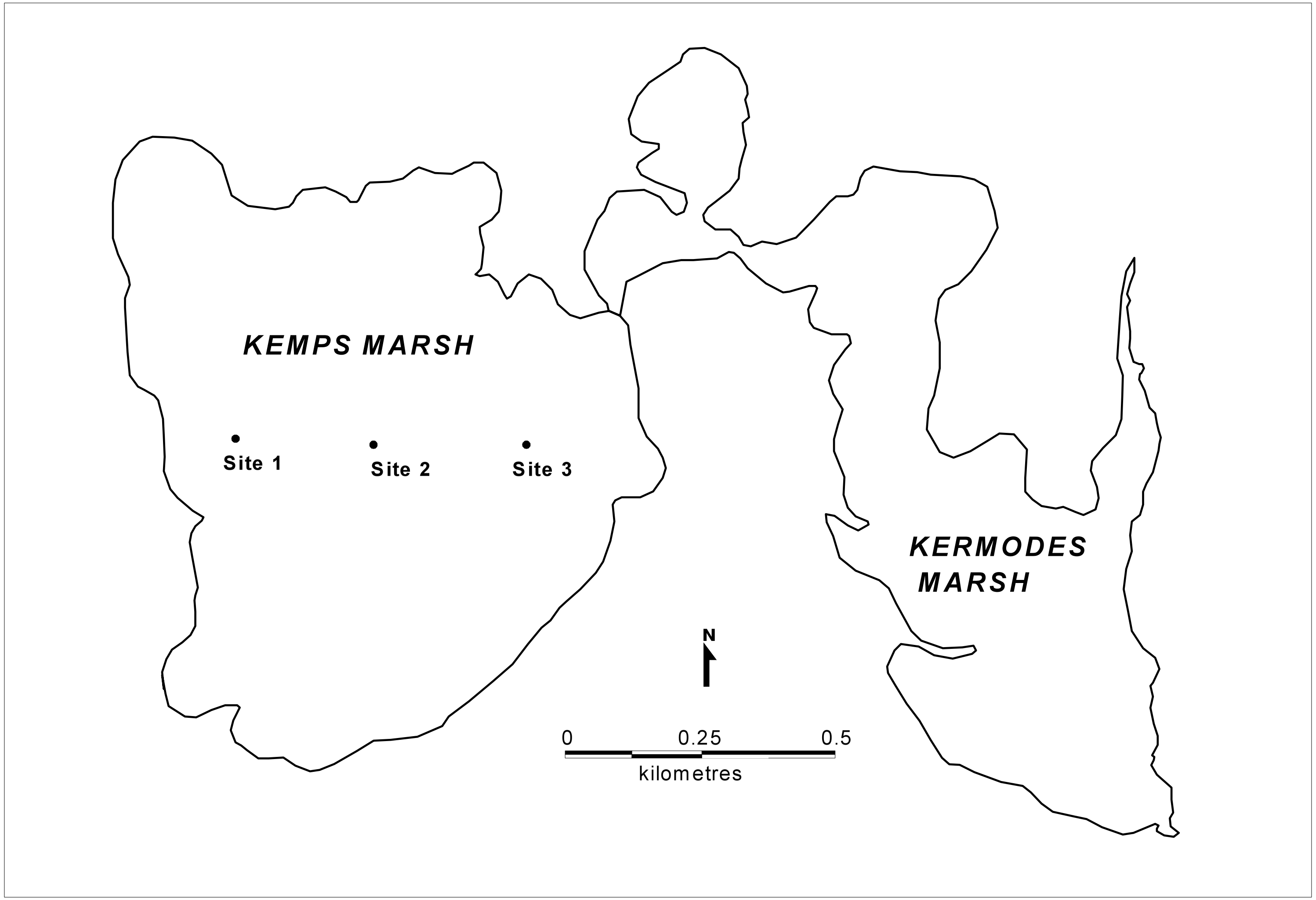

Figure 6. Map of Kemps/Kermodes Marsh invertebrate sampling sites.

3. Results

3.1 Status of Lakes Crescent and Sorell

During the 12-month study period (July 2000 – July 2001), lakes Crescent and Sorell were in a very degraded state in terms of water quality as well as habitat diversity and availability. The lakes were experiencing record low water levels resulting in loss and degradation of habitat and high to extremely high water turbidity.

3.1.1 Climatic Conditions

This study was undertaken at the end of a significant drought period in the Interlaken area. Annual rainfall totals for the area were below average in 4 of the 5 years between 1997-2001 (Figure 7). In addition to below average annual totals, the annual rainfall patterns have also varied from the long term averages for the area (J. Deakin pers. comm.). As a result of the low and varied rainfall pattern, the net climatic losses from the lakes were relatively high resulting in near record low water levels in both lakes during the study (see section 3.1.2).

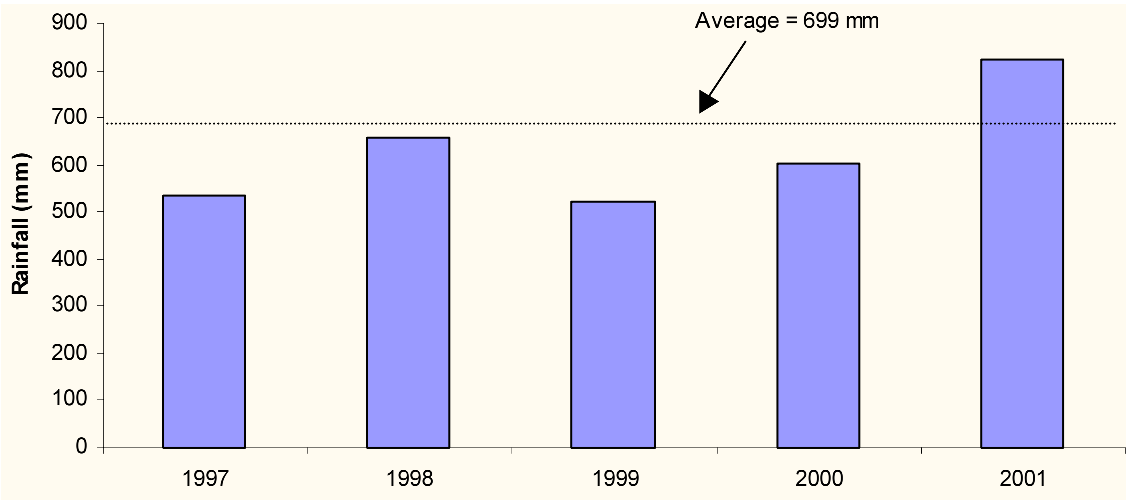

Figure 7. Total annual rainfall in the Interlaken area 1997-2001 (Deakin unpublished data). The historical average for the area is also shown.

3.1.2 Water Levels

Water levels in both lakes Crescent and Sorell remained near record historical lows during the study (Figures 8 and 9). Lake Crescent reached it's lowest recorded level of 801.770 m AHD during the study (March 2001) (Figure 8), while Lake Sorell reached it's lowest recorded level of 802.620 m AHD just prior to the beginning of the study period (April and May 2000) (Figure 9).

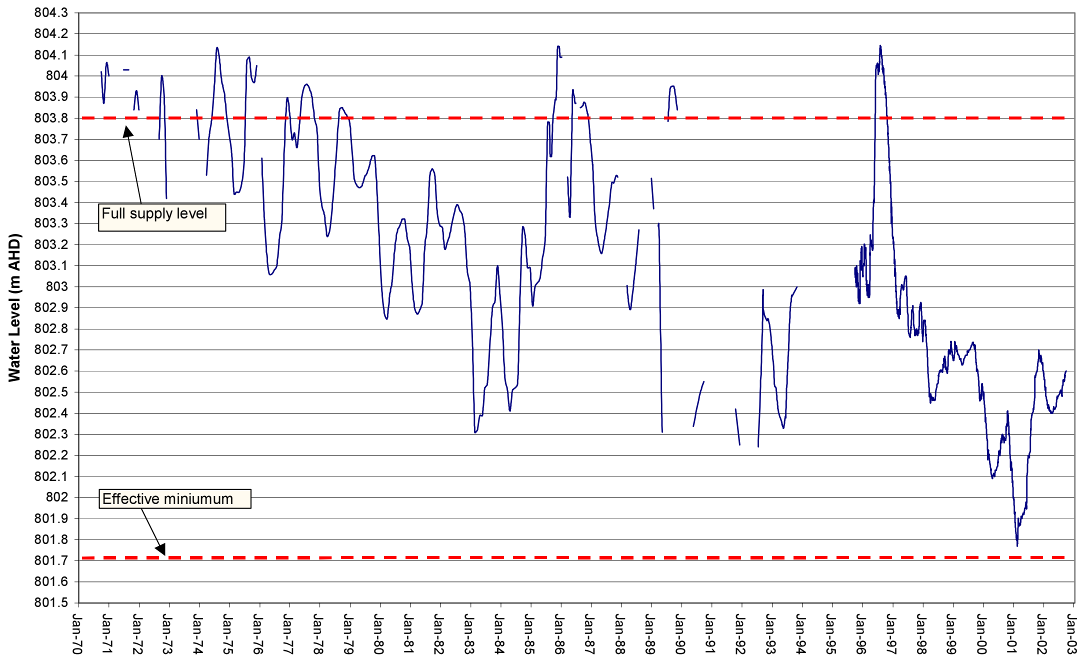

Figure 8. Water levels in Lake Crescent, 1970 – present (Deakin unpublished data).

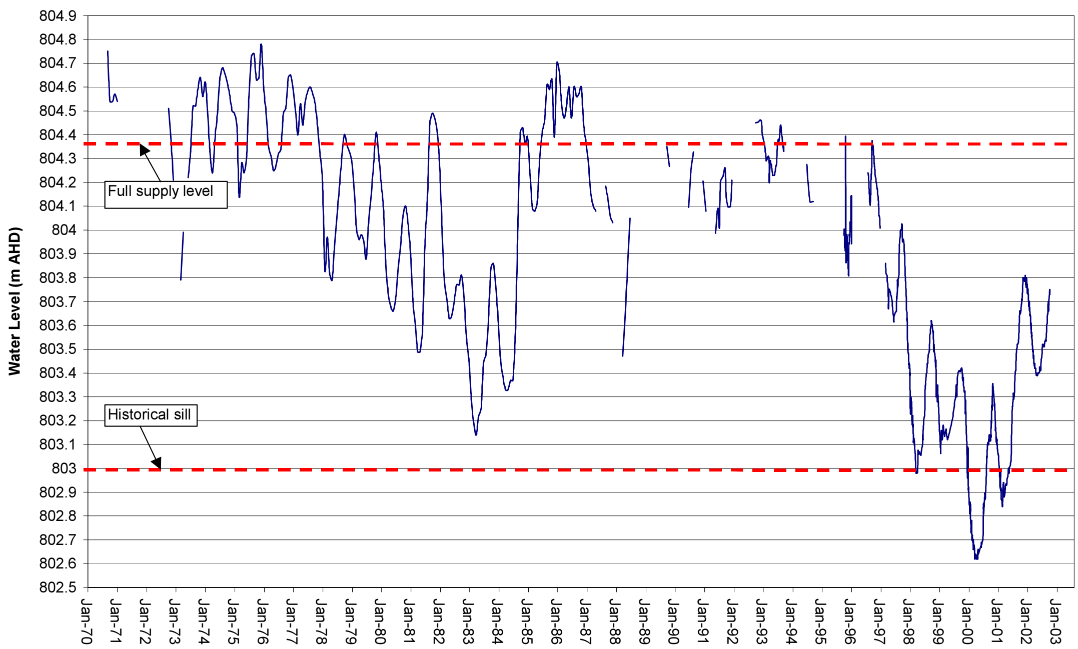

Figure 9. Water level in Lake Sorell, 1970 – present (Deakin unpublished data).

3.1.3 Physico-chemical Water Parameters

Physico-chemical water parameter monitoring by the *Water Quality Sub-project* indicated that both Lake Crescent and Sorell had very poor water quality during the study period (Uytendaal 2003).

Turbidity, which is a measure of water clarity, is thought to be the most important parameter in regard to the condition of the lakes and to the health of the invertebrate communities. High water turbidity decreases the penetration of light into the water column, which decreases the growth of aquatic plants (important invertebrate habitat). High turbidity can also cause the sedimentation of other substrates as turbidity is a direct measure of sediment loading in the water column and therefore reflects increases in erosion that can potentially lead to increases in sedimentation (A. Uytendaal pers. comm.).

Lakes Crescent and Sorell have experienced a steady increase in turbidity over the past 10 years (Figure 10). This increase in water turbidity coincides with a general decrease in water levels (Uytendaal 2003) (Figures 8 and 9). A strong relationship between turbidity and water levels has been quantified which indicates that low water levels and strong wind action are the driving forces behind the turbidity of the water in lakes Crescent and Sorell (Uytendaal 2003). During the study period (2000-2002) turbidity levels in both Lake Crescent and Lake Sorell averaged >100 NTU and reached extremely high levels (up to 400 NTU).

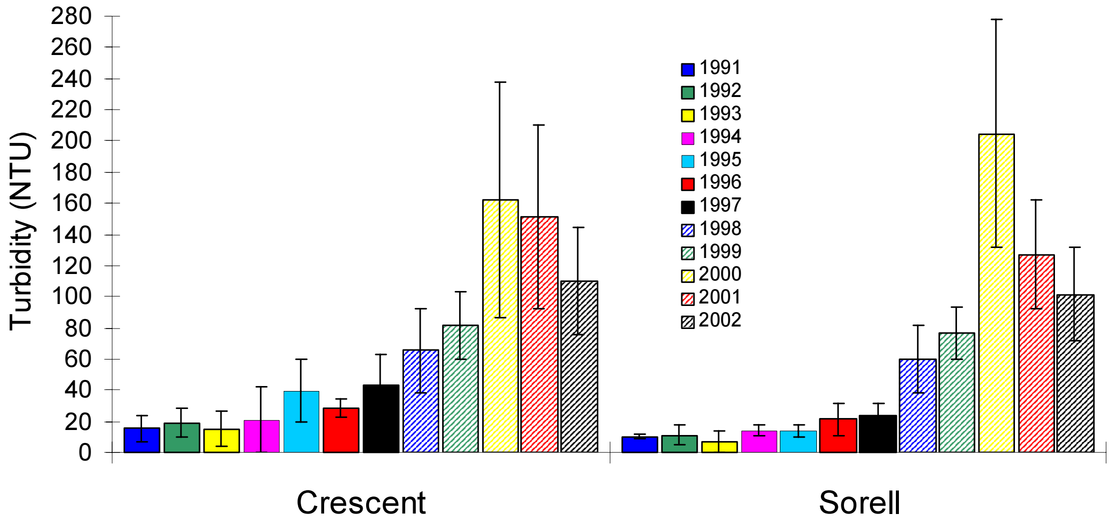

Figure 10. Mean annual turbidity levels in lakes Crescent and Sorell, 1991-2002. Means are plotted with one standard deviation confidence limits. Data is taken from (Uytendaal 2003).

Refer to Uytendaal (2003) for further information on the water quality of lakes Crescent and Sorell during the study period.

3.1.4 Habitat Diversity

The habitat diversity of the lakes Crescent-Sorell system has been significantly reduced in recent years through a number of processes. Prolonged low water levels in both lakes have caused significant decreases in habitat diversity and availability. The effect of low water levels on lakes Crescent and Sorell was particularly evident during the study period. Low lake levels have altered the types of substrate present in the littoral zones and have indirectly reduced the abundance of aquatic macrophytes where elevated water turbidity has decreased light penetration. Low water levels also increase steer stress experienced by benthic substrates which leads to the uprooting of aquatic plants. Agricultural practices have also impacted on the area through the draining of associated wetlands (such as Agnews Marsh) and the channellising of swamp areas. These works have caused flows to be less consistent in the in-flowing creeks and further decreased habitat diversity in the Crescent-Sorell system.

The main habitats that have been affected by the low lake levels and agricultural practices include:

- ***in-lake macrophyte (aquatic plant) beds***: Due to the recent high water turbidity and hence a decrease in the euphotic depth, plants have not been able to receive enough light for survival or growth in Lake Sorell. Severe disturbance of substrate by wind action is also thought to have contributed to the loss and lack of regeneration of in-lake macrophytes. In some areas, in-lake macrophyte beds that were previously in the littoral zone have actually been de-watered.

- ***rocky shorelines***: In Lake Crescent particularly, rocky substrate is only found on a few shores where it is inundated at water levels >802.20 m AHD. Water levels <802.20 m AHD leave the majority of the rocky shores de-watered. The large amounts of sediment that become mobile during periods of strong wind also smother the fringe of the rocky shorelines. In the case of Lake Sorell, the substrate of the lake is composed of large areas of rock and the rocky shorelines extend to quite low water levels, therefore in regard to rock habitats, low water levels are not an issue in Lake Sorell.

- ***sandy shorelines***: Sandy shorelines are also found in both lakes. The water levels at which these become inundated has not been surveyed but have been observed to approximate those found for rocky shores. Significant areas of sandy habitat have been de-watered during the recent low lake levels. The fringes of the shores that have been inundated also suffer from being smothered with sediment.

- ***adjacent wetlands***: The de-watering of adjacent wetlands and their disconnection from the main body of the lakes has eliminated vast areas of macrophyte dominated habitat from the lake systems. Grazing by cattle and sheep on the wetlands is also thought to have an impact on this habitat (Heffer 2003).

The reduction in the availability of different habitats is thought to be a significant threat to invertebrate communities in both lakes.

3.2 Invertebrate Fauna

3.2.1 Lakes Crescent and Sorell

All invertebrate species recorded in lakes Crescent and Sorell during this study are listed in Table 2 along with the findings of previous studies on the invertebrate fauna of these lakes. All data in Table 2 is expressed in terms of relative abundance as described by the various studies (see Appendix 1 for brief description of sampling methods of previous studies). The data from the entire period of the current study has been combined and the total number of specimens collected is expressed in a relative abundance scale.

Species Composition

A total of 47 species were collected in lakes Crescent and Sorell during the recent study. Forty species were recorded in both Lake Crescent and Lake Sorell and 33 of these species were found to be common to both lakes.

The composition of the invertebrate communities in both lakes was found to be very similar. The dominant groups were turbellaria (3 unidentified species), nematod (1 unidentified species), oligochaete (1 unidentified species), gastropod (3 species in each lake), crustacea (11 species in each lake) and insect (17 and 19 species in Lake Crescent and Lake Sorell respectively).

Insects (particularly insect larvae) were found to dominate the invertebrate fauna of lakes Crescent and Sorell. The insect fauna in both lakes included species of ephemeroptera, plecoptera, coleoptera, diptera and trichoptera. Generally only minor differences between the composition of species within each order of insects were observed between the two lakes. Differences included ephemeroptera - *Atalophlebia albiterminata* (was only found in Lake Crescent (LC)); coleoptera - *Sternopriscus tarsalis oscillator* (LC), *Kingolus auratus* (LS); diptera – *Coelopynia pruinosa* (LC), Family Dolichopodidae (LC), Family Athericidae and Ceratopogonidae (LS); trichoptera - *Helicopsyche murrumba*, *Aphiloheithrus AV6*, *Philorheithrus AV2* (LS).

The crustacean fauna in both lakes included similar numbers of species of cladocera, copepod, amphipod, isopod and single species of ostracod and decapod. The only difference in the crustacean fauna of the lakes was the occurrence of a copepod – *Harpactacoida* sp. only in Lake Crescent and Isopod – *Colubotelson joyneri* (?) only in Lake Sorell.

The most significant difference between the invertebrate fauna observed in lakes Crescent and Sorell is the occurrence of 7 species of trichoptera in Lake Sorell and only 4 in Lake Crescent. Previous studies have also found a similar trend in the trichoptera fauna of both lakes (Table 2).

The endemic gastropod – *Austropyrus* sp. was found to be abundant in both lakes Crescent and Sorell.

Table 2. Comparative invertebrate species list for lakes Crescent and Sorell. Results from past and present studies are included and '?' means unconfirmed identification.

Presence/absence and relative abundance of invertebrates is illustrated by:

[1] X indicates presence of species

[2] X infrequent, XX present, XXX abundant and XXXX very abundant

[3] X 1-10 individuals, XX 11-100, XXX 101-500, XXXX >500

[4] X 1-10 individuals, XX 11-100, XXX >100

[5] X <10 individulas, XX 10-100, XXX 100-1000 and XXXX >1000

[6] X 1-5 individuals, XX 6-20, XXX 21-100, XXXX >100

Species	**Lake Sorell**					**Lake Crescent**				
	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Fulton (1983)[4]	Hardie (2003)[5]	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Chilcott (1986)[6]	Hardie (2003)[5]
PORIFERA										
Family Spongillidae									X	
CNIDARIA										
Hydra sp.					X					XX
PLATYHELMINTHES										
Turbellaria										
Spathula sp.				XX						
Planarian A			XX					X		
Planarian B			X							
Triclad A		XX			XX		XXXX			XX
Triclad B		X			X		X			X
Triclad C		XX					XX			
Triclad D		XX			X		X			XXX
Un/ID sp.									X	
NEMERTEA										
Potamonemertes sp.				X						
Prostoma sp.										X
NEMATODA										
Un/ID sp. A									XXX	
Un/ID sp. B									XX	
Un/ID sp. C									X	
Un/ID sp. D									X	
Un/ID sp. E									X	
Un/ID spp.			XX		XXXX			XXX		XXXX
ANNELIDA										
Oligochaeta										
Haplotaxis ornamentus				X						
Haplotaxis sp.			X					X		
Phreodrilus magnaseta				XXX						
Phreodrilus plumaseta				XX						
Phreodrilus palustris				X						
Phreodrilus branchiatus				X						
Phreodrilus proboscidea				X					X	
Phreodrilus sp.			X					X		
Antipodrilus plectilus				XX					XXX	
Antipodrilus multiseta				X						
Telmatodrilus papillatus				X					XX	
Telmatodrilus multiprostatus			X	XX				X	X	
Limnodrilus hoffmeisteri			X	XX				X	X	
Diporochaeta lacustris				XX						
Rhyacodrilus fultoni									X	
Rhyacodrilus sp.				XXX						
Stylodrilus heringianus (?)				XX						
Fridericia sp. (?)			X							
Family Tubificidae									X	

Table 2. Continued…

Species	**Lake Sorell**					**Lake Crescent**				
	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Fulton (1983)[4]	Hardie (2003)[5]	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Chilcott (1986)[6]	Hardie (2003)[5]
Oligochaeta										
Un/ID sp. A									X	
Un/ID sp. B									X	
Un/ID spp.		XX			XXXX		X			XXXX
Hirundinae										
Un/ID sp.							X			XX
MOLLUSCA										
Gastropoda										
Gyraulus scottianus		X							XXX	
Gyraulus meridionalis				X						
Gyraulus sp.					XX					X
Potamopyrgus niger		XXX					XX	XX		
Potamopyrgus sp.			XX				XX	XX		
Physastra gibbosa				XX					XX	
Bulinus hainesii		X					X	X		
Angrobia sp.				XXX					X	
Austropyrgus sp.					XXXX					XXX
Glyptophysa sp.					XX					X
Glacidorbis sp.				X					X	
Bivalva										
Pisidium fultoni				XXX					X	
Pisidium cf casertanum		X					X	XXX		
Pisidium sp.					XX					XX
Sphaerium tasmanicum			XXX							
ARTHROPODA										
Acarina										
Oxus sp.				XX						
Lycosa sp.									X	
Family Hydryphantidae				X						
CRUSTACEA										
Cladocera										
Daphnia carinata	X				XXX	X				XXX
Ceriodaphnia quadrangular (?)	X				X	X				XXX
Bosmina meridionalis					X					XX
Bosmina hagmanni	X					X				
Un/ID sp.									XX	
Ostracoda										
Un/ID sp.					XX				X	XXXX
Copepoda										
Boeckella rubra	X					X				
Macrocyclops albidus	X					X				
Microcyclops leuckarti	X					X				
Harpactacoida sp.	X					X				X
Calanoid sp.					XXX					XX
Cyclopoid sp.					XX					X
Amphipoda										
Austrachiltonia australis		XX	XX	XXX	XXXX				XXX	XX
Austrachiltonia subtenuis							XXXX	X		
Antipodeus mortoni (?)					XXXX					X
Neoniphargus cf exiguus							X			
Family Gammaridae	X									

Table 2. Continued…

Species	**Lake Sorell**					**Lake Crescent**				
	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Fulton (1983)[4]	Hardie (2003)[5]	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Chilcott (1986)[6]	Hardie (2003)[5]
Isopoda										
Uramphisopis relictus				XX					X	
Uramphisopis australis								X		
Heterias petrensis					XXXX				X	XXX
Heterias sp.				X						
Colubotelson joyneri (?)					XXXX					
Colubotelson thomsoni (?)		X					XX			
Pseudasellus sp.		X					XX			
Decapoda										
Paratya australiensis				X	XXX				X	XX
Paratya tasmaniensis		XX								
Family Atyidae	X									
INSECTA										
Odonata										
Austrolestes analis									X	
Ephemeroptera										
Atalophlebia albiterminata				X						XX
Atalophlebia sp.									X	
Tillyardophlebia AV2					X					XXX
Atalonella delicatula		XX								
Atalonella sp.							X			
Plecoptera										
Eusthenia spectabilis/lacaustris					XX					XXX
Eusthenia sp.		X					XX			
Leptoperla varia					XX			X		XXX
Leptoperla tasmanica			X					X		
Leptoperla beroe				X						
Leptoperla sp.		X					X			
Dinotoperla bassae									X	
Dinotoperla sp.					X					X
Cardioperla sp.		XX								
Hemiptera										
Family Chrysomelidae									X	
Un/ID sp.									X	
Coleoptera										
Sternopriscus tarsalis oscillator										X
Sternopriscus clavatus									X	
Sclerocyphon lacaustris					XX					X
Sclerocyphon aquaticus		X								
Kingolus auratus					XXX					
Platynectes decempunctatus							X			
Berosus sp.									X	
Simsonia sp.		X								
Family Corixidae									X	
Family Hydrophilidae									X	
Family Curculionoidae									X	
Family Ditiscidae		X								
Diptera										
Coelopynia pruinosa			XX	XXX				XX	X	XXX
Procladius villosimanus			XX	XX				X	X	
Cryptochironomus griseidorsum				XX					X	
Chironomus oppositus				X					XX	
Polypedilum tonnoiri									X	
Polypedilum nr oresitrophus				X						

Table 2. Continued…

Species	**Lake Sorell**					**Lake Crescent**				
	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Fulton (1983)[4]	Hardie (2003)[5]	Burrows (1968)[1]	Leonard & Timms (1974)[2]	Timms (1978)[3]	Chilcott (1986)[6]	Hardie (2003)[5]
Diptera										
Ablabesmyia notabilis			XX	X				X	X	
Riethia sp.			XXX	XXX					XXXX	
Cryptocladopelma sp.								X		
Paramerina sp.				X					X	
Tanytarsus sp. (?)				XX						
Orthoclad A		X	XXX	X	XXX		X		X	XXX
Orthoclad B			XXX							
Orthoclad C			XXX							
Ceratopogonid A		X	X	XX	X			X	X	
Ceratopogonid B				X						
Family Muscidae									X	
Family Chironominae			XX		XXX					XXX
Family Tanypodinae					XXX					XX
Family Tipulidae					X					X
Family Dolichopodidae										X
Family Athericidae					X					
Family Limoniinidae		X								
Family Tabanidae		X								
Un/ID sp.				X					X	
Trichoptera										
Atriplectides dubius				XX	X					X
Ecnomus tillyardi				X	XX					XX
Helicopsyche murrumba				X	XX					
Helicopsyche sp.		XXX								
Aphilorheithrus AV6					X					
Aphilorheithrus sp.				X						
Philorheithrus AV2					X					
Notalina parkeri				XX					X	
Notalina AV9					X					X
Notalina sp.					X					X
Family Leptoceridae		X	X				X	X	X	
Family Conoesucidae				X						
Family Rhyacophilidae			X							
Family Hydroptilidae			X							
Total No. of Species	**9**	**26**	**24**	**48**	**40**	**7**	**20**	**20**	**52**	**40**

Species Abundance

The abundance of species in the invertebrate communities of lakes Crescent and Sorell was found to be similar although some differences were evident (Table 2). Nematods, oligochaetes and diptera were abundant in both lakes. Dominant nematod and oligochaete species were not identified. The dipteran fauna was dominated by chironominae, orthocladinae and tanypodinae species.

Gastropods and macro-crustacea (amphipods, isopods and a decapod) were more abundant in Lake Sorell than in Lake Crescent, although still common in Lake Crescent. The gastropod fauna was dominated by *Austropyrus* sp. and *Austrachiltonia australis*, *Antipodeus mortoni* (?), *Heterias petrensis*, *Colubotelson joyneri* (?) and *Paratya australiensis* were the abundant macro-crustaceans.

Micro-crustacea, ephemeroptera and plecoptera fauna were more abundant in Lake Crescent than Lake Sorell with *Daphnia carinata* and *Ceriodaphnia quadrangular* (?) and an unidentified species of ostracod being the dominant micro-crustaceans. *Tillyardophlebia AV2* dominated the ephemeroptera fauna and *Eusthenia spectabilis/lacaustris* and *Leptoperla varia* were the major plecopterans.

3.2.2 Wetlands

During the study period the wetlands associated with lakes Crescent and Sorell remained relatively dry and did not become inundated from main lakes. Therefore sampling was not undertaken on a major scale in the wetlands. However, Kemps Marsh did hold a significant volume of water over a period of approximately 5 months during spring/summer 2001/02, which allowed macrophytes to germinate and grow and invertebrate communities to establish.

All invertebrate species recorded in Kemps Marsh during this study are listed in Table 3. The data from each site has been combined and the total number of specimens collected is expressed in a relative abundance scale.

Species Composition

A total of 50 macroinvertebrate species (and 1 vertebrate species) were recorded in Kemps Marsh (Table 3). The species composition of the wetland fauna was dominated by acarina (5 species), micro-crustacea (8 species) and insects (27 species).

The micro-crustacean fauna included species of cladocera, ostracods and copepods. The insect fauna included species of odonata, hemiptera, coleoptera, diptera and trichoptera.

The endemic gastropod – *Austropyrus* sp. was not recorded in Kemps Marsh.

Table 3. Kemps Marsh invertebrate species list. Where X = present, XX = common, XXX = abundant and XXXX = very abundant.

Species	Relative Abundance
CNIDARIA	
Hydra sp.	X
ANNELIDA	
Oligochaeta	
Oligo sp.	XX
Un/ID spp.	XXX
Hirudinea	
Glossiphoniid sp.	X
Un/ID sp.	X
MOLLUSCA	
Gastropoda	
Glyptophysa sp.	XXXX
Gyraulus sp.	XXXX
Bivalva	
Psidium sp.	XXX
Sphaerium sp.	XX
ARTHROPODA	
Acarina	
Peza ops	XX
Eylais sp.	X
Orobatid sp.	XX
Lycosid sp.	X
Un/ID sp.	X
CRUSTACEA	
Cladocera	
Ceriodaphnia quadrangular	XXX
Ilyocryptus sp.	XX
Chydorid spp.	XXX
Ostracoda	
Un/ID sp. 1.	XX
Un/ID sp. 2.	X
Copepoda	
Harpactacoid sp.	XX
Calanoid sp.	XXX
Cyclopoid sp.	XXX
Amphipoda	
Austrochiltonia australis	XXXX
INSECTA	
Odonata	
Austrolestes analis	XXX
Hemiptera	
Sigara neboissi	X
Sigara australis	X
Anisops sp.	X
Sigara sp.	X
Corixiid sp.	X
Coleoptera	
Hyderodes shuckhardi	XX
Antiporus femoralis	XX
Onychohydrus scutellaris	X
Chostonectes gigas	X
Hygrobia australis	X
Sternopriscus sp.	XXX

Table 3. Continued…

Species	Relative Abundance
Coleoptera	
Platynectes sp.	XX
Megaporus sp.	XX
Enochrus sp.	XX
Berosus sp.	XX
Hydrochus sp.	X
Haliplus sp.	X
Curculioid sp.	XX
Diptera	
Tanypod spp.	XXXX
Chironominidae chiro spp.	XXXX
Chironominidae ortho spp.	XXX
Ceratopogonid sp.	X
Trichoptera	
Notoperata sparsa	X
Notalina AV6	XXXX
Notalina AV10	XXX
Notalina sp.	XX
AMPHIBIA	
Crinia signifera	XX
Total No. of Species	**50 (+ 1 vertebrate)**

Species Abundance

The abundant invertebrate species in Kemps Marsh (Table 3) were found to be gastropods *Glyptophysa* sp. and *Gyraulus* sp., amphipod - *Austrochiltonia australis*, dipteran families Tanypodinae and Chironominidae and trichopteran - *Notalina AV6*.

3.2.3 Comparison of Wetland and Lake Fauna

The invertebrate fauna of Kemps Marsh was found to vary greatly from that of lakes Crescent and Sorell. Significant differences were found in both the composition and abundance of fauna in general and the diversity of some fauna groups.

Of the 50 invertebrate species recorded in Kemps Marsh (Table 3), 32 (64%) were not currently present in lakes Crescent and Sorell (Table 2). A further 6 species had been recorded in lakes Crescent and Sorell during previous studies but were not found during the current study.

Significant differences in the composition and abundance of the invertebrate fauna in Kemps Marsh compared to that of lakes Crescent and Sorell included:

- Increase in the diversity of acarina and hemiptera.
- Decrease in the diversity of amphipods, crustacea and diptera.
- Absence of isopods, decapods, ephemeroptera and plecoptera.
- Presence of odonata.
- Increase in the abundance of gastropods.
- Change in faunal composition of trichoptera and coleoptera, with coleoptera also showing an increase in diversity.
- Presence of amphibia (vertebrate).

4. Discussion

4.1 Significant Findings of Invertebrate Community Surveys

4.1.1 Lakes Crescent and Sorell

The invertebrate fauna of lakes Crescent and Sorell was found to be similar in structure to that of other lakes on Tasmania's Central Plateau (Fulton 1983a, b; Timms 1978). Lakes Crescent and Sorell have similar fauna although differences in the structure of invertebrate communities are evident.

4.1.2 Wetlands

The invertebrate fauna of the Kemps Marsh was found to be typical of freshwater temporal wetlands in Tasmania (T. Sloane pers. comm.).

At the time of the invertebrate sampling in Kemps Marsh the wetland had been wet for 11 months and the water level (~220 mm) was decreasing (Heffer 2003). It is suspected that at the time of sampling (mid summer) the fauna was actually decreasing in diversity with many species having completed the aquatic stages of their life cycle.

4.1.3 Comparison of Lake and Wetland Communities

The brief examination of the invertebrate fauna in Kemps Marsh during this study is thought to provide insight into the invertebrate communities of all of the wetlands associated with lakes Crescent and Sorell. The results of the wetland survey have shown that the invertebrate fauna of the wetlands associated with lakes Crescent and Sorell have significantly different fauna to that which is found in the main body of each lake. The difference in the invertebrate fauna between the wetlands and the main body of the lakes is thought to be primarily due to habitat differences. The wetlands provide a temporary, still water, vegetated habitat. Kemps Marsh was dominated by aquatic macrophytes at the time of the invertebrate sampling, whereas macrophytes were basically absent from in-lake areas. At the time of the study in-lake habitats in Lake Sorell were dominated by rock, sand and sediment substrates, whilst Lake Crescent was dominated by sediment substrate.

It should also be noted that fish were thought to be absent from Kemps Marsh at the time of the invertebrate sampling. Predation pressure by planktivorus and benthivorus fish has been found to influence the structure of macroinvertebrate communities (Wong *et al.* 1998; Zimmer *et al.* 2000). Kemps Marsh was not connected to the main body of Lake Sorell at the time of sampling and had not been properly connected since being dry. Therefore brown trout (*Salmo trutta*) and golden galaxias (*Galaxias auratus*), which are abundant in Lake Sorell, were not observed or thought to be present in Kemps Marsh. It is suspected that a small number of short-finned eels (*Anguilla australis*) may have been in the wetland.

The lack of fish fauna would have altered the structure and abundance of the invertebrate community, from what would be observed when the wetland is fully connected to the lake.

The lakes are thought to provide the most secure habitat for some invertebrate species that may periodically occur in the wetland (ie during high water levels when the lakes flood into wetlands). Some invertebrates such as isopods and *Paratya australiensis* are thought to migrate into the wetlands during periods of high water level and then retreat back to the lakes when the wetlands become disconnected to the lakes and/or dry out (T. Sloane pers. comm.).

The significant differences observed between the invertebrate fauna of the lakes and the wetland show how important the wetland areas are to the invertebrate fauna of the Crescent-Sorell system. Despite the close proximity of the wetlands and in-lake areas, it is the different habitats that each area provides that makes each area critical for maintaining the diversity of the invertebrate fauna of the Crescent-Sorell system.

4.1.4 Comparison of Current and Historical Status of Invertebrate Communities

Several studies have previously examined the invertebrate fauna of lakes Crescent and Sorell (Borrows 1968; Chilcott 1986; Cleary 1997; Fulton 1983a; Leonard & Timms 1974; Roberts 1973; Timms 1978), however the fauna inhabiting the wetlands associated with these lakes had not been surveyed prior to the current study. Therefore, only the structure of the in-lake invertebrate communities can be compared to that of the historical data.

It is difficult to draw any significant conclusions in regard to changes in the invertebrate fauna of lakes Crescent and Sorell in recent years. Previous studies have focused on specific aspects of the communities (ie certain habitats or specific species) and have used different sampling methodologies to that employed during this study. In addition, variation in accuracy and level of the taxonomy undertaken by the different studies has made it difficult to draw direct comparisons between the findings of past studies and those of the current study.

Prior to the recent decrease in water levels in Lake Sorell, in-lake macrophyte beds were abundant. These macrophyte beds have since died-off as a result of the elevated water turbidity and disturbance of sediment substrates. The invertebrate fauna of the macrophyte beds was not examined by previous studies, however it is thought to have been comprised of a diverse mixture of invertebrates found in both wetland and in-lake habitats by the current study (T. Sloane pers. comm.). An example of the fauna that may have utilised the in-lake macrophyte beds, which are now basically non-existent in Lake Sorell, are odonata insects including both zygopterans and anisopterans. These insects are more likely to prefer macrophyte and wood debris habitats (Gooderham & Tsyrlin 2002). The zygopteran – *Austrolestes analis* was found to be abundant in Kemps Marsh during this study but was not found in either lake. *A. analis* was however recorded in littoral macrophyte habitat in Lake Crescent by Chilcott (1986). Therefore this species, along with other odonata species, is likely to have occurred in the in-lake macrophyte beds of Lake Sorell.

It is interesting to note the number of species that previous studies examining the macroinvertebrate fauna of lakes Crescent and Sorell has recorded in each lake. Leonard and Timms (1974) studied the littoral rock fauna and recorded 20 and 26 species in lakes Crescent and Sorell respectively. Timms (1978) examined the benthic fauna and found 20 and 24 species in lakes Crescent and Sorell respectively. Fulton (1983) recorded 48 species in the benthic fauna of Lake Sorell, while Chilcott (1986) found 52 species in the benthic and littoral fauna of Lake Crescent. Forty species were recorded in both Lake Crescent and Lake Sorell by the present study.

It would appear that the structure of the invertebrate communities of lakes Crescent and Sorell has remained reasonably stable despite alterations to in-lake habitats in recent years. However, due to the reduction in the diversity and amount of habitat(s) that are available (eg. de-watered rocky shorelines) it is thought that the abundance and population size of certain species has significantly decreased.

4.2 Threatening Processes

The macroinvertebrate communities of lakes Crescent and Sorell and their associated wetlands are currently facing several threatening processes. These threats have the potential to significantly alter the distribution, structure and abundance of macroinvertebrate communities.

4.2.1 Lake Levels

Alteration to the water level regime of lakes Crescent and Sorell is thought to be the main threat facing the invertebrate communities in these lakes. Low water levels can cause significant losses of habitat, decrease habitat diversity and severely degrade the condition and stability of certain habitats.

Littoral zones in lakes can be regions of high biodiversity and productivity, serving as crucial habitat for macroinvertebrates and fish (James *et al.* 1998). Large water level fluctuations have been found to decrease the diversity of macroinvertebrate fauna in the littoral zone of lentic waters (Hunt & Jones 1972; Kaster & Jacobi 1978). Depending on the type of littoral substrates being de-watered/flooded the recolonisation of invertebrate communities after a significant drawdown/inundation may take months (Kaster & Jacobi 1978), years (Hunt & Jones 1972) or may not happen if littoral habitats are not restored (eg. re-establishment of macrophytes, desiltation of rocks).

Many invertebrate species are known to have specific habitat requirements including rock, sand and macrophyte substrates. The low water levels in lakes Crescent and Sorell that have persisted during the study were found to cause a significant decrease in the stability and diversity of the habitats available to the invertebrate communities. James *et al.* (1998) has shown that the presence of macrophytes and habitat stability both have a major effect on the distribution of invertebrates in a New Zealand lentic environment.

At high water levels the littoral habitats in lakes Crescent and Sorell are comprised of areas of rock, sand, sediment and macrophyte substrates. Low water levels in both lakes tend to de-water rock, sand and macrophyte substrates along shorelines leaving the littoral zones dominated by sediment. In the case of Lake Crescent, water levels <801.50 m AHD de-water basically all rock and sand shore habitat. It is not until water levels are >802.20 m AHD that a significant proportion of rocky shore habitat is inundated.

Low water levels in lakes Crescent and Sorell have been found to cause significant increases in water turbidity and a general decrease in water quality (Uytendaal 2003). The effect of high water turbidity on invertebrates has not been studied in great detail. Low water levels were also found to cause the siltation of some substrates during this study with the increased amount of suspended sediment in the water column smothering other substrates. This was particularly evident on windward rock and sand shores. The increase in turbidity associated with low water levels also decreased the abundance of in-lake macrophytes by increasing light attenuation into the water column, hence reducing the growth and survival of macrophytes and their ability to regenerate and increasing physical disturbance through increased turbulence (Uytendaal 2003).

The results of the Kemps Marsh invertebrate survey conducted during this study have illustrated how different the invertebrate communities of the wetlands are to those found in the in-lake areas of lakes Crescent and Sorell. The habitat provided by the wetlands is therefore critical to maintain the diversity of the invertebrate fauna of the Crescent-Sorell system.

The major wetlands that connect to the main body of Lake Crescent are Clyde Marsh and the Ramsar listed Interlaken Lakeside Reserve. These wetlands connect to the main body of Lake Crescent at water levels above 802.7 and 802.8 m AHD respectively (Heffer 2003). The major wetlands that connect to the main body of Lake Sorell are Kemps/Kermodes Marsh, Silver Plains Marsh and Robertsons Marsh. These wetlands connect to the main body of Lake Sorell at water levels between 803.6 and 803.9 m AHD (Heffer 2003).

It is important that the water regime requirements of the aquatic vegetation in the Crescent-Sorell wetlands are considered in the management of lakes Crescent and Sorell (see Heffer (2003) for further information). The structure of invertebrate communities in temporal wetlands is influenced by the regime of flooding (Leslie *et al.* 1997; Neckles *et al.* 1990), including the duration, timing, frequency and intensity of the flooding (Boulton & Jenkins 1997). It is suspected that the wetland invertebrate communities of the Crescent-Sorell wetlands will also benefit from water level regimes recommended for the aquatic vegetation. Given the temporal nature of these wetlands, the flora and fauna (including invertebrates) that inhabit these areas rely on seasonal fluctuations in water levels. Water level regimes for the wetlands should not provide permanent inundation or de-watered conditions in the wetlands for extended periods. Instead natural seasonal cycles in water levels should be maintained.

4.2.2 Other Threats

Other threatening processes that the invertebrate communities of lakes Crescent and Sorell are facing include the impacts associated with introduced fauna (fish and invertebrates) and flora and the alteration of wetland habitats through draining and grazing.

Of the six fish species present in lakes Crescent and Sorell (brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), European carp (*Cyprinus carpio*), common galaxias (*Galaxias maculatus*), short-finned eel (*Anguilla australis*) and golden galaxias (*Galaxias auratus*)), only *G. auratus* and *A. australis* are indigenous to the lakes. The addition of introduced fish to the fish fauna of lakes Crescent and Sorell is likely to have changed the structure of the invertebrate communities of these lakes through predation on certain species on invertebrates. *C. carpio* have the potential to degrade habitat and reduce water quality through their bottom feeding behaviour.

Recreational use of the lakes has the potential to cause further introductions of flora and fauna species, particularly via unclean equipment, such as boats and waders.

The draining and grazing of the wetlands associated with lakes Crescent and Sorell are also thought to threaten macroinvertebrate communities. These agricultural practices have the potential to reduce the condition and amount of wetland habitat that is available to invertebrates. The further construction of permanent drains in wetlands also has potential to significantly alter the periodic flooding regimes and water levels of these temporal wetlands.

4.2.3 Summary of Threatening Processes

The main threats to the invertebrate communities of lakes Crescent and Sorell are associated with low water levels. These threats include:

- decrease in the diversity of in-lake habitat
    - loss of rocky shore habitat, particularly Lake Crescent
    - loss of in-lake macrophyte habitat, particularly Lake Sorell
    - loss of sandy shore habitat
- reduction in available habitat
    - disconnection and de-watering of adjacent wetlands
    - reduction of lake volume
- decrease in water quality
    - high to very high water turbidity
    - siltation of rock and sand shores
    - limit growth and survival of in-lake macrophytes

Other general threats to macroinvertebrates include:

- competition and predation from introduced fauna,
- draining and grazing of adjacent and associated wetlands
    - restrict distribution and abundance of some species by decreasing and/or disturbing available habitat
    - alteration to flooding regimes and water levels
- recreational use of lakes
    - potential for introduction of flora and fauna

5. Management Recommendations for the Protection of Macroinvertebrate Communities

The macroinvertebrate communities of lakes Crescent and Sorell are a critical component of the ecosystem associated with these lakes. Invertebrates are at the lower end of the food chain providing valuable food resources for fish, waterbirds platypus and other animals as well as having a significant conservation value of their own. In the case of lakes Crescent and Sorell, populations of the endemic gastropod *Austropyrus* sp. hold significant conservation value. The management of lakes Crescent and Sorell needs to provide suitable habitat for maintaining abundant and diverse invertebrate communities.

Several management recommendations in regard to the protection of the golden galaxias (*Galaxias auratus*) populations in lakes Crescent and Sorell (Hardie 2003) are also relevant to invertebrate communities. It is suggested that these recommendations be also taken into account for the management of the invertebrate communities.

In light of the results of the invertebrate community survey that has been undertaken and threatening processing that have been identified, several management issues have been highlighted. Management issues are briefly discussed and recommendations for management are detailed.

5.1 Lakes

5.1.1 Water Level Regime

Water level management in lakes Crescent and Sorell needs to ensure that the proposed regimes provide suitable habitat for invertebrates. Low water levels have been identified as a significant threat to the invertebrate communities in lakes Crescent and Sorell. Low water levels can decrease the amount and diversity of habitat that is available to invertebrates in lakes Crescent and Sorell.

The water level regimes of lakes Crescent and Sorell have been artificially manipulated over the past 150 years, during which time the natural seasonal fluctuations of the water levels have been altered significantly. It is important that natural fluctuations are allowed to occur, particularly in wetland habitats, as natural fluctuations in water levels aid the germination and growth of aquatic macrophytes.

Recommendations for the management of the water levels in lakes Crescent and Sorell include:

- Maintaining both lakes at mid to high levels to protect habitat diversity and ensure good water quality.
- Natural seasonal cycles in water level regimes should be retained and altered as little as possible.

- Maintaining water levels in Lake Crescent above 802.20 m AHD, the level above which rocky shore habitat becomes inundated.
- The recommendations of the *Wetlands Sub-project* regarding lake level regimes should be implemented to ensure the adjacent wetlands remain healthy (ie. protect invertebrate habitat).
- The recommendations of the *Water Quality Sub-project* regarding lake level regimes should be implemented to ensure the water quality in lakes Crescent and Sorell improves and is maintained in a healthy state (ie. protect invertebrate habitat).

5.1.2 Recreational Activities

Lakes Crescent and Sorell are used for recreational fishing and duck shooting. Both activities pose threats to invertebrate communities. Anglers and shooters using lakes Crescent and Sorell need to ensure that their equipment (ie waders and boats) is clean to minimise the risk of introducing flora and fauna from other waterways.

The accidental introduction of non-indigenous fauna through the use of fishing bait poses a significant risk to invertebrate communities. Since the discovery of European carp (*Cyprinus carpio*) in lakes Crescent and Sorell, the Inland Fisheries Service (IFS) has managed this issue by eliminating the use of fish as bait in all non-tidal waters in Tasmania and by closing Lake Crescent to the public. It is recommended that the 'artificial lure only' regulation should apply to both lakes Crescent and Sorell fisheries in order to minimise the risk of introducing additional non-indigenous fauna.

Recommendations for the management of the recreational activities which lakes Crescent and Sorell support, include:

- Educate anglers and shooters about the risk of introducing flora and fauna in lake Crescent and Sorell by using unclean equipment.
- Regulate lakes Crescent and Sorell as 'artificial lure only waters' (ie no bait fishing).

5.1.3 Agricultural Practices

Agricultural activities within the catchment primarily involve the grazing of sheep and cattle. Four of the five major adjacent wetlands to lakes Crescent and Sorell are currently grazed. Some of the adjacent wetlands have also been channelised (drained) to maximise their grazing potential. Alterations to the hydrology of the wetlands and the grazing of these areas by domestic stock, have the potential to restrict the distribution of invertebrates and damage their habitat.

The use of fertilisers on surrounding pasture land also has the potential to increase the nutrient concentrations of the water in lakes Crescent and Sorell and degrade water quality.

Education and involvement of land owners/managers in the Crescent-Sorell catchment in regard to management issues, is thought to be a priority to improve the condition of the wetland habitats and ensure their protection in the future.

Recommendations for the management of agricultural activities in the catchment of lakes Crescent and Sorell include:

- Informing landowners and residents of the findings of the *Lakes Crescent and Sorell Rehabilitation Project* and of the significance of the Crescent-Sorell system.
- Develop partnership approaches with landholders for managing the wetlands and adjacent agricultural areas.

5.2 Future Monitoring

This study has provided a base-line data set on the status of the macroinvertebrate communities in lakes Crescent and Sorell during a period of low water levels. Unlike previous studies, the current project has surveyed all of the major habitats that were available to invertebrates during the study using simple sampling techniques that can be easily replicated. Therefore the species lists provided by this study will be suitable for future comparisons.

As this study was conducted during an extended period of low water levels (with record low levels occurring in each lake during sampling), the results only provide insight into the effect of low water levels. To fully examine the effect of water levels on the invertebrate communities the lakes need to be sampled during a period of relatively high water levels. Surveying the invertebrate communities when water levels are higher will also determine if management strategies and water regimes are maintaining healthy invertebrate communities.

Recommendations for the future monitoring of macroinvertebrate communities in lakes Crescent and Sorell include:

Lakes

- Sample the invertebrate communities of lakes Crescent and Sorell during an extended period of high water levels (possibly > 803.20 m AHD and 804.20 m AHD in Crescent and Sorell respectively).
- Replicate the bimonthly lake sampling undertaken during this study on 2 to 3 occasions in lakes Crescent and Sorell.
- Sample in-lake macrophyte beds (if/when present) for invertebrates.
- Compare the diversity and abundance of the invertebrate communities to the results obtained for in-lake habitats during the current study.

Wetlands

- Sample the invertebrate communities of Kemps Marsh (Lake Sorell) and Interlaken Lakeside Reserve (Lake Crescent) during an extended period of high water levels (possibly > 803.20 m AHD and 804.20 m AHD in Crescent and Sorell respectively).
- Replicate the wetland sampling undertaken during this study on 2 occasions during summer.
- Compare diversity and abundance of invertebrate communities to the results obtained for Kemps Marsh during the current study.

5.3 Further Research

During this study a comprehensive species list for the invertebrate communities of lakes Crescent and Sorell has been complied during a period of very low water levels. The findings of this study have also highlighted the need for further research in areas relating to the direct effects of low water levels on invertebrates. Of particular interest are the effects of high water turbidity, siltation of substrates and extended dry periods in temporary wetlands on invertebrates.

Recommendations for future research include:

- Examine the effect of high turbidity on invertebrates.
- Examine the effect of the siltation of rock and sand substrate on lake dwelling invertebrates.
- Examine the resilience of wetland invertebrate communities to extended periods of de-watering.
- Examine invertebrate communities within in-lake macrophyte beds in other lakes on Tasmania's Cental Plateau.
- Study the invertebrate communities of other lakes on Tasmania's Central Plateau which experience elevated turbidity levels (such as Shannon Lagoon and Woods Lake).

6. References

Borrows G. B. (1968). A comparative study of the major zooplankton species in Lake Sorell and Lake Crescent, Tasmania. BSc Hon Thesis. University of Tasmania, Hobart.

Boulton A. J. & Jenkins K. M. (1997). Flood regimes and invertebrate communities in floodplain wetlands. In: *Wetlands in a Dry Land: Understanding for Management* (ed. W. D. Williams). Environment Australia, biodiversity Group, Canberra.

Buckney R. T. (1976). Aspects of the chemical variability of some Tasmanian inland waters. *Australian Journal of Marine and Freshwater Research* 27: 351-358.

Cheng D. M. H. & Tyler P. A. (1973a). The effect of diatom populations on silica concentrations of Lakes Sorell and Crescent, Tasmania, and the utilisation of tripton as a source of silica. *British Phycology Journal* 8: 249-256.

Cheng D. M. H. & Tyler P. A. (1973b). Lakes Sorell and Crescent - a Tasmanian paradox. *Internal Revue Gesamten Hydrobiologie* 58: 307-343.

Cheng D. M. H. & Tyler P. A. (1976a). Nutrient economies and trophic status of Lakes Sorell and Crescent, Tasmania. *Australian Journal of Marine and Freshwater Research* 27: 151-163.

Cheng D. M. H. & Tyler P. A. (1976b). Primary productivity and trophic status of Lakes Sorell and Crescent, Tasmania. *Hydrobiologia* 48: 59-64.

Chilcott S. J. (1986). The Effects of a 0.5 m Water Level Increase on Lake Crescent. Inland Fisheries Commission, Hobart.

Cleary C. (1997). Habitat preferences of the endemic Hydrobiid gastropods, "Austropyrgus" sp., and other aquatic gastropods from Lakes Sorell and Crescent, Central Plateau, Tasmania. BSc Hon Thesis. University of Tasmania, Hobart.

Fletcher, A. R., Morison, A. K. & Hume, D. J. (1985). Effects of Carp, *Cyprinus carpio* L., on communities of aquatic vegetation and turbidity of waterbodies in the lower Goulburn River basin. *Australian Journal of Marine and Freshwater Research* 36: 311-327.

Fulton W. (1983a). Macrobenthic fauna of Great Lake, Arthurs Lake and Lake Sorell, Tasmania. *Australian Journal of Marine and Freshwater Research* 34: 775-785.

Fulton W. (1983b). Qualitative and quantitative variation in the macrobenthic fauna of the original and new lake areas of Great Lake and Arthurs Lake, Tasmania. *Australian Journal of Marine and Freshwater Research* 34: 787-803.

Gooderham J. & Tsyrlin E. (2002). *The Waterbug Book: A Guide to the freshwater Macroinvertebrates of Temperate Australia*. CSIRO Publishing, Melbourne.

Hardie S. A. (2003). Current Status and Ecology of the Golden Galaxias (*Galaxias auratus*). Inland Fisheries Service, Hobart.

Heffer D. (2003). Wetlands of Lakes Sorell and Crescent: Conservation and Management. Inland Fisheries Service, Hobart.

Hunt P. C. & Jones J. W. (1972). The effect of water level fluctuations on a littoral fauna. *Journal of Fish Biology* 4: 385-394.

James M. R., Weatherhead M., Stranger C. & Graynoth E. (1998). Macroinvertebrate distribution in the littoral zone of Lake Coleridge, South Island, New Zealand - effects of habitat stability, wind exposure, and macrophytes. *New Zealand Journal of Marine and Freshwater Research* 32: 287-305.

Kaster J. L. & Jacobi G. Z. (1978). Benthic macroinvertebrates of a fluctuating reservoir. *Freshwater Biology* 8: 283-290.

Kirkpatrick J. B. & Harwood C. E. (1981). The Conservation of Tasmanian Wetland Macrophyte Species and Communities. Tasmanian Conservation Trust Inc., Hobart.

Kirkpatrick J. B. & Harwood C. E. (1983). Plant communities of Tasmanian wetlands. *Australian Journal of Botany* 31: 437-451.

Kirkpatrick J. B. & Tyler P. A. (1988). Tasmanian Wetlands and their Conservation. In: *The Conservation of Australian Wetlands* (eds. A. J. McComb & P. S. Lake) pp. 4. Surrey Beaty and Sons Pty Ltd, Sydney.

Leonard B. V. & Timms B. V. (1974). The littoral rock fauna of three highland lakes in Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 108: 151-156.

Leslie A. J., Crisman T. L., Prenger J. P. & Ewel K. C. (1997). Benthic macroinvertebrates of small Florida pondcypress swamps and the influence of dry periods. *Wetlands* 17: 447-455.

Neckles H. A., Murkin H. R. & Cooper J. A. (1990). Influences of seasonal flooding on macroinvertebrate abundance in wetland habitats. *Freshwater Biology* 23: 311-322.

Roberts P. C. (1973). The taxonomy and some aspects of the ecology of a new species of *Heterias* (Janiridae, Parasellidae, Asellota, Isopoda, Crustacea) from Lake Crescent, Tasmania. BSc Hon Thesis. University of Tasmania, Hobart.

Tatrai, I., Lammens, E. H., Breukelaar, A. W. & Klein Breteler, J. G. P. (1994). The impact of mature cyprinid fish on the composition and biomass of benthic macroinvertebrates. *Archival Hydrobiologia* 131(3): 309-320.

Timms B. V. (1978). The benthos of seven lakes in Tasmania. *Archival Hydrobiology* 81: 422-444.

Uytendaal A. (2003). Water Quality in Lakes Crescent and Sorell: Underlying Processes and Management Options. Inland Fisheries Service, Hobart.

Wong A. H. K., Williams D. D., McQueen D. J., Demers E. & Ramcharan C. W. (1998). Macroinvertebrate abundance in two lakes with contrasting fish communities. *Archival Hydrobiology* 141: 283-302.

Zimmer K. D., Hanson M. A. & Butler M. G. (2000). Factors influencing invertebrate communities in prairie wetlands: a multivariate approach. *Canadian Journal of Fisheries and Aquatic Science* 57: 76-85.

Personal Communications

Jenny Deakin, Lakes Sorell and Crescent Rehabilitation Project, Inland Fisheries Service, Hobart.

Brett Mawbey, Lakes Sorell and Crescent Rehabilitation Project, Inland Fisheries Service, Hobart.

Tom Sloane, SSS Wildlife Services, Richmond.

Adam Uytendaal, Lakes Sorell and Crescent Rehabilitation Project, Inland Fisheries Service, Hobart.

7. Appendices

1. Description of Sampling Methods and Relative Abundance Scales of all Invertebrate Studies on Lakes Crescent and Sorell

Study	Sampling Method and Relative Abundance Scale
Burrows (1968)	X indicates presence (no relative abundance)
Leonard and Timms (1974)	X Infrequent, XX Present, XXX Abundant, XXXX Very Abundant (combined data from under 5 rocks from 5 sites/lake)
Timms (1978)	X 1-10 individuals, XX 11-100, XXX, 101-500, XXXX >500 (per square metre from 7 sites in Lake Sorell and 5 sites in Lake Crescent)
Fulton (1983)	X 1-10 individuals, XX 11-100, XXX >100 (per square metre of benthos)
Chilcott (1986)	X 1-5 individuals, XX 6-20, XXX 21-100, XXXX >100 (per 3 net sweeps)
Hardie (2003)	X <10 individuals, XX 10-100, XXX 101-1000, XXXX >1000 (total specimens collected)