South Esk – Great Lake
Water Management Review

Scientific Report on Great Lake

August 2003

Prepared by
Hydro Tasmania

The research that was undertaken for this study was commissioned by Hydro Tasmania and conducted by *Freshwater Systems Pty Ltd*.

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GREAT LAKE

1. ASSESSMENT OF ISSUES AND STATUS

Background

During the environmental review and community consultation that was undertaken as part of the South Esk – Great Lake Water Management Review, a range of issues, primarily environmental, were identified that were associated with water management practices at Great Lake. Additionally, a number of responses to questionnaires distributed to the community specifically referred to issues in Great Lake.

This report presents information collected during technical studies undertaken on Great Lake as part of the second stage of the Water Management Review process. These studies were scheduled to:

- assess issues and their status prior to detailed investigation;
- collect and analyse additional data on biological issues and lake levels;
- develop management objectives for the lake; and
- propose possible options for environmental management of the lake.

Analysis of the preferred options, in terms of feasibility, costs and potential interactions, was carried out at a later stage of the Water Management Review process, when management options across the whole of the South Esk – Great Lake catchment were considered together.

Development History

The modern Great Lake is an artificial impoundment with a surface area of some 17,612 hectares and a volume at full supply of about 3.1 billion cubic metres. Prior to impoundment, the original lake was a shallow water body with a surface area of 11,330 hectares and extensive marshy perimeters. In it's original state, Great Lake was renowned for its diversity of aquatic fauna.

In 1910 a project to impound water from the Great Lake Catchment commenced, with the aim of producing electricity at the Shannon Power Station. This involved the construction of the first of 3 dams on the Shannon River at Miena. Water from the Shannon power station was then diverted to the Ouse River, where turbines were operating at Waddamana.

A second, higher dam, constructed at Miena in 1922, further increased the capacity of the lake, and water was diverted into Great Lake from the Ouse River below Lake Augusta by the construction of the Liawenee Canal. This provided more control over flows in the Ouse River and allowed more efficient usage of water for generation purposes.

To increase the amount of water available for hydro-electric power generation, a further storage (Arthurs Lake) was created, with water pumped to a flume carrying it through the Tods Corner Power Station and into Great Lake. This was in preparation for the commissioning of the Poatina Power Station, which would make use of the 830 m head down the face of the Great Western Tiers by diverting water from Great Lake into the South Esk Catchment via Brumbys Creek.

The third and final dam at Miena was constructed in 1967 and was raised further in 1982, effectively bringing the full supply level in Great Lake to 1039.37 m above sea level. This final development gave the impoundment an active operating range of just over 21m. Since the commencement of water level records (1916) water level has ranged from as low as 1020.2 mASL to as high as 1035.1 mASL.

Biological Issues

Native Flora

Great Lake is recognised as having a very high natural biodiversity, as demonstrated by its listing in the Directory of Important Wetlands in Australia (Blackley *et al.* 1996). This is largely due to the presence of endemic fauna, aquatic macrophyte beds (algae of the genera *Chara* and *Nitella*) and the diverse biological communities associated with these. A number of vulnerable, rare and/or threatened species are known to exist in the lake, with 11 species listed under the Tasmanian *Threatened Species Protection Act 1995*.

Characeous algal beds are desirable in natural freshwater systems, as they provide refuge for fish and invertebrates as well as improving water quality. In Great Lake, at least one native fish, *Paragalaxias eleotroides*, appears to be closely linked to these algal beds. This species is currently listed as vulnerable under the Tasmanian *Threatened Species Protection Act 1995* and has been nominated for listing under the Federal *Environmental Protection & Biodiversity Conservation Act 2000.*

The charophyte beds (commonly referred to as the ‘algal beds’ or ‘shrimp beds’) are historically known to occupy areas adjacent to shores of Great Lake, in areas protected from the predominant north-westerly winds (Davies and Fulton, 1987). In 1987 they were reported to occur over a limited depth range, restricted to between 15 m and 19 m below full supply level or 1024 - 1020 m above sea level (Davies and Fulton, 1987). It was reported that this range began approximately two metres above the normal minimum operating level. Since this first survey, three other surveys have indicated that the charophyte beds ‘migrate’ up or down slope in response to changing lake levels.

Below average rainfall in the Great Lake catchment during recent years has resulted in Great Lake water levels being drawn down towards normal minimum operating level, resulting in exposure and desiccation of some of these algal beds. These lake level changes, particularly the large recent drawdowns, have been identified as one of the major threats to these algal beds and consequently their associated fauna.

A review of the biology and ecology of the charophytes *Nitella* sp. and *Chara* sp. that occur in Great Lake was undertaken by Hydro Tasmania in 2002 (Jones, 2002). The review concluded that the family Characeae are a hardy well-adapted genus whose presence indicates generally good water quality. Species grow to 20 – 60 cm high, and are anchored to the bottom of freshwater lakes by well-developed rhizoids. The growth pattern is complex and reproduction via highly specialised structures is characteristic of the whole genus. Charophyte beds are widely considered desirable in natural freshwater lakes, as they provide refuge for fish and invertebrates as well as having an important role in nutrient cycling. Their ability to re-establish and migrate within an ecosystem is well documented. In the case of Great Lake, what remains unclear is whether the associated aquatic fauna are as flexible and resilient to lake level changes, and whether rapid, substantial reductions in area of charophyte habitat is a threat to aquatic faunal populations.

The historical information that has been published on biological issues was reviewed in more detail during the 'data collection' phase of this technical study, and was used to develop a survey and assessment program.

Fauna of Conservation Value

Table 1 lists the species of significance in Great Lake. A number of these are now known to be associated with the algal beds.

Species	Common Name	Distribution	Habitat	Status
Paragalaxias dissimilis	Shannon paragalaxias	Endemic to Great Lake, Shannon and Penstock Lagoon	Most common around rocky shoreline	Vulnerable x
Paragalaxias eleotroides	Great Lake paragalaxias	Endemic to Great Lake, Shannon and Penstock Lagoons	Most common in weed beds, also occurs around shoreline.	Vulnerable x
Triplectides elongatus	Great Lake Caddis 1	Great Lake area	Weedy areas of lake and tributaries	restricted distribution
Costora iena	Great Lake Caddis 2	Endemic caddisfly to Great Lake area only	Weedy area of lake and tributaries	Extinct – not collected since 1930's x
Asmicridea grisea	Great Lake Caddis 3	Endemic caddisfly to Great Lake area only.	Weedy area of lake and tributaries	Restricted distribution
Glacidorba pawpela	Great Lake Snail	Endemic to Great Lake area and Pelion	Benthos and soft sediments	Rare X
Tasniphargus tyleri	Great Lake Amphipod	Endemic to Great Lake	Weed beds	Rare X
Uramphisopus pearsoni	Great Lake Phreatoicid 1	Endemic to Great Lake	Lake benthos	Rare X
Onchotelson brevicaudatus	Great Lake Phreatoicid 2	Endemic to Great Lake and Shannon Lagoon	Lake benthos	Rare X
Onchotelson spatulatus	Great Lake Phreatoicid 3	Endemic to Great Lake	Lake benthos	Rare X
Mesacanthotelson setosus	Great Lake Phreatoicid 4	Endemic to Great Lake and Shannon Lagoon	Lake benthos	Rare X
Mesacanthotelson tasmaniae	Great Lake Phreatoicid 5	Endemic to Great Lake	Deep sections of lake benthos	Rare X
Beddomia tumida	Great Lake Hydrobiid	Endemic to Great Lake	Unknown	Vulnerable x
Ancylastrum cumingianus	Planorbid Limpet	Endemic to Great Lake, Shannon Lagoon, Lake St Clair and Mt Field	Weed beds	Restricted distribution

X = Status according to the Tasmanian *Threatened Species Protection Act* 1999.

Others as classified by Invertebrate and Vertebrate Advisory Committees (TASPAWS 1994a, b, c).

Table 1: Fauna species of conservation significance in Great Lake. (source - South Esk-Great Lake Hydro Catchment Environmental Review)

Fish Migration and Dispersal

The potential for translocation of fish species into Great Lake from other nearby water bodies has been recognised as a potential environmental issue. This includes the translocation of *Galaxias tanycephalus* and *Paragalaxias mesotes* from Arthurs Lake via Arthurs Flume and the movement of *P. julianus* from the Western Lakes into Great Lake via Lake Augusta and the Liawenee Canal.

Exotic Species

Exotic fish species in Great Lake include the two trout species, brown (*Salmo trutta*) and rainbow (*Oncorhynchus mykiss*). These are major predators of the endemic fish species and the presence of trout in the lake is one of the predominant threatening processes associated with the decline in native fish populations.

Redfin perch of several year classes have also been found in a farm dam connected to Great Lake by a drain, and there was some risk that redfin had colonised in the lake. This presents the potential for movement of this species up the Liawenee Canal and the subsequent risk of infestation of Lake Augusta and other lakes within the World Heritage Area. Construction by Hydro Tasmania of a barrier to the upstream passage of exotic fish on Liawenee Canal is believed to have eliminated this risk.

The exotic water plant, Canadian pondweed (*Elodea canadensis*) has been reported in Great Lake at Tods Corner and is likely to have been translocated to Great Lake from Arthurs Lake via the Arthurs Flume. This plant is a secondary prohibited aquatic weed introduced from North America and is now found in many lakes throughout the Central Highlands. It prefers warm, shallow, slow moving water and forms fast growing, dense beds which out-compete native macrophytes. As a result, this species has the potential to impact on the native macrophyte beds of Great Lake.

Recreational Fishing

Fishing concerns raised during the community consultation period related to navigational and boat safety issues due to submerged rocks and stumps that are brought closer to the surface with water level changes. Respondents to postal surveys suggested that these hazards be clearly marked. Appropriate camping sites, littering and lack of toilet facilities were also raised as issues requiring attention. It was suggested that camping not be permitted within 30 m of the lake foreshore.

As noted above, Great Lake supports a large, self-sustaining population of exotic brown trout (Salmo trutta) and a smaller population of exotic rainbow trout (Oncorhynchus mykiss). Angler survey data from the Inland Fishery Service indicates that for the period 1996 - 99, between 30 – 34 % of the 10 – 12.5 thousand anglers to whom recreational fishing licences were issued had fished Great Lake. The extrapolated harvest for 1998 - 99 was over 33,700 brown trout, 7000 rainbow trout and 100 Atlantic Salmon. The average number of days per angler spent at the lake declined from 7.25 in 1996 - 97 to 5.64 in 1998 - 99.

Assessment of the impact of lake water level on angler success over the period 1985 - 1996 was completed using correlation analysis as per Davies and Sloane (1988). In summary, this analysis found no correlation between the Inland Fisheries Service data and water level data for Great Lake. However, it must be noted that the Inland Fisheries Service data are coarse, of low resolution and potentially skewed as a result of non-uniform sampling techniques.

2. FORMULATION OF STUDY OBJECTIVES

The most significant issue identified for Great Lake is the management of the native *Chara* and *Nitella* sp. algal beds, which appear to play a critical role in maintaining biodiversity within this system and is critical habitat for a number of rare and threatened species. There was very little information about the current state and distribution of these beds and targeted ecological investigations were seen as most important.

The following priorities were identified by Dr Peter Davies of *Freshwater Systems Pty Ltd* for assessment relating to Hydro Tasmania's management of water level in Great Lake:

- assessment of the overall distribution of *Chara* and *Nitella* algal beds and other macrophytes within Great Lake, following observations that the major beds originally described in 1987 (Davies and Fulton, 1987) had significantly increased in extent and moved to higher altitudes in 1999/2000;
- assessment of the relative importance of the algal beds as habitat for endemic and other fish and macroinvertebrate species within the lake, including those species listed under the Tasmanian *Threatened Species Act (1995)*; and
- assessment of the habitat requirements of key native fish and macroinvertebrate species within the lake, including the listed species.

The ultimate aim of this work was to identify options for management of Great Lake to minimise the potential impacts of lake-level change on the threatened species occurring within the lake.

3. DATA COLLECTION AND ANALYSIS

Dr. Peter Davies was subsequently commissioned by Hydro Tasmania to undertake a study to investigate the priorities listed above. This work involved reviewing historical information regarding the algal beds, undertaking surveys on their present distribution and an examination of the use of this habitat by the various threatened species found in the lake. The following sections present this information, concluding with a discussion of results and recommendations for further action.

Review of Historical Data

Major changes in the flora and fauna of Great Lake have occurred since management of levels for hydro-electric power generation commenced in the 1920s. Early records of Great Lake (eg Legge and Cramp, in Banks, 1973) indicated that the lake had extensive areas of emergent and submerged macrophytes associated with shallow, shelving shorelines. Several waterbird species were associated with these macrophyte communities, and are infrequently or no longer observed at the lake. Davies and Sloane (1988) described the major changes in characteristics of brown trout populations in the lake since the 1920s, describing a major 'boom' period in the fishery during the 10 – 20 years following construction of the Miena Dam. They attributed increases in fish growth rates and size to increases in access to freshly inundated shorelines, with associated increases in food availability. The period from the 1940s to the present was characterised by much lower and relatively stable growth rates of trout. During this period, the lakeshore has been dominated by a characteristic ‘bathtub ring’ consisting of periodically inundated and exposed boulder-cobble armoured substrate. This zone is also typified by absence of finer sediment grain sizes, largely due to the relatively high wave energies during periods of inundation, and an absence of terrestrial or aquatic vegetation.

A series of extensive charophyte beds, known to the angling community as the ‘shrimp beds’ or algal beds, were known to exist in Great Lake at least since the 1960s, and probably earlier. Fulton (1983) first described the presence of limited areas of lakebed dominated by *Chara* or *Nitella* ‘stonewort’ algae during faunal surveys conducted in the late 1970s. He also ascertained that the majority of the lake bed (> 80 %), below ca 1020 m altitude, is characterised by soft fine-grained sediment deposits with no associated macro-algal or plant communities, whose fauna is dominated by worms (oligochaetes) and chironomids (midges). His study was focussed on comparing soft sediment faunas of Great and Arthurs Lakes, and his sampling method (Eckman grabs) did not allow sampling of the fauna associated with the ‘bathtub ring’ zone or the algal beds – both of which are normally dominated by a cobble-boulder armour layer.

Subsequent investigations were conducted in the late 1980s (Davies and Fulton, 1987) including exploratory dive surveys of algal distribution. This work showed that:

- there were five large and three smaller algal beds within the lake;
- all algal beds were clearly delimited in depth range at both the upper and lower margins;
- that they only occurred on shorelines sheltered from strong pre-frontal north-westerly winds;
- that they were associated with deposits of fine sediment on the upper slopes of the lake bed; and
- that, in 1987, they were constrained between approximately 1,024 and 1,020.6 m altitude, with the lower margin being consistent across all beds surveyed and, in the southern lake, associated with the upper edge of the original (pre-dam) lake shore. The similarity in the altitude of the lower margin of all beds surveyed suggested a limit imposed by low light levels (light attenuation).

Exploratory sampling suggested that a distinct faunal community was associated with these beds (Davies and Fulton, unpublished data), as opposed to the community characterising the majority of the lakebed (Fulton 1983). That fauna appeared to be characterised by the presence of the endemic crustacean (‘Great Lake shrimp’) *Paranaspides lacustris*, and larger numbers of the endemic fish *Paragalaxias eleotroides*. In addition, a netting survey of a range of habitats within the lake (Davies and Fulton, 1987) showed that:

- Juvenile and old (>6 years) brown trout, the latter frequently in poor condition, generally inhabited the 'bathtub ring' zone.
- A predominance of rainbow trout and of poor conditioned older brown trout were caught in nets suspended in open water at the surface.
- Brown trout, frequently in good condition, ranging between 2 and 6 years of age formed the majority of the catch recorded from nets set on the lake bed within the *Chara* beds, and that the age and size characteristics of this sub-population were consistent with those fish observed in the lake's principal spawning run at Liawenee Canal (Davies and Sloane, 1987).
- Stomach contents of trout caught in nets set within the *Chara* beds were dominated by *Paranaspides* and *Paragalaxias* and caddis nymphs. A proportion of stomachs from trout caught in the 'bathtub ring' zone and open water also contained *Paranaspides* – indicating that these fish had also fed in the *Chara* beds.

Davies and Sloane (1988) found a negative correlation between trout condition in anglers' catches and lake depth. They interpreted this as being due to the greater proportion of good condition trout in anglers' catches as lake levels decreased, as the proportion of shore-based fishing effort in the vicinity of the *Chara* beds increased. This argument was predicated on an assumption that brown trout frequently have localised home ranges on lake beds, as has been observed elsewhere.

Overall, this early work by Davies and Sloane led to the following initial conclusions:

- That the *Chara* beds were a major reservoir of aquatic faunal and floral biodiversity, particularly in their role as vestigial habitat for fauna endemic to the lake.
- That the occurrence of significant areas of *Chara* in the absence of other macrophyte species was a characteristic of a regulated lake with significant short and long-term changes in level, as observed elsewhere.
- That the beds were highly significant feeding habitats for brown trout, especially that portion of the population responsible for the majority of spawning and hence recruitment.
- That the trout population did not feed significantly on the benthic fauna of the dominant substrate of the lake, deep water fine silt sediments, which therefore did not contribute directly to fishery productivity.
- As a result, the beds may be a major driver of fishery production within the lake and hence their management should be seen as central to maintaining the viability of the Great Lake trout fishery.
- In addition, the beds are probably the major habitat for a number of the aquatic species endemic to this lake, and listed under the *Threatened Species Protection Act* (1995). The location of these beds suggests that they may be highly vulnerable to wave action, and dependent on areas with low wave energy and the potential for fine silt deposition at positions high enough on the shore profile for light not to limit growth.
- Periodic observations since the 1960s have been made of exposure ('dewatering') of the upper areas of the beds, with associated die-off.

It was noted that there had been insufficient rigorous sampling to firmly support the above conclusions regarding the importance of the beds as habitat for endemic and threatened fauna. It was proposed by Dr Davies that this should be rectified by a stratified sampling program to formally evaluate abundance and diversity of macroinvertebrate and fish within and outside the algal beds, and determine the true status of these species and the degree to which water management is an issue in their conservation.

In addition, it was suggested that conservation of the *Chara* beds might be largely a matter of water level management. A key unknown factor was the degree to which the position of the beds on the shore profile was ‘plastic’ i.e. to what degree the algal beds could move with changes in lake levels. The exposure of beds during rapidly declining summer water levels would cause dessication and death of these plants, and this would undoubtedly have an impact on resident fauna. Since damming, Great Lake levels have exhibited major long-term peaks, which are correlated with the Southern Oscillation Index (Harris *et al.*, 1988). It was not known if the lower margins of the beds would shift in response to light limitation during longer term shifts in lake level.

Algal Bed Surveys

Initial surveys of the algal beds were conducted in 1999 and these were designed to address the following questions:

- What was the current status and position of the known major *Chara* beds in Great Lake in 1999?
- Had the beds moved significantly (in elevation) and what are the implications for water management?

A dive survey was conducted in the summer of late 1999, to establish the upper and lower depth (altitudinal) limits of the five major *Chara* beds at three locations (transects) within each bed. In addition, a single transect was established in the centre of each bed. At each 8 m interval, percentage of algal cover, mean algal height and water depth to the substrate were recorded. The margins of each bed were defined using a 10 % cover criterion.

The following beds were surveyed: Sandbanks Bay, Canal Bay, Elizabeth Bay, Tods Corner (northern and western beds) and Reynolds Island shore. This initial survey was followed up by another survey in April/May 2001, which covered additional parts of the lake and assessed further movement in the elevation of the charophyte beds. The location of all transect sites is given in Table 2. It is important to note that the surveys conducted during the 1999 study were conducted following a period of relatively high lake levels between 1996 and 1999.

Results of Algal Bed Surveys

Extensive algal cover was observed at all previously surveyed transects at which algal cover had been noted. Thus all major beds in Sandbanks Bay, Reynolds Island, Becketts Bay, Elizabeth Bay and Muddy Bay, Tods Corner and Canal Bay were still maintained substantial charophyte beds, with several additional macrophyte species also observed in Tods Corner (including *Potamogeton* sp. and *Elodea canadiensis*). Algae were again observed at Brandums Bay. New areas of algal cover were observed in Little Bay and Grassy Bay, as well as south of Grassy Point at Alanvale Bay. These are not believed to represent major areas of *Chara* but should continue to be included in future surveys.

The survey of April/May 2001 supported the findings of the 1987 and 1999 surveys on the distribution of algae, with the addition of several new areas. The dominant charophyte beds were still associated with shores that are moderately to highly sheltered from north-westerly to westerly wind action.

Most charophyte beds had dense cover for much of their extent, frequently ranging up to 80 – 100 %, especially in Elizabeth, Canal, Sandbanks and Little Bays, Reynolds Island and Tods Corner. Algal height was variable but generally between 10 and 20 cm, with maximum heights of around 30 cm. *Potamogeton* in Tods Corner was taller (up to 50 cm), and tended to occur at greater depths than the *Chara*, particularly in the southern and eastern corners of the bay.

During the latter survey, the upper margins of all charophyte beds surveyed were associated with the water's edge, with most beds showing signs of extensive stranding of *Chara* and *Nitella* upslope on newly dewatered substrate. The declining water levels that occurred during the summer of 2000/01 had resulted in the loss of charophyte habitat. The upper margins of beds in slightly exposed situations were associated with reduced cover within 1m depth of the shoreline. Beds on highly sheltered shores tended to maintain high charophyte algal cover right to the water's edge. It was apparent that wave action at the shoreline in less sheltered conditions limits *Chara* development to a depth of around one metre.

		Shore margin		Deep margin	
Site	**Site Name**	**Easting**	**Northing**	**Easting**	**Northing**
Elizabeth Bay	Elizabeth Bay East	480542	5362965	480597	5362759
	Elizabeth Bay Lateral Margin 1	481130	5363031		
	Elizabeth Bay West	480312	5362100	-	-
Beckett's Bay	Beckett's Bay Centre	479773	5353994	479820	5353879
	Beckett's Bay 1	478650	5352560	478634	5352693
	Beckett's Bay Lateral Margin 1	478477	5352590		
	Beckett's Bay 2	478530	5353373	478549	5353358
Muddy Bay	Muddy Bay 1	481718	5360500	481707	5360354
	Muddy Bay Lateral Margin 1	481826	5359745		
	Muddy Bay 2	482355	5360608	482185	5360429
	Muddy Bay 3	482115	5360092	481980	5360131
Canal Bay	Canal Bay 1	475057	5362541	475144	5362353
	Canal Bay 2	475813	5362340	475755	5362213
	Canal Bay 3	476318	5362470	476325	5362316
	Canal Bay Visual 1	476325	5362316	476312	5362198
	Canal Bay Visual 2	476312	5362198	476240	5362062
	Canal Bay Visual 3	476494	5362438	476506	5362307
	Canal Bay Visual 4	476687	5362465	476723	5362354
Reynolds Island	Reynolds Is. 1	476719	5366004	476797	5365889
	Reynolds Is. Lateral Margin 1	476719	5366004		
	Reynolds Is. 2	477597	5366221	477620	5366065
	Reynolds Is. 3	478213	5365710	478127	5365652
	Reynolds Is. Visual 1			476594	5365738
Tods Corner	Tods Cnr. Sth. 1	481585	5354742	481693	5354890
	Tods Cnr. Sth. Lateral Margin 1	481523	5354839		
	Tods Cnr. Sth. 2	482184	5354030	-	-
	Tods Cnr. Sth. 3	482398	5353515	482523	5353587
	Tods Cnr. Sth. Visual 1	482523	5353587	482558	5353641
	Tods Cnr. Sth. Visual 2	482083	5354596	482113	5354666
	Tods Cnr. Nth. 1	482820	5354824	482671	5354850
	Tods Cnr. Nth. 2	482922	5355566	482859	5355385
	Tods Cnr. Nth. 3	481693	5355361	481767	5355243
	Tods Cnr. Nth. Lateral Margin 1	481600	5355270		
Sandbanks Bay	Sandbanks 1	485141	5369806	485206	5369713
	Sandbanks Lateral Margin 1	485206	5369713		
	Sandbanks 2	484637	5369833	484678	5369774
	Sandbanks 3	484036	5369477	484209	5369402
	Sandbanks Visual 1	485390	5368984	485271	5368923
	Sandbanks Visual 1	485381	5369584	485318	5369570
	Sandbanks Visual 3			484093	5368955
Brandum Bay	Brandum Bay Visual 1	473179	5370275	473277	5370262
Little lake Bay	Little Lake Bay Lateral Margin 1	475843	5373555		
	Little Lake Bay Lateral Margin 2	476051	5374284		
	Little Lake Bay 1	475744	5373634	475811	5373710
	Little Lake Bay 2	475600	5374022	475779	5373952
	Little Lake Bay 3	475938	5374283	475988	5374153
	Little Lake Bay Visual 1	476348	5374198	476371	5374089
Grassy	Grassy Bay Visual 1	477234	5373123	477284	5373262
	Grassy Point Visual 1	476495	5372711	476340	5372636
Sth. Grassy	Sth. Grassy Point Visual 1	477498	5371748	477336	5371656
Alanvale Pt	Alanvale Point Visual 1	473924	5371385	473999	5371408

Table 2: Location of transect sites, Great Lake, surveyed between 28/4 and 4/5/2001

During the April/May 2001 survey, the majority of *Chara* beds had deep water margins (i.e. with cover falling to less than 10 %) located at around 1022 m altitude (a mean of 1021.8 m (equating to 5.3 m depth in late April 2001), see Table 3 and Figure 1. The depths of these margins were consistent with depths observed in 1999 and 1987, but were significantly higher in elevation (altitude) than was found in both previous surveys.

This, combined with lower altitudes observed for peak charophyte cover in 2001, indicated that all beds had moved significantly downslope (to lower attitudes) in 2001 since 1999, associated with decreasing Great Lake water levels. This is discussed in more detail below.

Bay	Site	Elevation of Lower Margin	Depth below surface of lower margin
Todds Corner	Nth. Transect 1	1022.47	4.43
	Nth. Transect 2	1024.67	2.23
	Nth. Transect 3	1023.87	3.03
	Sth. Transect 1	1024.87	2.03
	Sth. Transect 2	1025.17	1.71
	Sth. Transect 3	1024.57	2.33
Sandbanks Bay	Transect 1	1024.97	1.93
	Transect 2	1024.87	2.03
	Transect 3	1025.37	1.53
Reynolds Is.	Transect 1	1023.97	2.93
	Transect 2	1025.27	1.63
	Transect 3	1023.67	3.23
Canal Bay	Transect 1	1026.32	0.58
	Transect 2	1022.4	4.5
	Transect 3	1021.5	5.4
Muddy Bay	Transect 1	1024.47	2.43
	Transect 3	1024.87	2.03
Becketts Bay	Transect 1	1024.67	2.23
	Transect 2	1024.57	2.33
	Transect 3	1024.67	2.23
Elizabeth Bay	Transect 1 (West)	1026.57	0.33
	Transect 2 (East)	1024.37	2.53
Little Bay	Transect 1	1025.17	1.73
	Transect 2	1025.07	1.83
	Transect 3	1024.07	2.83

Table 3: Elevations of deep water margins of *Chara* beds in eight embayments in Great Lake, surveyed between 28th April and 4th May, 2001. Water level at the time was 1026.9 mASL.

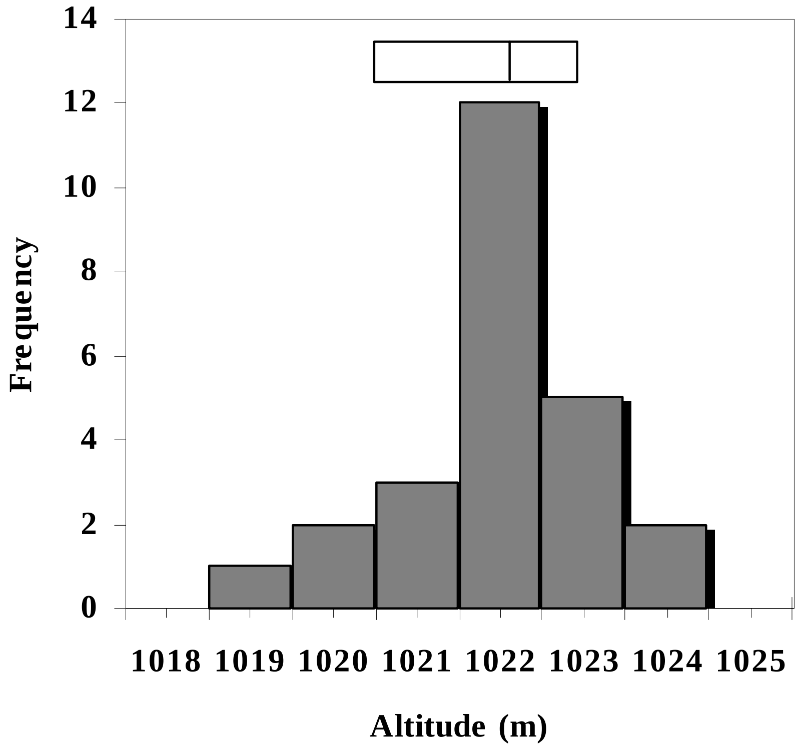

Figure 1: Frequency distribution of altitude of lower margins of *Chara* beds derived from all transects in the seven bays surveyed in 2001. Also shown as a box-plot (centre-line and outer margins of box = median, 25 and 75 percentiles). Water level at the time was 1026.9 mASL.

The distribution of algal cover with depth is shown in Figure 2, across all transects. The variable density at depths < 1 m is associated with the variable influence of wave action on shore algal development, as discussed above. A peak in higher cover at depths between 2 m and 4 m depth was observed for most transects, along with a reduction in cover at depths from 4.5 to 6 m associated with the lower bed margins.

The distribution of algal height with depth and cover is shown in Figure 3. Charophyte height was generally greatest at greater depth and cover.

Algal cover was also most pronounced on silt substrates (see Figure 4) and there was a strong association between silt, either alone or among small boulders, and high (>35 %) mean *Chara* cover. Silt-dominated substrates, including silt associated with small boulders, were associated with significantly greater *Chara* cover than mud, pebble or gravel substrates (all $p < 0.002$ by ANOVA [analysis of variance]). Flat rock substrate (often with isolated patches of silt on the surface) was intermediate in cover, while consolidated soil substrates, while uncommon, had high algal cover.

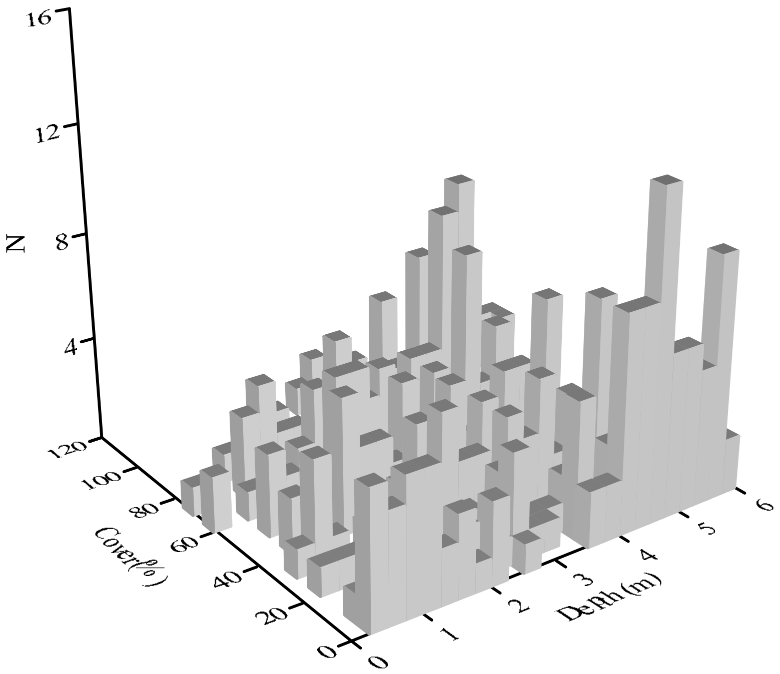

Figure 2: Distribution of algal cover across depth for all transects in Elizabeth, Canal, Sandbanks and Little Bays, Reynolds Island (SE shore) and Tods Corner. Note the variable density at depths < 1 m, the general peak in higher cover at depths between 2 and 4 m depth, and the reduction in cover at depths from 4.5 to 6 m.

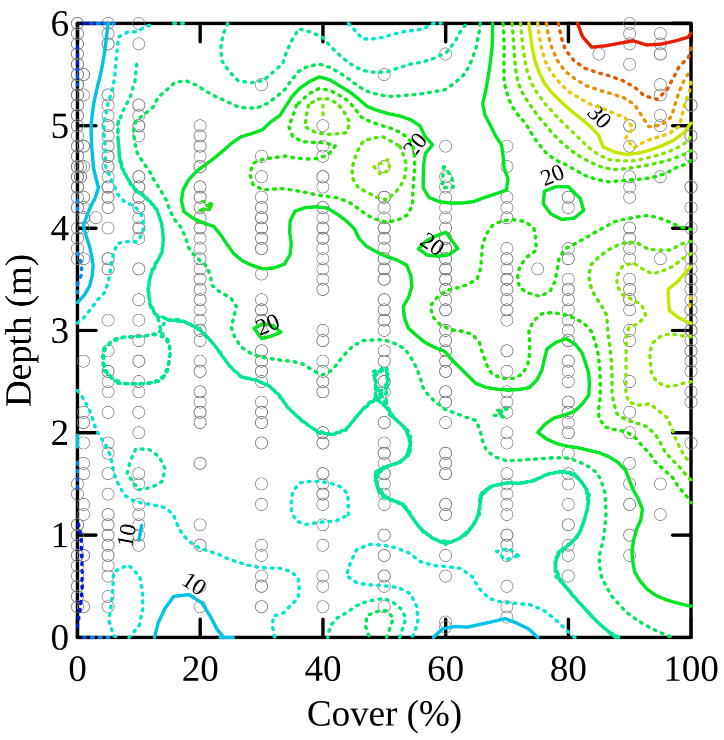

Figure 3: Distribution of algal height with water depth and percentage of cover in major Great Lake *Chara* beds. Note general trend to greater height at greater depth and cover, greater heights (20 – 40 cm) associated with dense cover (> 80 %) for all depths > ca 2m, with some high (> 20 cm) algae at intermediate cover (20 – 70 %) at depths between ca 3 and 5.5 m.

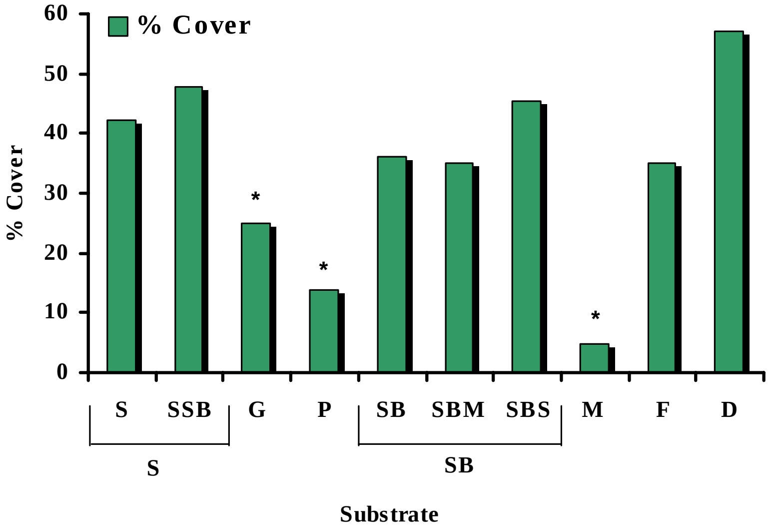

Figure 4: Mean percentage of cover of *Chara* by substrate type within *Chara* beds of Great lake. S = silt, SB = small boulders, G =gravel, P = pebble, M = mud, F = flat rock, D = packed soil/dirt, SSB = sand and small boulder, SBM and SBS = small boulder and mud/silt. Asterisks indicate significantly lower cover than at other substrates.

Discussion of Changes in Altitude and Lateral Position of Algal Beds

It is apparent when comparing the results of surveys in 1987, 1999 and 2001 that the position of the charophyte beds in Great Lake changes significantly with changes in water level.

The lower margins of the beds range up to 10 m below the surface, and vary between bays. Bays and shores in highly sheltered situations (eg south of Reynolds Island) tend to have more extensive charopyhte beds extending to greater depths. These locations have been observed to have clearer water, with low levels fo suspended sediment. High water clarity is associated with deeper light penetration, deeper extent of charophytes with diffuse lower margins (ie the beds don't have a sharp cut-off at depth). Bays and shores in a more exposed situation (eg Elizabeth Bay), tend to have charophyte beds over a shallower range. Such locations are more often associated with turbid, cloudy water, especially during periods of strong westerly/north-westerly winds. Here the charophyte beds have a shallower lower edge, which is often sharp and distinct.

Charophyte bed upper margins in 2001, as in 1999, were all at the water's edge with areas of stranded algae evident upslope. Under these conditions, as noted above, there is a localised effect of wave energy on the viability of *Chara* near the water's edge which restricts algal growth within ca one metre depth from the edge. The upper limit in 1987 was not associated with the water's edge, and was similar in form to the lower edge i.e. not sharp or distinct, but patchy. The 1987 survey was conducted during a period of rising lake levels, while the surveys in 1999 and 2001 were conducted during a period of sharply declining summer-autumn levels. The upper limit of the *Chara* beds therefore appears to be strongly determined by whether the lake level is rising or falling.

There was no evidence from the 1999 and 2001 surveys that there has been a marked lateral change in the distribution of *Chara* in the main algal beds at Sandbanks, Elizabeth, Muddy, and Canal bays or at Reynolds Island or Tods

Corner. Potentially extensive beds in Little Bay and Grassy Bay were observed in 2001, along with narrow but possibly laterally extensive beds south of Grassy Point and on the western shores near Brandums and Alanvale Bays. These observations suggest that any such beds probably account for 20 % or less of total charophyte area within the lake. However, it does suggest that the lateral extent of charophytes may be dynamic in these more marginal situations. Changes in lateral extent may result from changes in lake level, but also from longer (> 1 year) changes in substrate distribution caused by periods with less intense storms.

Inspection of altitudinal changes in position of charophyte bed upper and lower margins within the six main bays surveyed (see Table 4), indicates that:

- the lower margins had shifted to a mean of approx. 2.5 m lower elevation in 2001 than in late 1999;
- the upper margins in both cases were within 1 m of the lake water surface; and
- the lower margin observed in late 1999 was some 3.7 m higher in altitude than in 1987.

Together with inspection of lake levels, these observations suggest that a maximum rate of migration of *Chara* bed margins is of the order of 2 m elevation per year.

In summary, charophyte beds migrate up and down the lakebed slopes with rising and falling lake levels. The depth and nature of the lower margin of the beds varies by location around the lake, and is apparently influenced by water clarity, which is controlled by the degree of suspension of sediment in the water where the lakeshore is exposed to wind and wave action.

	1987	1999	2001
Upper Margin	1024.00	1032.94	1027.03
Lower Margin	1020.60	1024.26	1021.77

Table 4: Mean elevations (m) of the upper and deepwater margins of Chara beds in Great Lake as surveyed in May 1987, October 1999 and May 2001. Means for 1999 and 2001 both calculated from transects in Canal, Sandbanks, Elizabeth, Becketts Bays, Reynolds Island and Tods Corner for comparison. 1987 levels estimated from transect observations in Swan, Canal, Elizabeth Bays and Reynolds Island.

Fish and Invertebrate Distributions

Survey Methods

Four locations were sampled in the mid-depth of each *Chara* bed in 2001, and at the same depth on neighbouring non-weed bed areas in each of four embayments – Elizabeth bay, Reynolds Island (southeast shore), Becketts Bay, and Sandbanks Bay. At each sampling location, six sample units were taken of the benthic fauna, and the resulting material pooled to form a single sample from each location. Each sample unit consisted of a modified 500 micron mesh surber sampled operated by a diver, with a sampling area of 0.09/m^2, and sampling was conducted by hand disturbance of the benthos with manual washing of the suspended material through the net.

All samples were preserved with 10% formalin. Samples were processed as follows:

- the entire sample was sorted for fish and *Paranaspides* and phreatoicids;
- the sample was then subsampled to 20 % in a Marchant box subsampler;
- the 20 % subsample sorted completely and all taxa identified and counted for all taxa (except nematodes which were too numerous to sort and count within the time available); and
- all taxa from the 20 % sub-sample were then identified to family level (except for Turbellaria, Annelida, Hydracarina, and the crustacean groups: Copepoda, Isopoda, Janirids, Ostracoda, Cladocera, Chydorid, Syncarida, Mecoptera).

Due to the low level of the lake during summer-autumn, a comparison of the fish fauna was attempted of *Chara* and non-*Chara* areas in 15 locations, by conducting wader-operated backpack electroshocking of shoreline sections between 0.5 and 0.8 m depth. Standard runs of ca 20 min shocking time were conducted at each site. In addition, a fyke net was set overnight at each sampling location, parallel to the shore. All fish caught were identified and counted prior to release. Presence of *Chara* was noted at each sampling location.

General Observations

Phreatoicids were present in all four sampled bays (Becketts, Elizabeth and Sandbank Bay and Reynolds Island), but were highly patchy in distribution, both between sample locations within habitats, and also between bays. The overall mean abundance was 27/m^2, with a peak abundance of 623/m^2 (at one sample location in Elizabeth Bay). A significant number of sampling locations did not contain phreatoicids (6 out of 32 locations).

A total of six species were observed, four of which are listed under the *Threatened Species Protection Act* (1995), indicated below by an asterisk:

*Onchotelson brevicaudatus**	Smith, 1909
*Onchotelson spatulatus**	
*Mescocanthotelson setosus **	Nicholls, 1944
*Mescocanthotelson tasmaniae**	Thomson, 1894
Mescocanthotelson fallax	
Mescocanthotelson decipiens	

The most common species across all locations sampled was *M. setosus*, occurring in 15 of the 32 sampling locations, and in all four bays. *M. tasmaniae* was only found in Becketts Bay, on rocky bed habitat, while *O. spatulatus* was only found in Elizabeth Bay (in both habitat types). *M. decipiens* and *M. fallax* were the least common and least abundant, occurring in only four sampling locations across two bays (Sandbanks and Becketts).

No specimens of *Uramphisopus pearsoni* Nicholls, 1943, another species listed under the *Threatened Species Protection Act* (1995) were observed. Recent collections by Buz Wilson (National Museum of Sydney) suggest that this species is very rare within the lake, and appears to be currently restricted to soft sediments on the original lake bottom.

Paranaspides lacustris was relatively abundant, particularly given the likely relatively low efficiency of capture of this mobile species, with a mean abundance of 8.9 and 0.86/m^2 in charophyte and rocky bed habitats, respectively. A maximum abundance of 211/m^2 was observed at one sampling location in Becketts Bay. Again, diver-estimated abundances were much lower, with a mean of 0.05/m^2 of charophyte bed area observed. Diver observations indicated that *Paranaspides* was widespread - being present at 26.8 % of locations observed within charophyte beds.

Benthic sampling in both charophyte and rocky bed habitats resulted in the collection of substantial numbers of fish, all of which were identified as *Paragalaxias dissimilis*. Mean densities were 4.98 and 1.61/m^2 in *Chara* and rocky bed habitats respectively. *P. dissimilis* was found in 20 of the 32 sampling locations, and occurred in both habitats in all bays. Diving observations indicated much lower densities, with a grand mean of 0.015 *Paragalaxias*/m^2 of charophyte bed area observed, reflecting the much lower efficiency of visual counts of this benthic and cryptic species. Diver observations indicated that *Paragalaxias* present at 11.8 % of locations observed within charophyte beds.

The shoreline electrofishing and fyke netting was conducted in shallow waters < 1 m deep, and therefore in the shore zone where charophytes are generally not well developed due to local wave action. The sites selected for sampling did not allow formal evaluation of differences between embayments. Therefore, a comparison of charophyte bed and rocky substrate habitats is not possible with these data. The data (see Table 5a and Table 5b) do show that there is a reasonably high abundance of native fish in the shallow shore zone, with relative abundances in the following order; *Paragalaxias dissimilis* >> *P. eleotroides* > *Galaxias truttaceus* > *G. brevipinnis*.

Previous experience (Davies unpub. data) has shown that *Salmo trutta* is not caught efficiently by the backpack electroshocking method at Great Lake, due to low conductivities and high visibility, and that fyke netting with standard mesh size does not effectively capture juveniles (0+ to 1+) fish, which are known to be abundant along this shoreline, and its abundance is probably greatly underestimated. Results for *S. trutta* are therefore inconclusive.

Site Code	Site	Habitat	G. brevipinnis	P. dissimilis	P. eleotroides	S. trutta	Total
5	Rainbow Point	R		6.86	4.90		11.76
7	Muddy Bay	RC		65.67	3.98		69.65
8	Tods Corner	RC	4.00	122.00			126.00
11	Beckets Bay	C		10.00	8.00		18.00
13	Little Lake Bay, SW Point	RC	2.87	127.17	1.91		131.95
14	Reynolds Island	RC		5.00	2.00		7.00
15	Little Lake Bay, SW Point	R	1.99	132.12	10.93		145.03
16	Bay north of intake	RC		87.51	7.96	1.33	96.80
19	South Muddy Bay	R		49.59	3.97	1.98	55.54
20	Tods Corner and Shoobridge Island	RC		80.00	10.00		90.00
22	Beckets Bay	R		34.00	4.00		38.00
24	Reynolds Island	RC		24.00	3.00		27.00
25	Elizabeth Bay	RC		15.76	3.94		19.70
25	South of Howell's Island Point, Elizabeth Bay	C		4.00			4.00
32	SW Intake Bay (North)	R		12.00	1.00		13.00
	Mean		**2.95**	**51.71**	**5.04**	**1.65**	**56.90**

Table 5a. Fish catches from electrofishing of shore zones at 15 locations in Great Lake on 3rd July 2001. All numbers are N fish/20 min battery time. G. = *Galaxias*, P. = *Paragalaxias*, S. = *Salmo*

Site Code	Site	Habitat	G. truttaceus	G. brevipinnis	P. dissimilis	P. eleotroides	S. trutta	Total
5	Rainbow Point	R			2.28	1.14	1.14	4.56
7	Muddy Bay	RC						0.00
8	Tods Corner	RC			17.18			17.18
11	Beckets Bay	C			45.03	3.75		48.78
13	Little Lake Bay, SW Point	RC	1.01		4.04	1.01		5.05
14	Reynolds Island	RC			1.12			1.12
15	Little Lake Bay, SW Point	R		1.04	27.97	1.04		30.04
16	Bay north of intake	RC	2.02		8.07	1.01		9.08
19	South Muddy Bay	R			3.07			3.07
20	Tods Corner and Shoobridge Island	RC			11.26	1.02		12.28
22	Beckets Bay	R			13.00			13.00
24	Reynolds Island	RC			4.26	1.06		5.32
25	Elizabeth Bay	RC						0.00
25	South of Howell's Island Point, Elizabeth Bay	C	1.08		7.58			7.58
32	SW Intake Bay (North)	R			3.08			3.08
	Mean		**1.37**	**1.04**	**11.38**	**1.43**	**1.14**	**10.68**

Table 5b Fish catches from fyke netting of shore zones at 15 locations in Great Lake on 3rd July 2001. All numbers are N fish/24 hr net set time. G. = *Galaxias*, P. = *Paragalaxias*, S. = *Salmo*

Overall densities of Phreatoicids, *Paragalaxias dissimilis* and *Paranaspides lacustris* in charophyte and rocky bed habitats estimated from benthic sampling in four embayments are shown in Figure 5. There was substantial variability in densities for all three groups; caused primarily by substantial differences between bays, however, two-way ANOVA (analysis of variance) did indicate that densities of all three groups were significantly higher in charophyte beds than on rocky shore habitat.

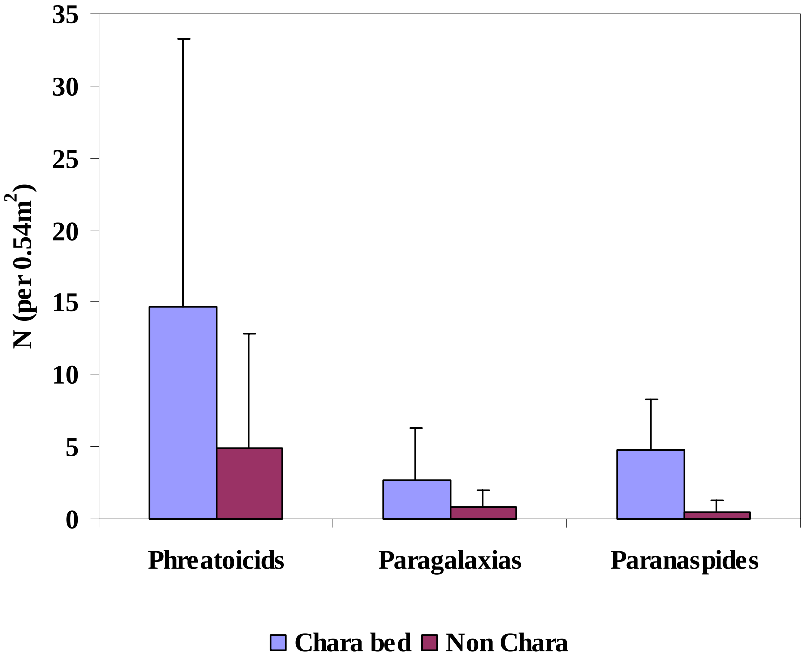

Figure 5: Mean benthic densities of Phreatoicids, *Paragalaxias dissimilis* and *Paranaspides lacustris* observed at four locations in each of four embayments within Great Lake, compared between charophyte and rocky bed habitats. Bars represent standard deviations.

Fish and Paranaspides Distributions within Chara Beds

Diver estimates of densities of *Paranaspides* and fish were derived for all algal survey transects except those in Elizabeth Bay. These estimates were not accurate as densities of fish estimated by diving and electrofishing in the same depth and algal cover range were significantly different (estimates made by divers being lower by two orders of magnitude). In addition, shrimp densities estimated by benthic sampling were significantly higher than those estimated by diver observations. Casual observations by divers of high fish densities under individual rocks (up to 17 *Paragalaxias* being observed under one 30 cm boulder when upturned), suggest that both electrofishing and diver-observations have low efficiency.

However, diver counts were believed to be reasonably consistent across depths and transects, and allowed ready differentiation of *Paragalaxias* and *Galaxias* fish genera. In addition, the trends in densities of fish and *Paranaspides* estimated by divers were not consistent with declining observation efficiency at higher algal cover, indicating that these trends were likely to be real rather than a product of poor visibility with high algal cover. This was facilitated by the tendency for *Paranaspides* to inhabit the upper margins and tops of charophyte stands.

Paranaspides densities varied with depth and algal cover (see Figure 6 and Figure 8), with density increasing with both depth and percentage of charophyte cover. By contrast, both *Paragalaxias* and *Galaxias* appear to occupy different ranges of depth and algal cover, with *Paragalaxias* appearing to occupy a range of depths and charophyte densities, but generally at intermediate values (Figure 7 and Figure 9), and galaxias being lower in density and favouring dense algae at shallower depths (Figure 7 and Figure 10).

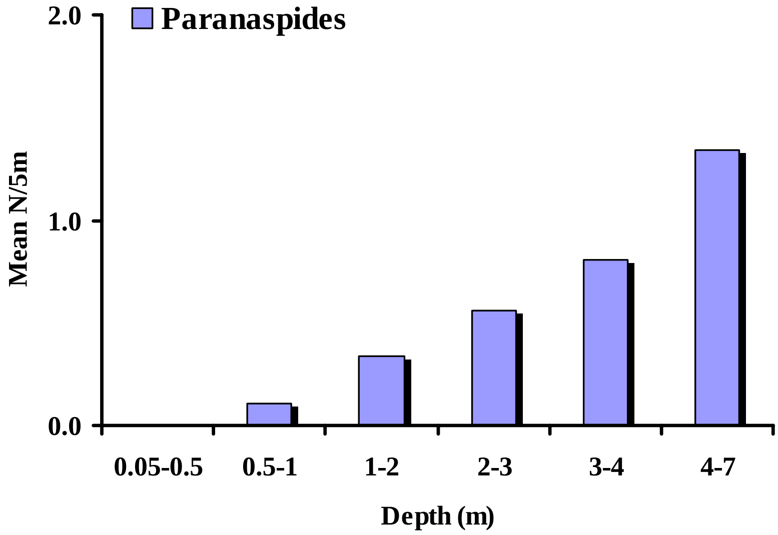

Figure 6: Mean density (number observed per 5 m transect swim) of *Paranaspides* with depth within Great Lake algal beds. Note absence of *Paranaspides* in shallow shore zones.

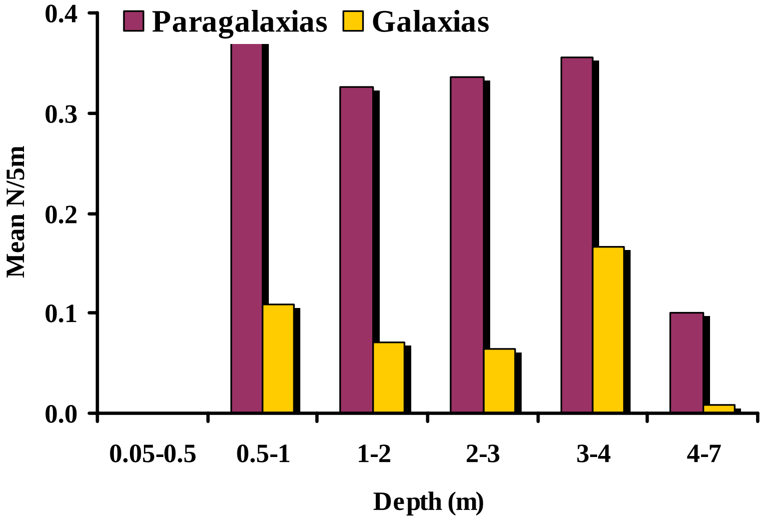

Figure 7: Mean density (number observed per 5 m transect swim) of *Paragalaxias* and *Galaxias* with depth within Great Lake algal beds. Note lower density of *Galaxias*, absence of fish in shallow shore zones, and different depth distributions.

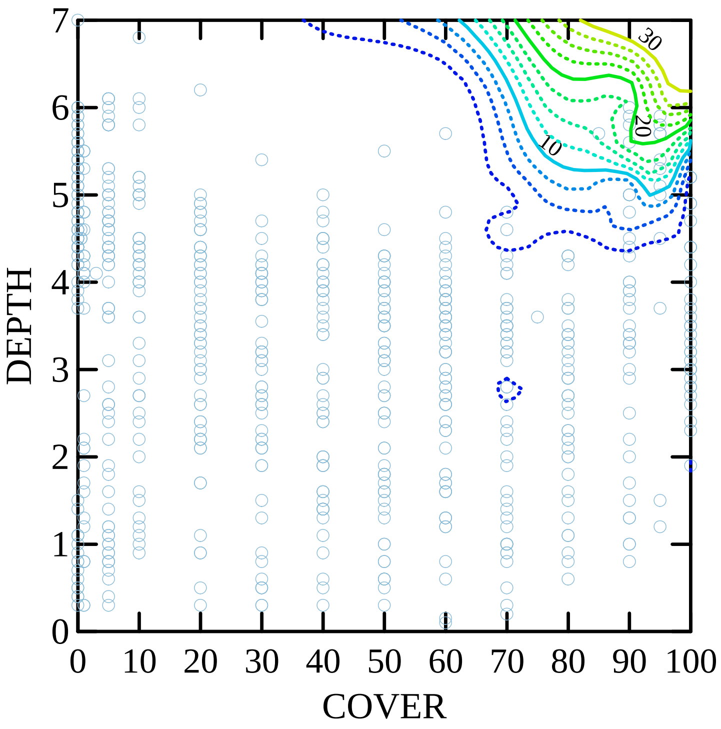

Figure 8: Contour plot of density of *Paranaspides lacustris* in Great lake charophyte beds against depth (m) and algal cover (%). Note strong association of *Paranaspides* with greater charophyte cover and greater depth. Circles indicate locations of transect observations from which contours are derived.

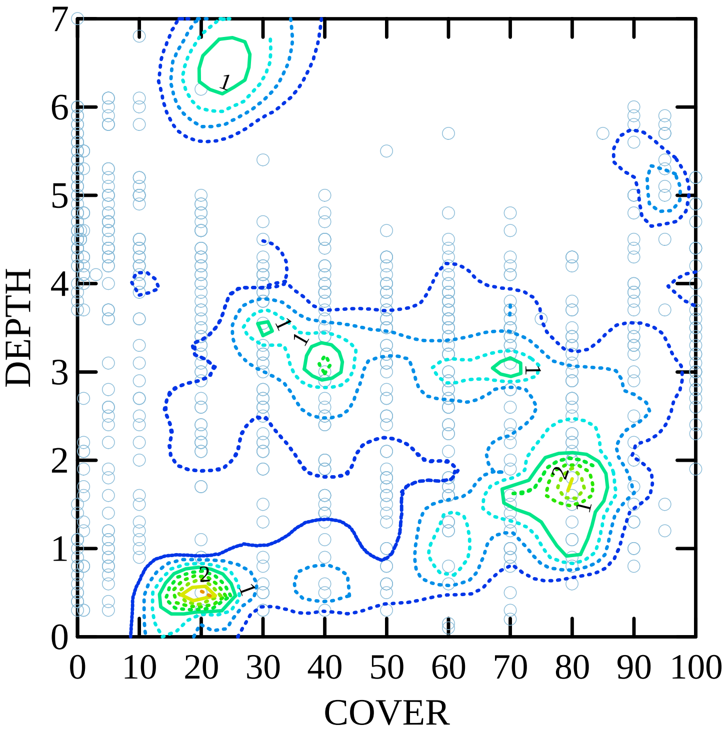

Figure 9: Contour plot of density of *Paragalaxias* (*dissimilis*, see text) in Great lake charophyte beds against depth (m) and algal cover (%). Note patchy association of *Paragalaxias* with shallow to intermediate depths over a range of charophyte cover. Circles indicate locations of transect observations from which contours are derived.

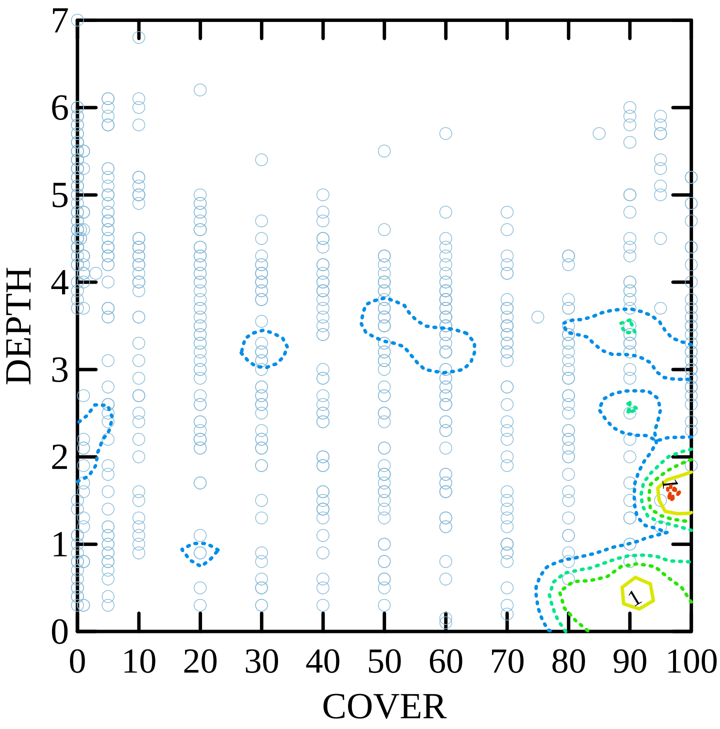

Figure 10: Contour plot of density of *Galaxias* in Great lake charophyte beds against depth (m) and algal cover (%). Note association of *Galaxias* with greater charophyte cover at shallow (< 2 m) depths. Circles indicate locations of transect observations from which contours are derived.

Associated Benthic Fauna

Table 6 presents a summary of the benthic macroinvertebrate fauna from *Chara* and rocky bed habitats collected in Elizabeth Bay. The *Chara* bed habitat is significantly more diverse and abundant than the rocky bed habitat ($p < 0.001$ and 0.005, respectively by t-test, $n = 4$), with between 1 and 5 more taxa at 'family' level occurring in the charophytes (with a mean of 15) than outside it. Thus, in addition to higher abundances of *Paragalaxias dissimilis* and *Paranaspides lacustris*, *Chara* bed habitat is characterised by higher abundances of Turbellaria, Parameletid amphipods, Ostracods, Chironomid and Tanypod larvae, Atriplectid and Leptocerid caddis larvae, Dytiscid diving beetles and Phreatoicids, than rocky substrate. This reflects the siltier and less exposed nature of the charophyte areas, as well as *Chara*'s more complex microhabitat. There were no taxa that were more abundant in the rocky habitats, with the single exception of the phreatoicid *Mesocanthotelson tasmaniae*, which appears to be restricted to that habitat in Becketts Bay, as discussed above.

			Rocky substrate	***Chara***
Platyhelminthes	Turbellaria		1	22
Mollusca	Bivalvia	Sphaeridae	3	24
	Gastropoda	Planorbidae		8
Oligochaetae			140	229
Arachnida	Hydracarina		2	6
Crustacea	Amphipoda	Paramelitidae	2	11
	Copepoda		4	23
	Janirids		10	39
	Ostracoda		1	39
	Cladocera		478	58
Diptera	Chironomidae	Chironominae	11	494
		Orthocladiinae	10	4
		Tanypodinae	1	129
	Trichoptera	Atriplectrididae	2	6
		Leptoceridae		19
		Dytiscidae		4

Table 6: Mean abundances of benthic macroinvertebrates ($n/0.1m^2$) on rocky substrate and charophyte habitats, Elizabeth Bay, Great Lake, in May 2001. Data does not include *Paranaspides lacustris*.

Discussion and Conclusions

Algal Faunal Associations

It appears that the charophyte beds in Great Lake form a significant habitat for a range of macroinvertebrate taxa as well as for *Paragalaxias dissimilis*. The beds contain a significantly more diverse and abundant macroinvertebrate fauna than other benthic habitats on the lake slopes.

No attempt was made to compare the fauna of these habitats with that of the main lake bottom, which forms an extensive area of silt substrate and whose fauna is known to be dominated by worms (Fulton, 1983). However, examination of Fulton’s Eckman grab data across habitats and with our data indicates that the charophyte beds contain a significantly more diverse fauna.

In addition, the charophyte beds are the preferential habitat for the Great Lake shrimp. *Paranaspides lacustris*, with a 10 times greater abundance within than outside the beds. The Great Lake phreatoicids, of which we observed six of the seven species known from the lake, also show a significant preference for the *Chara* habitat. Two species do not however, with *Uramphisopus pearsoni*, which we did not collect, occurring only, and rarely, in deeper habitats (Fulton 1983 and B. Wilson 2001, pers. comm.), and *Mesocanthotelson tasmaniae* only being found in samples outside charophyte beds in Becketts Bay.

Overall, this study confirms that the Great Lake charophyte beds are of ecological and bio-conservation significance. Previous analysis of trout diet and fishery data has suggested that they are also of major significance for sustaining the lake’s trout fishery (Davies and Fulton 1987, Davies and Sloane 1987).

There is also a second and intriguing pattern to the biological communities within Great Lake. A number of embayments contain distinctive or unique faunas, and this distribution may be a relict of the pattern of distribution that existed prior to the first inundation. However, this cannot be confirmed, as there is no data available on faunal distribution in the original lakes. Evidence supporting this hypothesis includes:

- the isolation of *Onchotelson spatulatus* to Elizabeth Bay (Originally Lake Elizabeth) where it occurs in large numbers, as observed by Fulton (1983) in 1975, and in 2001 (this study);
- the apparent isolation of *Mesocanthotelson tasmaniae* to Becketts Bay (this study);
- the restriction of *Uramphisopus pearsoni* to deep water in the northern part of the Great Lake (Fulton 1983, B. Wilson 2001 pers. comm.); and
- greater similarity of faunal composition within bays than within habitat type (this study).

Algal Beds and Lake Levels

The following analysis and interpretation of lake level and charophyte bed dynamics in Great Lake was developed by Dr Davies (Freshwater Systems) for Hydro Tasmania.

The altitudinal distribution of the Great Lake charophyte beds is responsive to changes in lake level, with beds migrating upslope during periods of rising water level. Beds are exposed during periods of rapidly falling level, but also show an ability to migrate downslope during those periods. From the few data that are available from this study and previous work in 1987, it has been estimated that the bed margins can migrate up and downslope at a maximum rate of about 2 m in altitude per year. Further surveys are required to refine this estimate.

From the limited number of surveys that have been undertaken, it may be considered unlikely that charophytes would become established across the original lake bottom as levels fall below 1020 mASL, due to:

- the rapidity with which levels fall under current operations, limiting the ability of charophytes to established;
- the loss of shelter from W-NW winds on shorelines at lower lake levels (< ca 1020 m); and
- the need for > 2-3 m depth for charophytes to establish on the exposed lake bottom.

While these factors may influence the distribution of the charophyte beds within the lake, the implications of these changes for the aquatic fauna are less obvious.

Taking into account the limitations to charophyte bed distribution listed above, an overall ‘model’ of *Chara* bed dynamics in Great Lake proposed by Dr Davies is as follows:

Rising lake levels

- existing charophyte beds migrate upslope, with:
    - the upper margin migrating at a maximum of ca 2m altitude per year as wave stress reduces and silt is deposited on-shore, staying ca 1 m below the water’s edge; and
    - the lower margins migrating upslope directly in response to decreasing light levels.
- some lateral extension of *Chara* distribution occurs on sheltered, western/north western shores where silt substrate occurs, depending on antecedent weather conditions.

Falling lake levels

- existing charophyte beds migrate downslope, with:
    - the upper margin migrating as wave stress increases and silt is winnowed from the substrate, and/or is exposed due to rapid falling levels i.e. at the same rate as lake levels decline, staying at least around 1 m below the water’s edge;
    - the lower margins migrating downslope at a maximum of 2m altitude per year in response to increasing light levels at depth; and
    - lower *Chara* bed margins limited to an altitude of ca 1016 –1018 m, depending on the depth of water above it;
- some lateral contraction of *Chara* distribution occurs on sheltered, western/north western shores where silt substrate occurs, depending on antecedent weather conditions.

A plot of the change in Great Lake level is shown in Figure 11 for the entire period of record. When the above model of charophyte bed response to level changes is applied to that record, the positions of the upper and lower margin levels are as shown in Figure 12 and Figure 13. Periods when sections of the charophyte beds were exposed by falling levels are shown by red bars. The original lake levels are shown in Figure 13, estimated by Dr Davies for this study, by inspection and measurement of an accurate and detailed landscape of Great Lake by Eugene Von Guerard, painted in 1874, and comparison with the known lake bathymetry.

Transect data for each of the studied charophyte beds was used to derive area of charophyte habitat over a range of lake levels. Values from all embayments were summed to derive total area for the lake, whose relationship with elevation was shown in Figure 14. This relationship is broadly linear and low in slope for much of the lake profile, though area declines steeply at depth. This steeper decline at low elevations is primarily due to the reduction in the number of viable beds at depth rather than a change in lakebed profile. This was therefore initially adopted as the standard form for the relationship between area of charophyte and elevation for all depth sequences between 1955 and 2001.

A sixth order polynomial regression was applied to this relationship in order to estimate the total area of charophyte over a range of elevations, as follows:

Equation 1

$$\text{Area (ha)} = 0.0311{*}\text{Alt}^{6} - 0.7262{*}\text{Alt}^{5} + 5.9336{*}\text{Alt4} - 19.907{*}\text{Alt3} + 29.761{*}\text{Alt2} - 7.6583{*}\text{Alt} - 0.9305$$

$(R^2 = 0.999)$ Alt = elevation above sea level

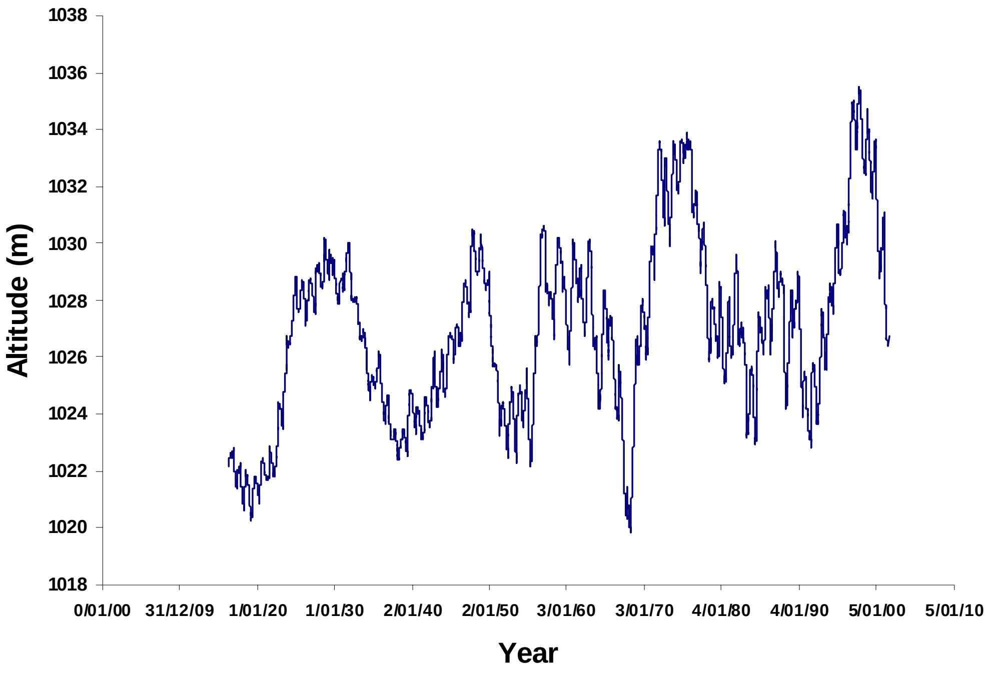

Figure 11: Great Lake levels, historical record to 2001

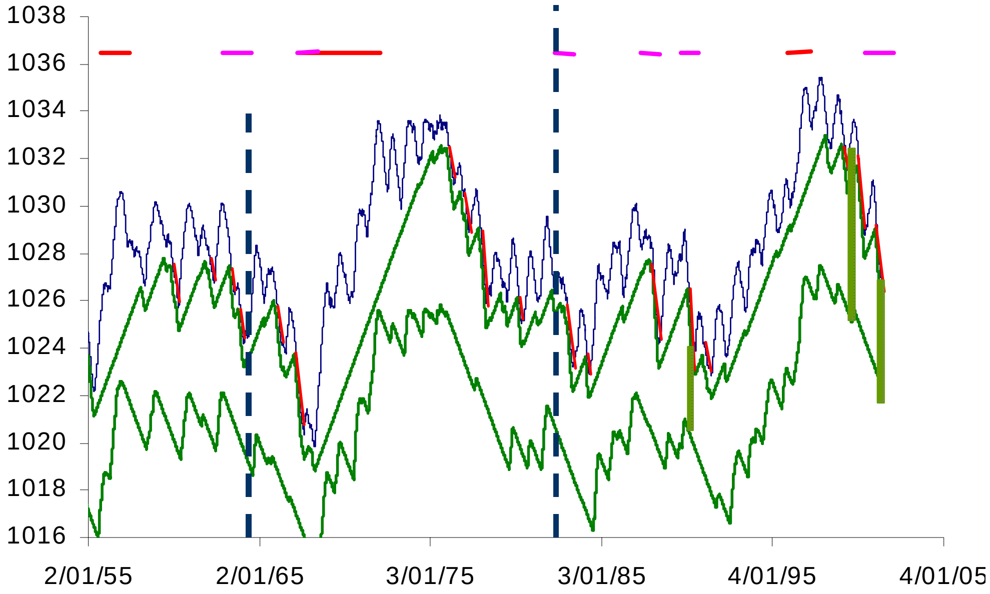

Figure 12: Estimated positions of upper and lower margins of charophyte beds, Great Lake (green lines), lake levels (blue lines) over the period 1955 - 2001. Red sloped lines indicate periods of exposure of upper sections of charophyte beds during rapid drawdown (> 2m /year). Vertical green bars indicate extent of beds measured during surveys. Vertical blue dashed lines indicate time and FSL associated with new dam in 1964 and raised dam level from 1982. Horizontal lines indicate periods of limited charophyte bed area (< 20 percentile values, see text) caused by rapid level declines (purple) and rapid level rises (red).

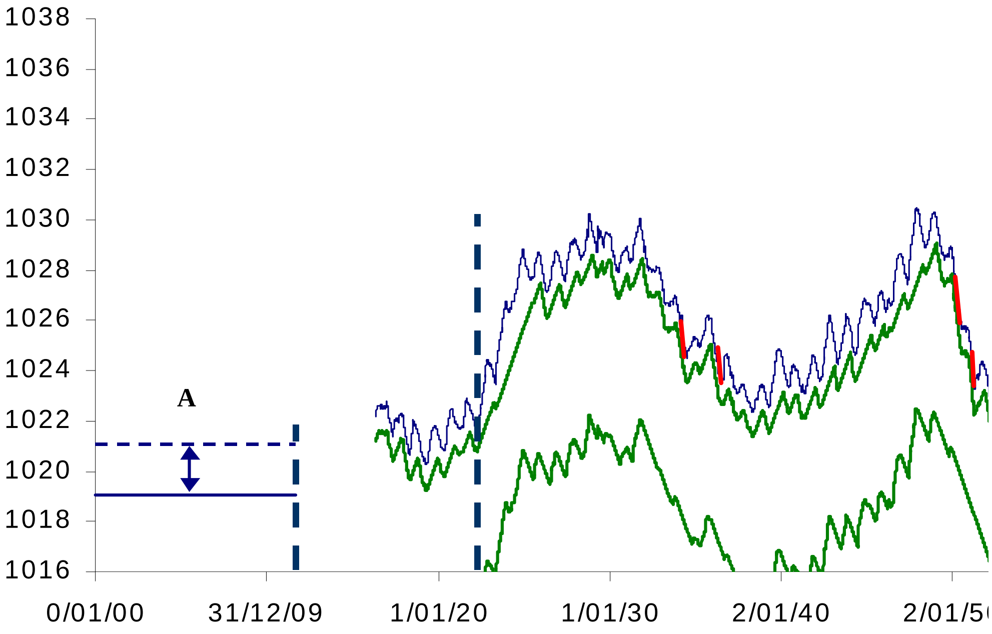

Figure 13: Estimated positions of upper and lower margins of charophyte beds, Great Lake (green lines), lake levels (blue lines) over the period 1900 – 1955. Red sloped lines indicate periods of exposure of upper sections of charophyte beds during rapid drawdown (> 2m /year). Blue horizontal lines at A are original summer (solid) and winter (dashed) lake levels (after Von Guerard, see text). Vertical dashed blue lines indicate timing and FSL's for the 1910 and 1922 dams.

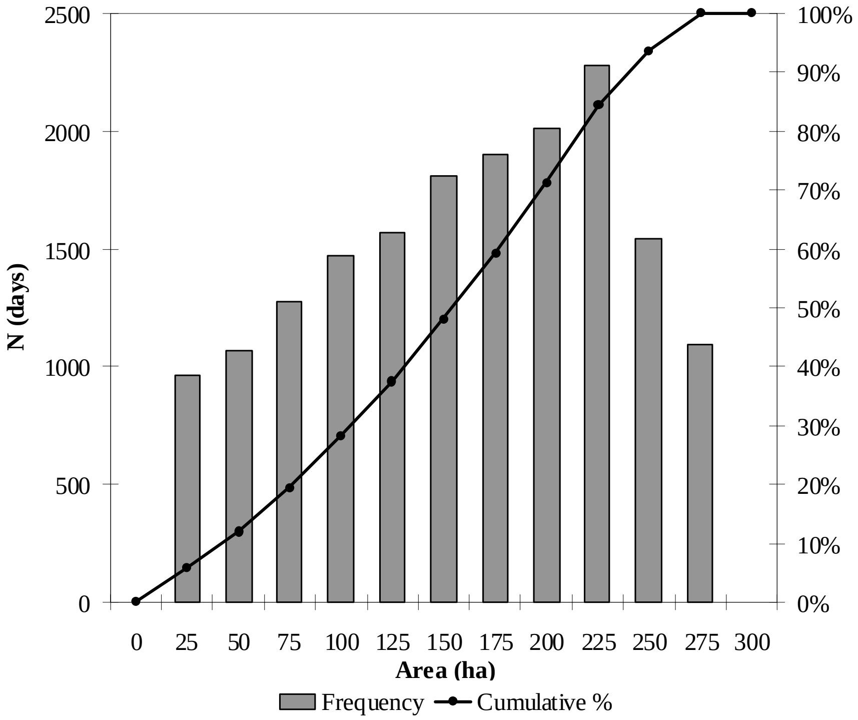

Figure 14: Frequency and cumulative frequency of occurrence of modelled total area of charophyte habitat in Great Lake from 1955 to 2001.

A time series of differences between the elevations of the upper and lower margins of charophytes in the lake was prepared. Equation 1 was used to convert this into a time series of total charophyte area for the period 1955 to 2001. Cumulative frequency distributions and time series for these data are shown in Figure 14 and Figure 15. The overall median area was 154 ha, but the plot shows high variability on short (1 - 3 year) time scales. Excursions below the 20 percentile of the areas, of 75.5 ha, are dispersed throughout the period, with 17 events in total between 1955 and 2001. There were six excursions to very low areas of 50 ha and less. Two long and very intense events resulted from both declining levels and ensuing rising levels associated with dry periods in 1952 - 56 and 1967 - 68.

All of these events are also indicated in Figure 12, superimposed on the lake level time series for 1955 - 2001. The majority of level declines happen within the summer-autumn period. A plot of percentage change in charophyte habitat area per 3-month period was therefore also prepared, covering the same period (see Figure 16).

All of the declines in charophyte area to levels below the 20-percentile value of 75.5 ha appear to have been caused by one of two processes:

- Sharp declines in lake level at rates exceeding the assumed maximum rate of downslope migration of the lower margin of the charophyte beds (i.e. > 2 m net per year) over a period of two years or more.
- Rapid rises in lake level following declines to low levels (ca 1020 –1 022) at rates exceeding the assumed maximum rate of upslope migration of the upper margin of the charophyte beds (i.e. > 2 m net per year).

It is interesting to note that, despite the significant event which occurred in 1967 - 68 (which resulted in very low lake levels followed by a rapid return to high lake levels - i.e. 1032 masl), the algal beds were able to re-establish to cover extensive areas within about 5yrs. From Figures 15 and 16, habitat loss of some degree may have been a frequent event in the past.

It is apparent that critical declines in charophyte habitat have occurred several times since the lake was first dammed. It is possible that locally endemic and rare fauna (and flora) were lost following the initial raising of the lake level in the 1910's to 1920's, with potentially further impacts associated with 'crunches' of cahrophyte habitat after that time. From this, the key question then arises: 'Are the threatened species communities present in the lake today sustainable given these frequent habitat 'crunch' periods?'

Little data exist on which to judge this risk, and it is Hydro Tasmania's intention to investigate the faunal relationships with the algal beds over a range of water level changes.

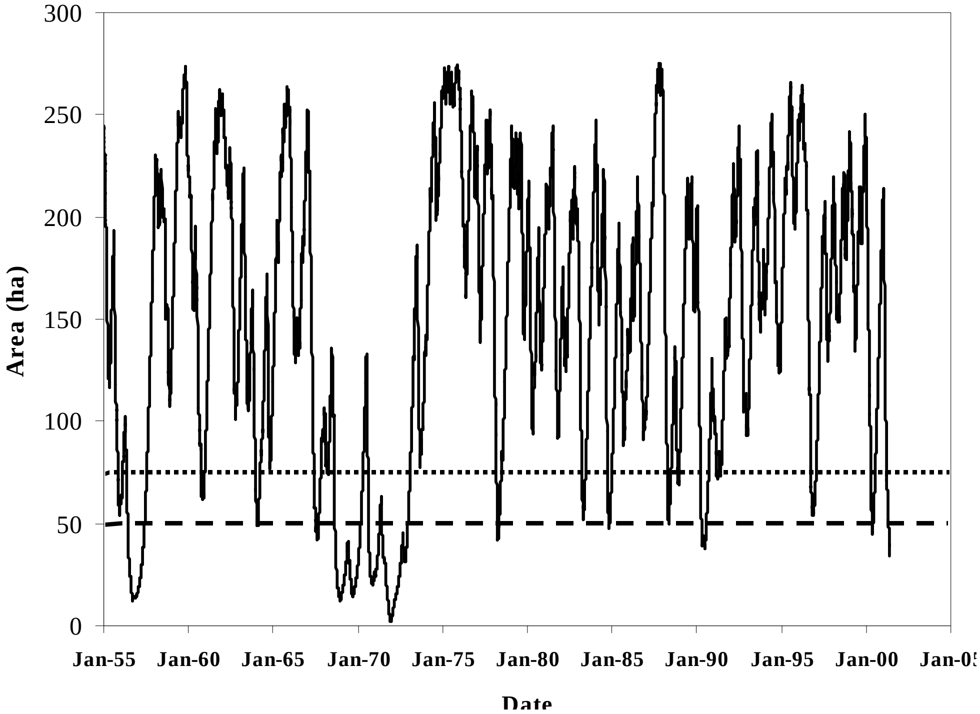

Figure 15: Time series of modelled total area of *Chara* habitat in Great Lake from 1955 to 2001. Horizontal fine dashed line shows lower 20-percentile value. Coarse dashed line shows proposed 50 ha limit.

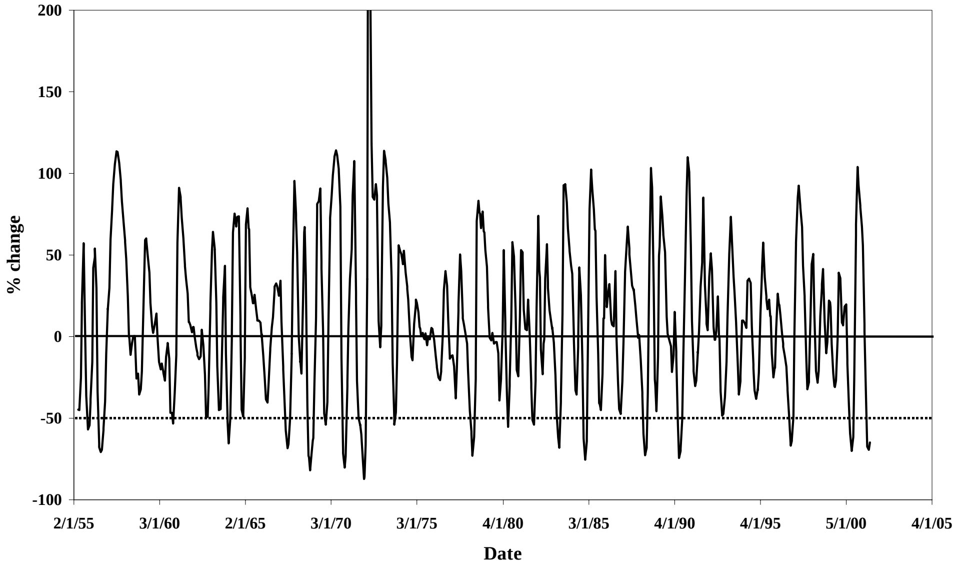

Figure 16: Time series of % 3-monthly change in modelled total area of *Chara* habitat in Great Lake from 1955 to 2001. Horizontal fine dashed line indicates 50% loss in habitat area over 3 months.

4. RECOMMENDATIONS FOR GREAT LAKE

Although the data gathered during this study has provided a significant additional body of information about the charophyte beds and their associated fauna in Great Lake, it is apparent that further work is required before any management measures can be considered or implemented. While the data collected to date has indicated that changes in water level causes changes in the range and distribution of the charophyte beds within the storage, there is still limited data on the rate of migration of charophyte bed margins, with only three sets of surveys of charophyte bed extent conducted to date.

Data from the faunal surveys suggest that *Paranaspides* and fish distributions differ with respect to water depth and the degree of cover provided by the charophyte beds. Almost all fauna (including mobile and benthic taxa) were found to be more abundant in charophyte habitat than in areas characterised by a rocky substrate.

From this a number of activities are required before appropriate options for management of the lake can be identified:

- Additional data on algal bed response to water level changes is required. Medium-term investigation is recommended so that a more detailed understanding can be gained of the vertical and lateral changes in charophyte distribution. These data will be useful in developing a more robust algal bed response model which can be used to assess the ecological consequences of a range of lake level change scenarios.
- Further review of charophyte ecology is required so that a more accurate determination can be made of the maximum rate of propagation of the flora of this group. Factors such as the importance of seasonal triggers to recruitment and the influence water level changes may have on this need to be better understood.
- At present there are only rudimentary data available on the bathymetry of the lake and this hinders the precise identification of potential habitat for colonisation by charophyte beds under different water level scenarios. More detailed and opportunistic bathymetric surveys while the lake is low will allow better delineation of habitat availability under various hydrological conditions.
- While the faunal surveys conducted during this study supports historical conclusions on the importance of the charophyte beds to fish and invertebrate species in the lake, additional data on habitat utilisation and the degree of faunal dependence on this habitat would enable an assessment of the minimum coverage at which the algal beds continue to provide significant habitat for these species. This would help identify critical minimum levels of charophyte habitat area needed to support the rare and threatened species with which they are associated.

It is envisaged that with the additional information and tools that will be developed as a result of the actions outlined above, modelling can be undertaken to identify future potential 'worst case' situations and this will enable the development of appropriate and viable options by which these situations may be managed or avoided.

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