THE MACROBENTHIC FAUNA OF GREAT LAKE AND ARTHURS LAKE, TASMANIA.

by

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HOBART

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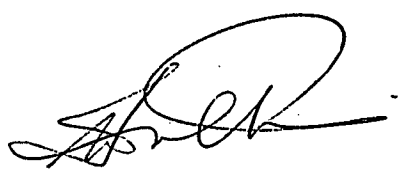
Old multiple-arch dam, Miena Great Lake, 1962

(Photo courtesy P. A. Tyler)

"Benthic collecting can be fun ...."

To the best of my knowledge, this thesis does not contain any material which has been submitted for any other degree or diploma in any university except as stated therein. Further, I have not knowingly included a copy or paraphrase of previously published or written material from any source without due reference being made in the text of this thesis.



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ABSTRACT

The histories of Great Lake and Arthurs Lake are outlined in terms of geology, geomorphology, discovery, previous biological collections and drainage alterations.

Collections of the benthic fauna were made from six sites in each lake every two months for a period of twelve months in Great Lake and fourteen months in Arthurs Lake. A total of 1560 grab samples in 20 sample series were examined. The number of individuals in each species was counted and total wet weights for each sample series were estimated. Physical data collected included sediment particle size distribution and organic content as well as temperature readings.

An accurate and comparatively complete species list for each lake has been compiled and affinities are discussed. Approximately 15 species collected during the survey have been recognised as new to science and taxonomic descriptions have been made, or are pending.

The data were briefly examined for variation within sample series at each site and for seasonal variation within a site. Some data on life histories of certain species are presented.

Detailed analyses of faunal variation between sites, within and between lakes were made. This was done using both qualitative and quantitative (numbers of individuals) data. Cluster analysis, using various sorting strategies, generally grouped sites from the original lake areas of both lakes before grouping sites from different levels of

the same lake. Principal coordinates analysis gave similar results.

Biomass levels are presented and discussed in terms of component species groups. Instantaneous growth rates of some species are briefly examined.

The species diversity and benthic biomass of the two lakes are discussed in relation to other Tasmanian, Australian and overseas lakes. The topics of lake typology and lake classification are examined both in relation to Australian lakes and in general. The question of prediction of lacustrine production levels is also briefly examined.

CHAPTER 1 INTRODUCTION

The benthic fauna of Tasmanian lakes as a unit has received little detailed study. This could also be said of much of the freshwater invertebrate fauna of the state. Timms (1978) has briefly examined the benthic fauna of Lakes St. Clair, Dove, Dobson, Sorell, Crescent, Leake and Tooms in Tasmania. However these studies were the result of small numbers of samples at a single point in time. Weatherley and Nicholls (1955) collected some benthic samples from Lake Dobson but did not identify the species in any detail. They did calculate biomass for this lake. A few other brief studies have been made of the littoral fauna of a few Tasmanian lakes (see Knott & Lake 1974; Leonard & Timms 1974; Knott et al. 1978).

All of these studies suffer, to some degree, from a lack of previous taxonomic work on the Tasmanian freshwater fauna. Species lists contain many unidentified taxa, which makes later comparative work more difficult.

1.1 AIMS

The objective of the project reported in this thesis was to examine the fauna of Great Lake and Arthurs Lake in sufficient detail to gain a reliable knowledge of that fauna both qualitatively and quantitatively, and to examine the variation in both of these characters throughout

the lakes, and over a complete cycle of the seasons. Considerable attention was given to the taxonomy of the various groups, with the invaluable co-operation of many specialists (see Acknowledgements), so that more meaningful species lists could be compiled. The study was not intended as an examination of methods, nor of species distribution on a small scale. Therefore, once the sampling procedure was established by analysis of the variation present within a series of samples, little further attention was to be given to such variation.

As both the lakes to be studied are subject to large and often unseasonal fluctuations in water level (see Figs. 1.1 - 1.2) due to their useage for hydro-electric purposes the littoral fauna is in a state of flux to the extent that it is virtually non-existent in some years. Hence the benthic fauna only was studied. The effects of fluctuating water levels on the littoral fauna of lakes has been the subject of several studies in various parts of the world (Hynes 1961; Grimas 1962, 1965; Paterson & Fernando 1969; Hunt & Jones 1972a).

The Great Lake in particular has undergone one major change in water level resulting in two areas which can be categorised as level 1 (original lake bottom) and level 2 (post flooding bottom). These areas were to be examined in order to investigate any apparent effects of the water level changes on the benthic fauna. Maps showing original levels and contours of both lakes are given in Figs. 1.3 - 1.4.

1.2 HISTORY

According to Maude (1965) Great Lake was discovered

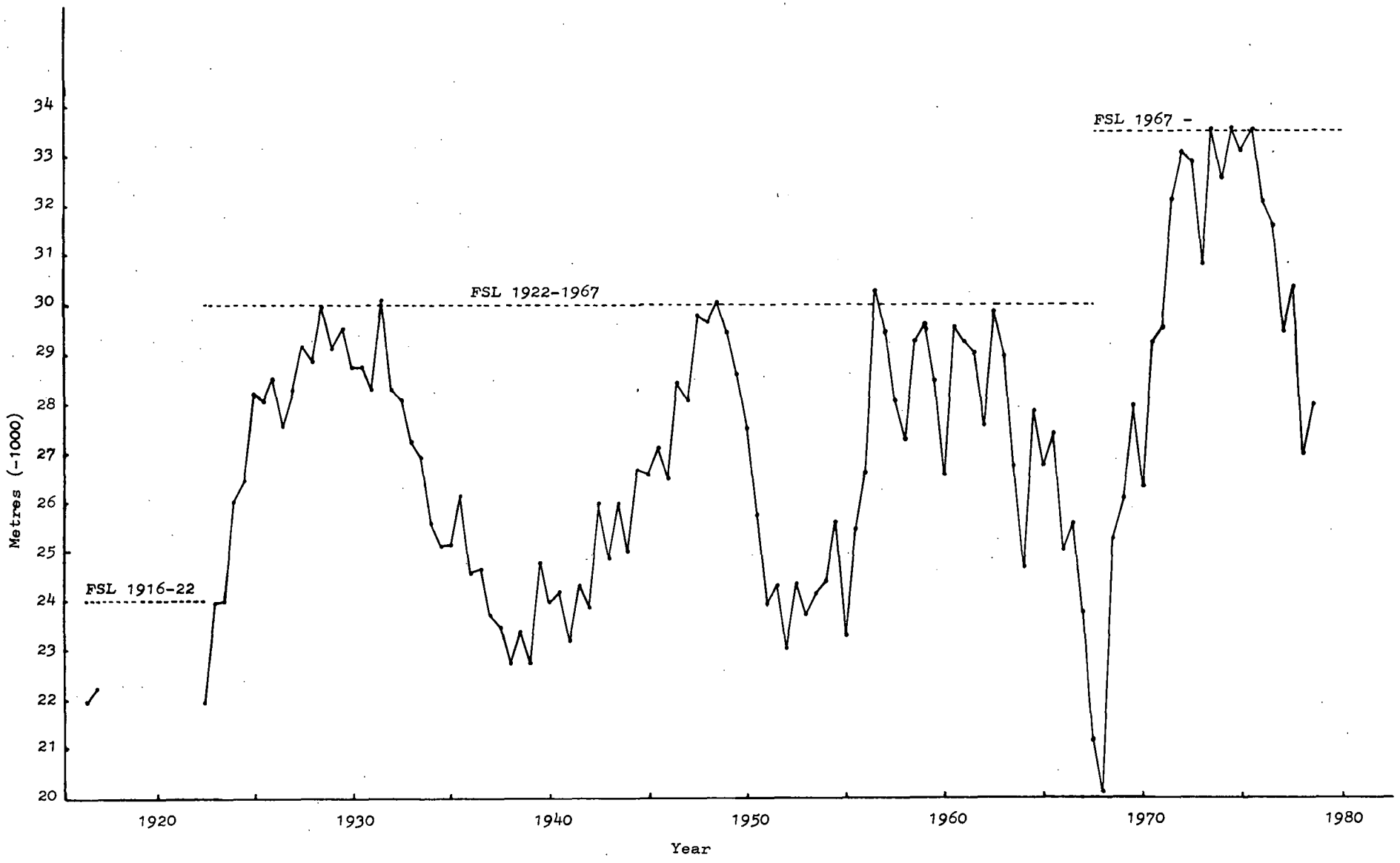


Fig. 1.1: Water level fluctuations, Great Lake, 1916-1979. (Values for February and September of each year from Hydro Electric Commission data).

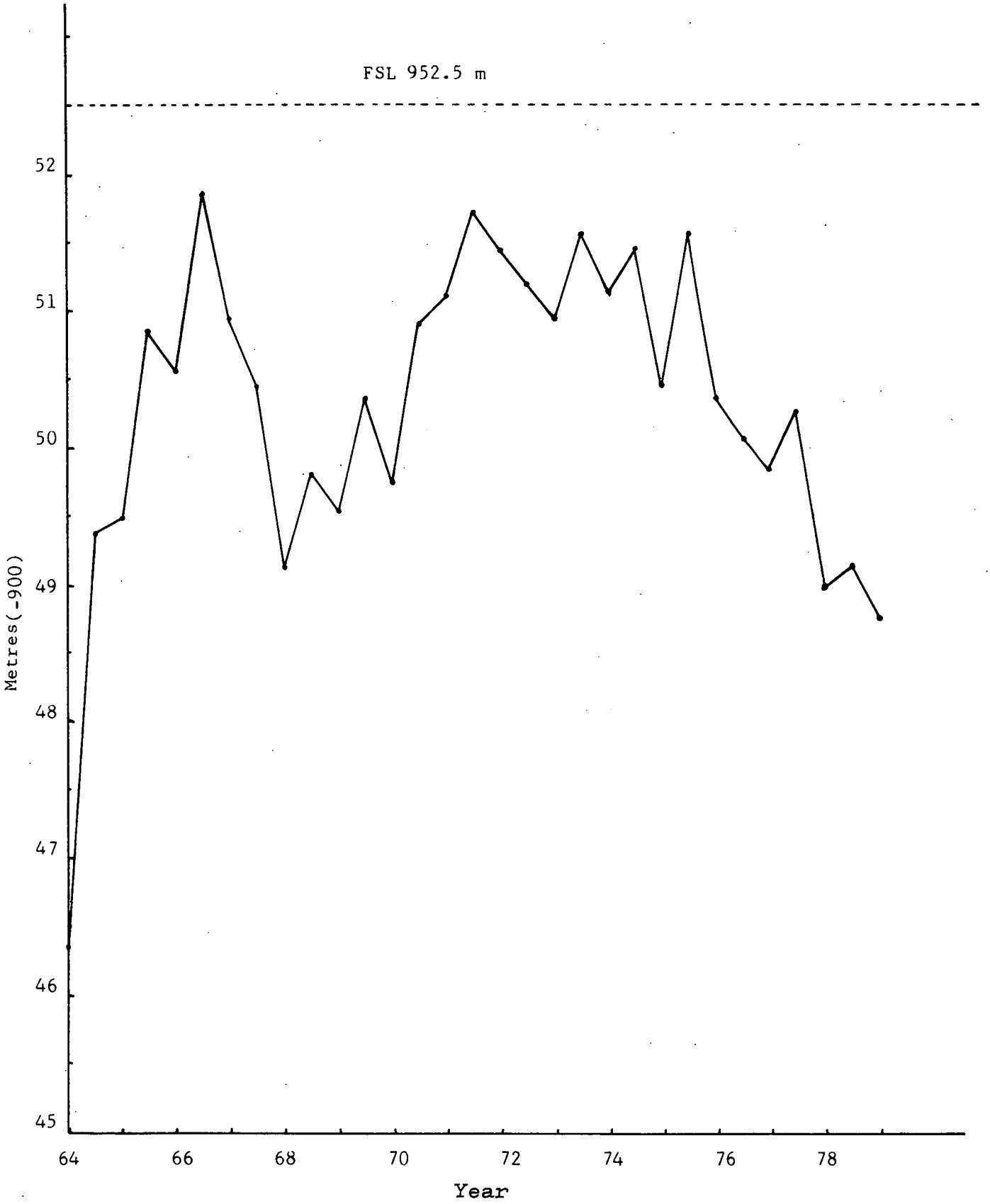


Fig. 1.2: Water level fluctuations, Arthurs Lake, 1964-1979. (Values for February and September of each year from HEC data).

Fig. 1.3: Map of Great Lake showing present and past water levels and approximate depth contours.

(Map based on detailed contour map supplied by Hydro Electric Commission, Tasmania).

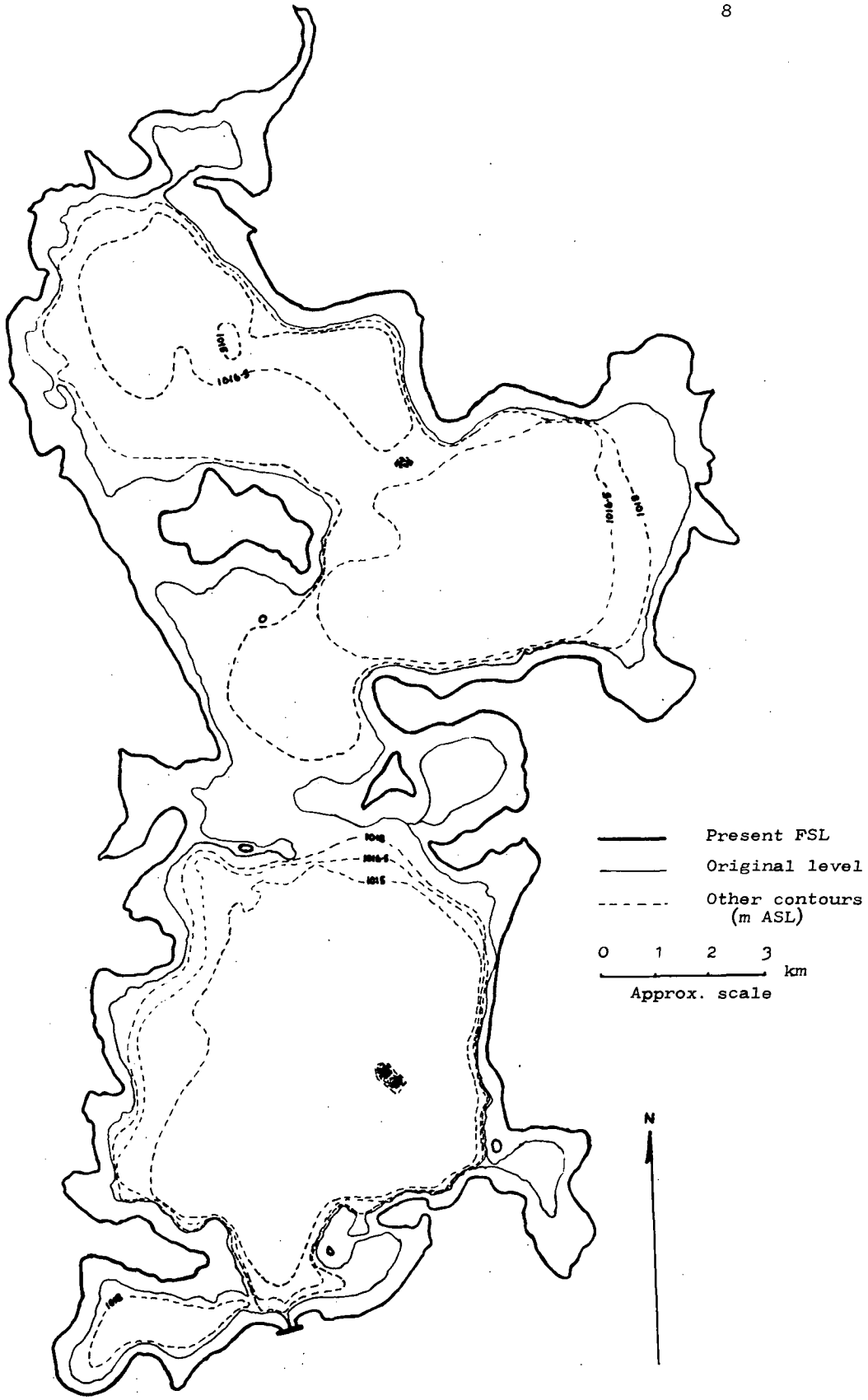
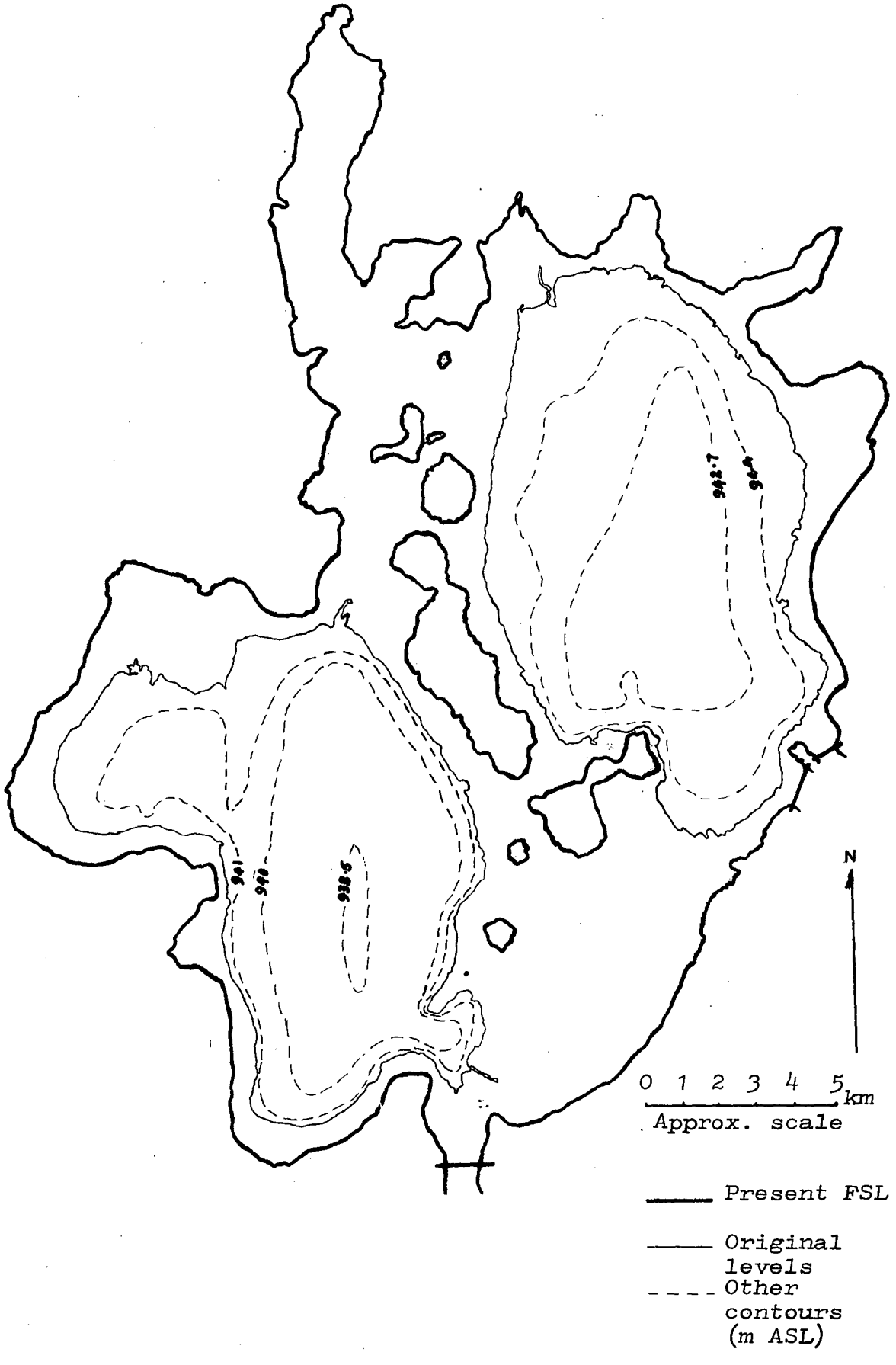

Present FSL
Original level
Other contours (m ASL)
0 1 2 3 km
Approx. scale
N

Fig. 1.4: Map of Arthurs Lake showing present and past water levels and approximate depth contours.

(Map based on detailed contour map supplied by Hydro Electric Commission, Tasmania).


N
0 1 2 3 4 5 km
Approx. scale
Present FSL
Original levels
Other contours (m ASL)

in 1815 by a kangaroo hunter named Toombs. A little later in 1817 a party led by a naval officer, John Beaumont, and a settler from the Jordon River, Robert Jones, travelled from the Jordon River to Great Lake and from there proceeded further west across the plateau (Shepherd 1974). The valleys of the Clyde, Shannon and Ouse Rivers were explored for most of their length by this time (Maude 1965) and graziers were beginning to run stock in the Bothwell district. By 1830 there were large numbers of cattle, many of them wild, grazing in the plateau area (Plomley 1966).

Stock grazing was the principal use of the central plateau area until about 1900 when trout were introduced into the area. This use continued but the area also became a popular recreational fishery. The waters of Great Lake, and to a lesser extent Arthurs Lake (then consisting of two separate lakes), received considerable attention after this time and successful stockings were made with brown trout, Salmo trutta L. and later with rainbow trout, S. gairdneri Richardson. Atlantic salmon, Salmo salar L., were also released in both lakes but they did not establish naturally reproducing populations. Further details of the acclimatisation of trout and salmon in these lakes are given by Gilmour (1973) along with interesting notes on the early days of fishing in these waters.

1.3 DRAINAGE ALTERATIONS

The first permanent dam on Great Lake was built across the Shannon River by the Hydro Electric Power and Metallurgical Company - the forerunner of the present

Hydro-Electric Commission of Tasmania. This was a gravity dam built for the purpose of maintaining a constant flow in the Shannon River and was completed in 1916. It increased the depth of Great Lake by about 3m to a supply level of 1022m. Prior to this anglers had placed a loose rock barrier across the Shannon River in order to keep the water level up in Swan Bay (Legge 1904). The Miena dam, completed in 1922, was built downstream from this. It was a multiple arch concrete structure built to supply the Waddamana power station. It increased the level of the lake to 1030m.

A third dam was completed in 1967 further downstream from the multiple arch dam. It was about 550m long and of rockfill construction. It increased the depth of Great Lake by a further 3.4m to a full supply level (FSL) of 1033.5m. A further increase of about 6m has been proposed for sometime in the early 1980's. Water levels already fluctuate considerably and have only been up to the FSL in 3 out of the 15 years since the completion of the last dam (see Fig. 1.1).

A rockfill dam was completed on the Lake River draining the two lakes originally known as Arthur Lakes in 1961. The lower, or west lake began to fill above its normal level of 942.5m in winter of 1963 and the two lakes began to rise as one (from 946m) in early 1964. The new FSL of Arthurs Lake became 952.5m, a rise of 10m over the original lower lakes' FSL. The water level of Arthurs Lake is also subject to considerable fluctuation (see Fig. 1.2).

There have been several other changes to the catchment of these lakes since the first dam construction. Liawenee Canal was constructed in 1921 to divert waters from the Ouse River drainage into Great Lake. This was originally a 12.6 cumec capacity canal but it was enlarged in 1940 to carry 18.2 cumecs. The canal was concreted over a period of years with the majority of the work being done in 1950-51. The mean flow rate of the canal is about 9.7 cumecs.

Small diversions were constructed on the upper Liffey River and on Westons Rivulet - Brumbys Creek. These commenced operation in 1963-64 and 1966 respectively. The two diversions convey on average about 0.7 cumecs to Great Lake throughout the year.

Pumping of water from Arthurs Lake into Tods Corner, Great Lake, commenced in May 1966. Water is pumped uphill from Arthurs Lake, then via approximately 6 km of fluming to Great Lake. The fall into Great Lake is used to power a small turbine which is in turn used to operate the pump at Arthurs Lake. The average rate of flow to Great Lake from this source is about 3.7 cumecs.

Since 1968 Shannon Lagoon has also supplied water to Great Lake via a pump at Miena. Water is pumped from the lagoon in winter when there is an excess. It supplies an approximate average rate of 0.3 cumecs.

Originally the major outlet from Great Lake was down the Shannon River. However, since the commencement of operation of the Poatina Power Station in 1964 and the closure of Shannon and Waddamana stations this outlet has only been used to supply riparian rights in summer. Poatina is now the major user of Great Lake (and Arthurs

Lake) water using a mean flow of about 18.7 cumecs. This water discharges via Brumbys Creek into the South Esk system.

Some water may be discharged from Arthurs Lake via the Lake River, again for riparian useage, but the majority is diverted into Great Lake via the pump on the western shore of Arthurs Lake.

1.4 GEOLOGY

Banks (1973a) considered the Plateau as "consisting of two main, nearly horizontal, layers of rock resting on a basement of older, steeply tilted rocks". The surface layer of rocks around Great Lake and Arthurs Lake is now predominantly dolerite having been originally injected into a layer of sedimentary rocks the uppermost layer of which has since eroded away. More detailed geological maps of the area around Great Lake and Arthurs Lake are given by Voisey (1949a, b).

The dolerite layer is generally between 60 and 300 m thick (Sutherland 1973) and appears to have intruded about 165 million years ago (McDougall 1961) about the time of the beginning of the Gondwanaland break up. There is a much thicker area of dolerite below Great Lake where a circular plug-like sheet between 1160 and 1280 m deep occurs (Jones et al. 1966). This is thought to have been the feeder from which the major Central Plateau dolerite intrusion arose. McDougall (1958) considered that the temperature of the dolerite would have

been close to 1100°C on intrusion. A very long cooling period would then have followed.

The overlying sedimentary rocks were gradually removed by erosion leaving a surface layer predominantly of dolerite. At this stage the area was probably an extensive plain (Banks 1973a).

As Antarctica began to move away from the Australian continent about 65 million years ago the plateau began to rise generally along northerly and north-westerly trending lines (Griffiths 1971). This left the plateau as a major horst with a relatively unbroken northern boundary but a series of broken levels to the south. Some time later, probably about 26 million years ago, tilting of the whole area occurred towards the south-east and fluvial deposits formed in ancestors to the Nile, Ouse and Shannon Rivers draining the plateau to the south (Banks 1973a).

The tilting was followed by a further period of volcanism 23.6 to 21.8 million years ago (Sutherland 1973). This was in the form of basaltic larva eruptions emanating from various points largely concentrated under and around the present site of Great Lake. The larva,on flowing into or down the river valleys caused some changes to the drainage structure of the plateau (Banks 1973a).

1.5 GEOMORPHOLOGY

Great Lake and Arthurs Lake both lie on the Lower Plateau Surface, the middle of the three main erosion surfaces described by Davies (1959) for the Central Plateau area. This surface lies between 900 and 1050 m. Davies

(1959) suggested that the three surfaces represent successive erosion levels separated by phases of uplift.

Natural drainage of Great Lake is to the south via the Shannon River. Arthurs Lake drains towards the southeast initially, but then north via the Lake River from Woods Lake.

Sometime within the last 25,000 years most of the Upper Plateau Surface was covered by ice (Banks 1973b). Glacial remnants are evident in the region of Lake Augusta but the ice sheet did not reach as far east as Great Lake. Banks (1973b) records that there is evidence for an earlier cold period in the central plateau area (see Derbyshire 1968; Paterson 1965) but the extent of its effect is not known. Periglacial activity was much more extensive and both Great Lake and Arthurs Lake were within the area of its influence (Nicolls & Dimmock 1965; Davies 1967). The results of this activity are apparent in the extensive block streams to the north and east of Great Lake and Arthurs Lake.

The origin of the larger central plateau lakes has given rise to some conjecture. Early opinion was that the Great Lake at least was formed by glacial overdeepening during the Pleistocene (Lewis 1933, 1945; Voisey 1949a).

More recent opinion is that the lake is of tectonic origin and probably has not been glaciated (Jennings & Banks 1958; Davies 1959, 1974).

Davies (1965) considered that the origins of the shallow lakes of the eastern part of the plateau were best explained "by invoking some slight tilting or subsidence to the north". The tilting would need to be a relatively

recent occurrence otherwise the shallow lakes would have filled with sediment (Banks 1973b). If this were the case and the tilting was gradual rather than sudden then emergent shorelines should be evident at the southern end of the lakes. Arthurs Lake and Woods Lake at least show some evidence of this.

Another theory suggested by Banks (1973b) is that some tilting of the plateau may have occurred as an iso-static response to the melting of the central plateau ice-sheets. This would have resulted in emergent shorelines on the western side of the lakes affected. Extensive areas probably attributable to this cause may be found on the western sides of Lake Sorell and Woods Lake as well as in Arthurs Lake (Banks 1973b). Alteration of the lakes as a glacio-isostatic response would mean that the lakes were already present before the ice melted.

Derbyshire and Peterson (1965) suggested that the lakes may have resulted from differential erosion during an earlier glaciation. However the occurrence of an earlier glaciation covering that area has yet to be established.

It appears that Great Lake is quite old and predates the Pleistocene glaciation, although not necessarily in its present form. The lakes to the east may be of more recent origin. Since glaciation there has been a dry period which allowed the formation of sand dunes to the east of Lakes Sorell and Crescent and Lagoon of Islands (Banks 1973b), but no major evidence of this is present at Great Lake or Arthurs Lake.

Seismic records since about 1960 show epicentres on or near the Plateau (Banks 1973b). Hence the area is still seismically active but evidence of deformation has not been seen on the ground.

1.6 BIOLOGICAL HISTORY

The Great Lake area was the centre of interest for many early collectors. Its vast area of cool shallow water contained many species formerly unknown to science. The crustacean fauna in particular was found to be rich in species variety and abundance (Smith 1908). This fauna was studied to varying levels by numerous later authors (e.g. Smith 1909a, b, c; Shepherd 1917; Manton 1929, 1930; Nicholls 1929, 1943, 1944, 1947; Williams 1965, 1974; Lake & Knott 1973). Many of these works concentrate on the unique syncarid Paranaspides lacustris, particularly those of Smith (1908, 1909b) and Williams (1965).

The abundance of fauna, particularly Crustacea, in the littoral zone of Great Lake was remarked upon by Smith (1908, 1909a), but by 1933 the shore fauna of the lake had been drastically reduced as a result of wide fluctuations in the water level (Tillyard 1933). Tillyard considered that P. lacustris was in danger of extinction and that the may-fly, caddis-fly, stone-fly and dragon-fly populations were low in diversity and generally few in number. Tillyard found two species of phreatoicids to be common both marginally and in deeper water. Only two years later, however, Cramp (1935) reports that P. lacustris was apparently quite easily collected in Great Lake.

The invertebrate fauna of Great Lake received further attention during the "fish food investigations" of J. W. Evans from 1936 to 1941. The results of these investigations were published in the reports of the Salmon and Freshwater Fisheries Commissioners. In one of these reports (Evans 1939a) brief details of the contents of dredge samples from Great Lake are given. P. lacustris was found to be common at all sites along with small galaxias, phreatoicids and caddis larvae. The large freshwater planorbid Ancylastrum cumingianus, which is not a true limpet as originally thought (Hubendick 1964), the snail Ameria sp., small bivalves and amphipods were also recorded from some sites. No mention was made of any chironomid larvae in the collections and they are only occassionally listed in the trout gut details from Great Lake (Evans 1937, 1939a, b). In a summary of his findings from trout gut analyses, Evans (1942) concluded that the benthic fauna appeared to be in no immediate danger. The major benthic invertebrates eaten by trout were phreatoicids, caddis larvae and 'limpets'. Evans also found that P. lacustris was far more abundant in the lake than trout gut contents suggested.

A further study of gut contents of Great Lake trout was carried out during the years 1961-1963 (Wilson 1966). Variations were shown from the findings of Evans (1942). There was a considerable increase in the percentage occurrence of plankton from 5% (Evans 1942) to 29% (Wilson 1966), P. lacustris 2-20, trichopteran larvae 48-69 and dipteran larvae 1-33. However of these the dipteran larvae and P. lacustris did not constitute a significant proportion of the total food volume but were merely more

widespread in their occurrence The plankton content could merely be an artifact of the collection time or a particular seasonal abundance. Wilson (1966) made the observation that P. lacustris "now appears to be much more abundant". This conclusion is difficult to follow as such a large animal as P. lacustris, if it was abundant in the 20% of stomachs in which it occurred, should contribute more than 1% by volume to the stomach contents.

No thorough investigation of the benthic fauna of Great Lake or Arthurs Lake has been undertaken until the present survey and most of the early interest centred on P. lacustris. However many other workers made collections of specific groups from Great Lake in particular. For example many caddis fly types were collected from the Miena area (see Mosely 1933, 1936; Mosely & Kimmins 1953; Neboiss 1977a) and large collections of phreatoicids were made by Nicholls (see Nicholls 1943, 1944).

The Great Lake area has proved to be of particular scientific interest in the past with many new species being first recorded there. Some species, particularly crustaceans are confined to the area. The region is also of particular value as a sport fishery and it was therefore considered necessary to examine the present day status of the benthic fauna of the larger lakes on the plateau. The surveys were to serve as a basis for future management of the lakes as well as providing qualitative and quantitative estimates of the present fauna.

CHAPTER 2 METHODS

In his paper on the analysis of quantitative benthic methods Kajak (1963) stated that the "number of samples should depend on the abundance of organisms, on the spatial differentiation and the amount of time available". In first starting on benthic survey work one could also add "the sampling device available" to this statement.

As there was no prior knowledge of the abundance of organisms or their spatial differentiation, preliminary reconnaisance was necessary. This was done with the sampling devices available at the time so that a program of study could be formulated.

2.1 SAMPLING DEVICE

The choice of the sampling method was largely governed by the availability of equipment. Many types of samplers, of varied design and efficiency, have been invented and most of these are covered in the reviews by Welch (1948), Zadin (1960), Southwood (1966), Holme (1964), Holme & McIntyre (1971), and Edmondson and Winberg (1971). The only two readily available for use were the Petersen grab and the Ekman (or Birge-Ekman) grab, both of which were in the form described by Welch (1948). The first of these relies on its own weight to close its jaws whilst the Ekman grab has a spring loaded closing mechanism.

In preliminary sampling in Great Lake both devices

retained similar sediment samples when used in soft substrates but the Petersen grab was unable to penetrate the substrate encountered at some of the shallower sites to the same extent as the Ekman grab. At these sites sticks often prevented the Petersen grab from closing but the spring-loaded jaws of the Ekman grab cut through sticks in most cases. Hence the Ekman grab was selected for use in the survey with the only modification being to place a compression spring across the existing jaw-springs to increase the closing pressure of the jaws.

Many authors have compared the efficiency of various types of sampling devices (see Brinkhurst 1974). The Ekman grab has been found to give comparable results to the other mechanical devices under normal lacustrine conditions.

2.2 SAMPLING PROGRAM

Sampling programs have received considerable coverage in the literature particularly in relation to the number of samples to be taken (see Lundbeck 1926; Berg 1938; Deevey 1941; Welch 1948; Lenz 1955; Kajak 1963; Elliott 1971). The statistical principles associated with sampling have been covered by several authors and benthic invertebrates have received particular attention from Elliott (1971).

In the absence of previous detailed studies on the benthos of Great Lake or Arthurs Lake it was necessary to determine the number of samples that had to be taken before a stable mean number of organisms per sample was obtained. Preliminary sampling using the Ekman grab was

carried out at one site in Brandum Bay, Great Lake on 14 September 1973. This site was later used as site SGL2 in the sampling program. The total number of organisms present in each sample was determined and a cumulative mean with each additional sample was calculated and expressed graphically (Fig. 2.1). Similar graphs were plotted for chironomid and trichopteran species (Fig. 2.1).

From each of these graphs it can be seen that the mean number of organisms in each sample became relatively stable after about 14 samples had been taken. After this stage there was a fluctuation of less than 5% of the mean for all organisms from 20 samples and less than 8% of the mean when individual species were considered. Hence a series consisting of at least 14 samples was desirable to give an accurate picture of the fauna.

Elliott (1971) gives the formula for calculating the number of sampling units in a random sample to an accurracy of 20% standard error of the mean as

$$n = \frac{25\ s^2}{\bar{x}^2}$$

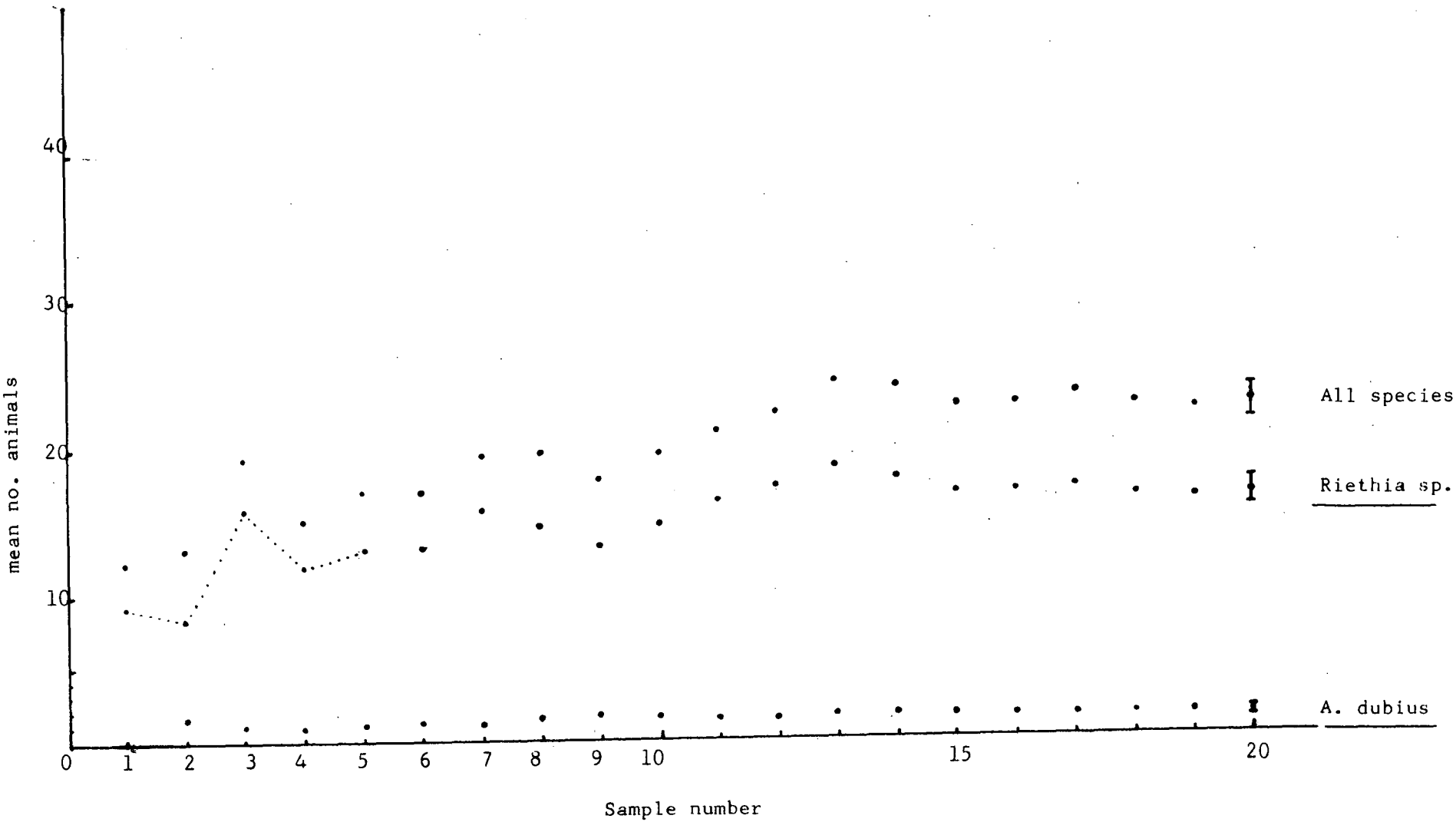
where s^2 = variance

$\bar{x}$ = mean

Elliott considered that this was a reasonable sampling error in most bottom samples.

Using the same data used for Fig. 2.1 in Elliott's formula the number of sampling units required is 8 when all organisms are considered. If the chironomid and trichopteran data are considered separately from the other organisms the value of n becomes 11 and 32 respectively.

Fig 2.1: Cumulative mean number of animals with each additional sample from DGL2 preliminary sampling 14 September 1973 (shows 5% limits of mean).



From these results a sample series consisting of 20 sampling units was selected. Other proposed sample sites were examined and the required number of sample units for these sites determined by similar means. The results were similar to those for Brandum Bay, therefore 20 sampling units were to be taken at this and the other stations selected.

Brief preliminary collections were later (14 January 1977) made at several sites in Arthurs Lake. Numbers of organisms encountered in this lake were of the same order as those of Great Lake hence, for uniformity, the number of samples in a series was maintained at 20 for the 1977-78 Arthurs Lake sampling program as well.

Later analysis of within sample variation (i.e. plots of number of species against number of samples) also supports this sample number (see Section 4.2.1.1).

2.2.1 Collection and Sorting of Samples

Each sample series was collected from a boat at anchor over the pre-determined site. The Ekman grab does not function satisfactorily unless its jaws are released with the grab in a vertical position. Movement of the grab sometimes occurred as release by messenger is obviously not instantaneous. Therefore some discretion was used in deciding when a satisfactory sample had been taken.

Once taken, each sample was placed in a separate container for transport and storage until sorting. The samples were kept at 10°C until they could be sorted.

Manual methods of sorting were extremely time consuming and greatly restricted the number of samples that could be handled. Various alternative sorting aids were therefore investigated. These included flotation techniques and the use of dyes such as rose bengal (see Lackey & May 1971).

The method eventually chosen involved the use of an elutriation apparatus as described by Lauff et al. (1961) (with minor modifications). This device is illustrated in Fig. 2.2. The efficient use of the device requires that the animals to be sorted be generally larger than the individual sediment particles collected with them. The raw sample is placed in a cylindrical column along with a quantity of water. Compressed air is then bubbled up from underneath, thus suspending the sediment and animals. The suspended mixture is then drained through a fine meshed sieve so that the fine materials pass through and the animals are retained.

The mesh size of the sieve was chosen by trial and error with an aperture size of 700μm being selected for use throughout the program. On close examination of the material which passed through this sieve there was not found to be a significant number of any particular organism with the possible exception of nematodes. Because of the size of these animals they would have been extremely difficult to separate from the additional extraneous material which would also have been retained had a smaller meshed sieve been used.

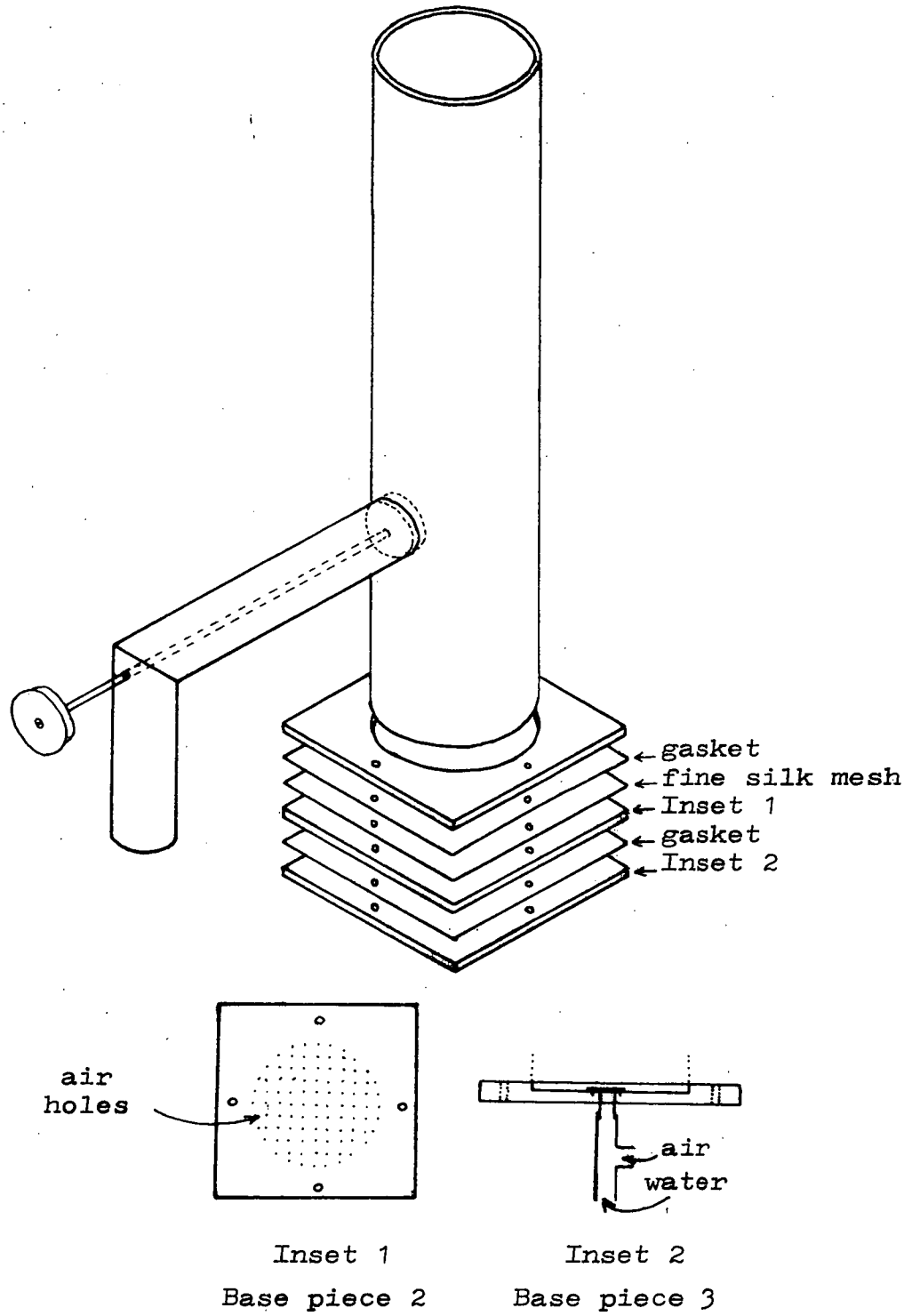
The material retained by the sieve was washed into a white tray and sorted macroscopically into major taxonomic

Fig. 2.2: Diagram of elutriation apparatus for sorting benthic fauna from fine substrates (after Lauff et al. 1961).

The unsorted sample is placed in the cylindrical column, water is added and compressed air is bubbled through it. The plunger in the side arm is then pushed in allowing the sample to pass out and through a fine sieve. More water can be added and the process repeated on the remainder of the sample. The stand supporting the apparatus (see Lauff et al. 1961) pivots to allow the remainder of the material below the outlet to be poured out the top of the tube.

The apparatus was constructed in perspex. Base piece 1 provides attachment to the column whilst the holes in base piece 2 provide for spreading of the air. Base piece 3 has the water and air inlet attachments and a cut away section for spreading of the compressed air. Rubber gaskets are inserted between each adjoining base piece to provide a water tight seal when bolted together. A piece of fine silk mesh is placed between base pieces 1 and 2 to prevent animals from moving out of the bottom of the column.

Further details of dimensions and construction are given by Lauff et al. 1961.


gasket
fine silk mesh
Inset 1
gasket
Inset 2
air
holes
air
water
Inset 1
Base piece 2
Inset 2
Base piece 3

groupings. Each group was preserved at this stage, the usual preservative being 70% ethanol with about 2% glycerine. Some groups were given special preservation, and some stages of certain species were retained live for further taxonomic study.

Final consideration of the limitations imposed by boat space, transport space and storage space as well as the mechanics of sorting indicated that about six series of twenty samples could be collected and processed within a period that could reasonably be regarded as one point in time for comparative purposes. The choice of sample sites was therefore governed by these limitations.

2.2.2 Sample Sites

There has been some discussion in the literature as to the choice of sites for a sampling program. Brinkhurst (1974) considered that the transect line should be abandoned for most purposes as depth is not always the dominant variable. He considered that random patterns of samples should be taken or else random samples within an identifiable zone.

Sampling in a random pattern would have required more 20 sample series than could have been handled. Therefore, rather than sacrifice quantitative accuracy six sites were selected in each lake based on their location, depth and sediment type. Conditions were rarely calm at either lake and the movement of the boat at anchor during sampling tended to give a randomising effect to the samples within each site, i.e. the choice was for random samples within an identifiable zone.

As outlined in Chapter 1, the level of Great Lake was raised by about 10 metres in 1922, thus inundating a large additional area of land. Thus there were two distinct levels in the lake, the original level (designated level 1) and the post 1922 level (designated level 2). A third level was infrequently inundated during the study periods and was therefore not sampled.

The Great Lake sample sites were chosen in three pairs in separate parts of the lake with one site in each pair being in level 1 and the other in level 2 (Fig. 2.3). Thus there is a depth difference in the sample site as well as a difference in age of sites. The three pairs of sites are also representative of distinct basins at the original lake levels (see Fig. 1.1).

In Arthurs Lake the newly flooded areas resulting from artificial water level changes are not as well defined as those of Great Lake hence the sample sites were chosen primarily because of their substrate type and position in the lake relative to each other (Fig. 2.4). Two of these sites are in the newly flooded area whilst the other four sites are in the original lake areas. Two of the latter four sites are in each of the two original lake basins (see Fig. 1.2).

To monitor seasonal variation, 20 samples were collected from each of the six sites at two monthly intervals throughout 1975 in Great Lake. This resulted in a total of 120 samples being taken from each site. Since this procedure had been established in Great Lake a similar program was followed in Arthurs Lake in 1977-78 except that a further 20 samples were taken from each of

Fig. 2.3: Sample sites in Great Lake. SGL1, SGL2 etc. refer to sites for routine sampling as given in Table 2.1. Numbers 1, 2 etc. refer to additional sites sampled in Great Lake. Data from these sites is included in Appendix 2, Part 2.

(Map based on contour map A11603 supplied by Hydro Electric Commission, Tasmania).

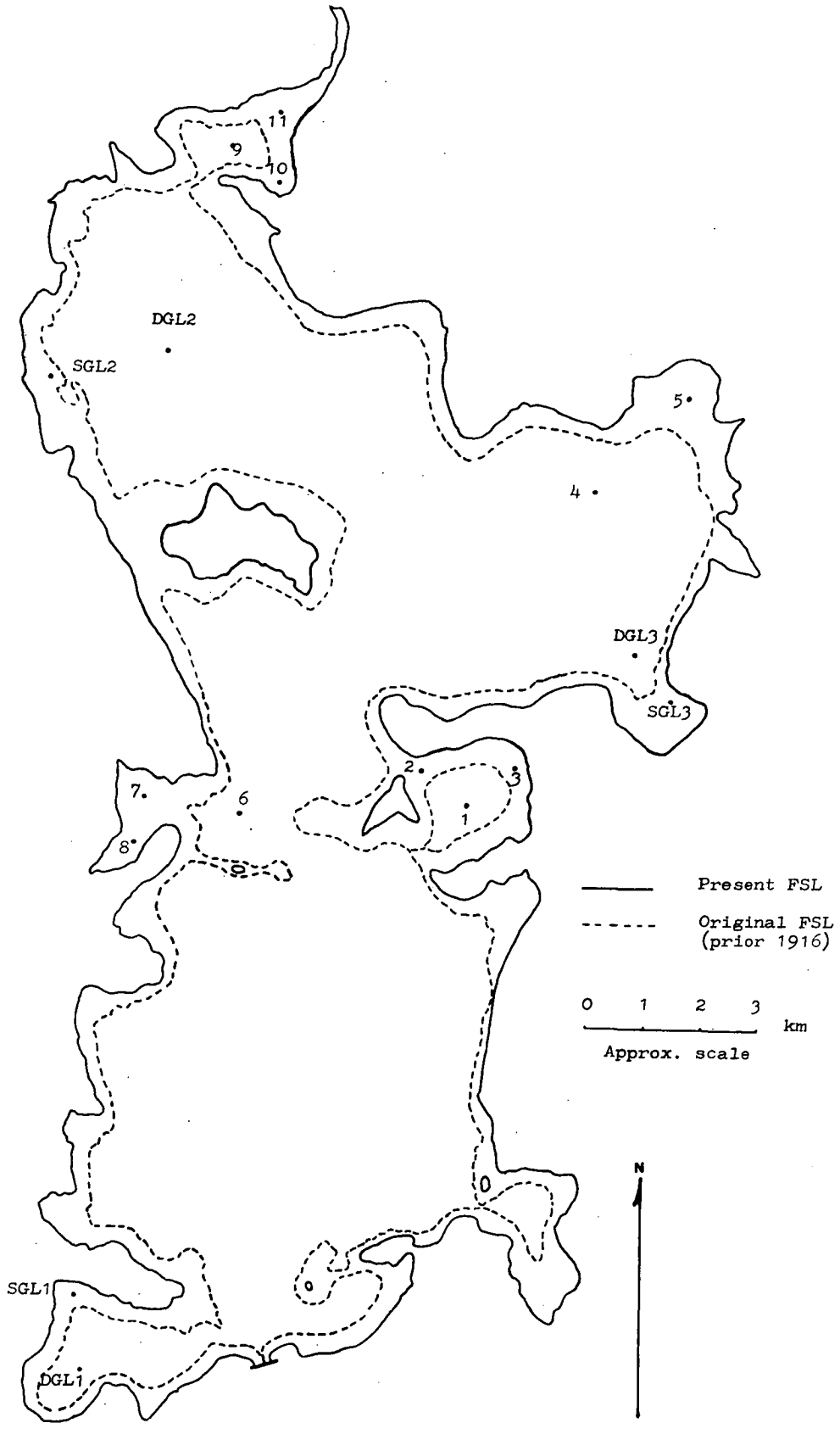
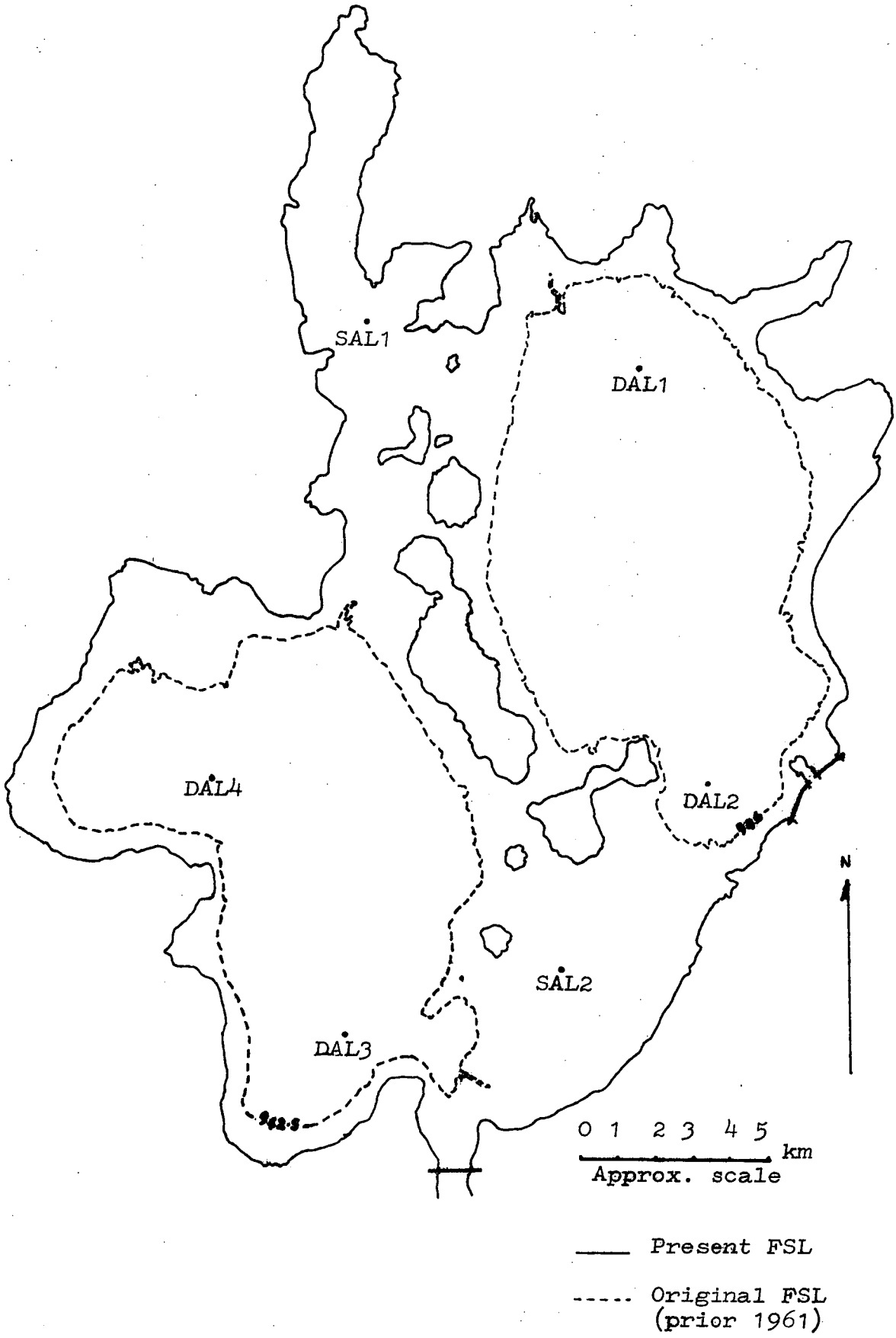

11
9
10
DGL2
SGL2
5
4
DGL3
SGL3
2
3
7
6
1
8
Present FSL
Original FSL
(prior 1916)
0 1 2 3
km
Approx. scale
N
SGL1
DGL1

Fig. 2.4: Sample sites in Arthurs Lake. SAL1, SAL2 etc. refer to sites for routine sampling as given in Table 2.1.

(Map based on detailed map supplied by HEC. Approximate contours from map A4067 also supplied by HEC).


SAL1
DAL1
DAL4
DAL2
SAL2
DAL3
N
0 1 2 3 4 5
km
Approx. scale
Present FSL
Original FSL
(prior 1961)

the six sites so as to provide an overlap in the seasonal samples.

The routine sites were located by compass bearing in Great Lake as it was thought that marker buoys would either be moved or cut loose by vandals. This decision was vindicated when marker buoys were later used in Arthurs Lake. All except one of these buoys was removed at least once during the 14 month sampling period. One of the sites had to be remarked four times during this time. The marking procedure used meant that the exact sample sites were not strictly consistent throughout the sampling time, but it was found that the sediment types were quite consistent over quite a large area in the vicinity of each sample site (with the possible exception of site WLN in Arthurs Lake).

2.2.3 Summary of Sampling Program

In summary the entire sampling program consisted of: 20 Ekman grab samples from each of six sites in Great Lake and Arthurs Lake. This procedure was repeated at two monthly intervals over 12 months in Great Lake during 1975 and over 14 months in Arthurs Lake during 1977-78. Sample sites are listed in Table 2.1 and sampling dates for each site are given in Appendix 1.

The limitation of the number of sites in each lake may mean that the species diversity of each lake was not fully investigated. However it was felt that it was better to have reliable data from the sites that were sampled. Several small series consisting of 3 samples each were taken from 10 other sites in Great Lake on 7 November, 1975

(see Fig. 2.3). Unfortunately this survey was curtailed by rough weather and was not extended over all the lake.

2.3 SITE DESCRIPTIONS, PHYSICAL AND CHEMICAL DATA

The location of the sampling sites in Great Lake are shown in Fig. 2.3 and those in Arthurs Lake are shown in Fig. 2.4. The names used for each sample site, depths from normal full supply level (NFSL), site abbreviations as used throughout the text and grid references for each site are given in Table 2.1. The grid references refer to the Tasmanian Lands Department 1:100,000 map series. Physical and chemical data on both lakes are also given in Tables2.2 and 2.3 and Figs. 2.5 - 2.7.

Swan Bay level 1, Great Lake (DGL1)

This site was situated in the original lake level in Swan Bay in the southeastern corner of Great Lake. The depth of the site was 15 m at NFSL and it was about 0.5 km from the nearest shore.

The sediment was predominantly a blue clay with a thin layer of dark brown silt on the surface.

Particle size analysis of the sediment (see Fig. 2.8) showed that there was usually more than 75% of the total weight of the sediment below 4 ø units (i.e. sub-sieve material). This was the finest sediment found from the Great Lake sites. Organic content, at 18.5%, was quite high compared to the other deeper sites (Table 2.4).

Table 2.1: Sample site data

Site	Depth from NFSL	Site Abbreviation	Grid ref. 1:100,000 Tasmap
Great Lake NFSL 1033.5 m			
Swan Bay level 1	15.5	DGL1	8214-744522
Brandum Bay level 1	17.5	DGL2	8214-742533
Cramps Bay level 1	16.5	DGL3	8214-842647
Swan Bay level 2	10	SGL1	8214-849639
Brandum Bay level 2	11.5	SGL2	8214-762701
Cramps Bay level 2	11	SGL3	8214-737696
Arthurs Lake NFSL 952.2 m			
Cowpaddock Bay	3	SAL1	8214-922567
Morass	6.5	SAL2	8213-943487
East Lake North	9.5	DAL1	8214-951562
East Lake South	9.5	DAL2	8214-964511
Ti Tree Bay	14	DAL3	8213-921479
West Lake North	11.5	DAL4	8214-903511

Table 2.2: Morphometric data for Great Lake and Arthurs Lake (principally from Peterson & Missen 1979)

	GREAT LAKE	ARTHURS LAKE
Catchment area (ha)	39600	26600
Maximum depth (m)	20	14
Mean depth (m)	15	7.9
Length (km)	27.8	12.8
Mean breadth (km)	5.7	5.1
Volume (km^3)	2.4	0.5
Area (ha)	15804	6459
Shoreline development	2.5	1.5
Volume development	2.3	1.7

Table 2.3: Water properties of Great Lake and Arthurs Lake (from published data)

Lake	TDS ppm	TFS ppm	K18 $uscm^{-1}$	ph	Colour pt units	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	S_1O_2	Ca^{2+} ppm	Mg^{2+} ppm	HCO_3^- ppm	Source
						←			μeq/l				→	←		→	
Great Lake	20.1	9	20.1	6.3	< 5	57	8	69	60	73	110	11	1.2				Buckney & Tyler 1973
Arthurs Lake	27.9	15.7	26.6	6.5	< 5	78	17	131	80	177	68	10	2.6				Buckney & Tyler 1973
Great Lake	22-23			6.6-6.9										1.6	0.5	4.9	Williams 1964
Great Lake	23			6.2										1.6	2.9	2.4	Williams 1964
Great Lake	24			6.3										1.2	0.2	4.9	Williams 1964
Great Lake	25			6.3										1.6	1.7	4.8	Williams 1964
Arthurs Lake	> 22													3.4	1.2	8.0	Williams 1964
"	27			6.1										2.4	4.4	9.8	Williams 1964

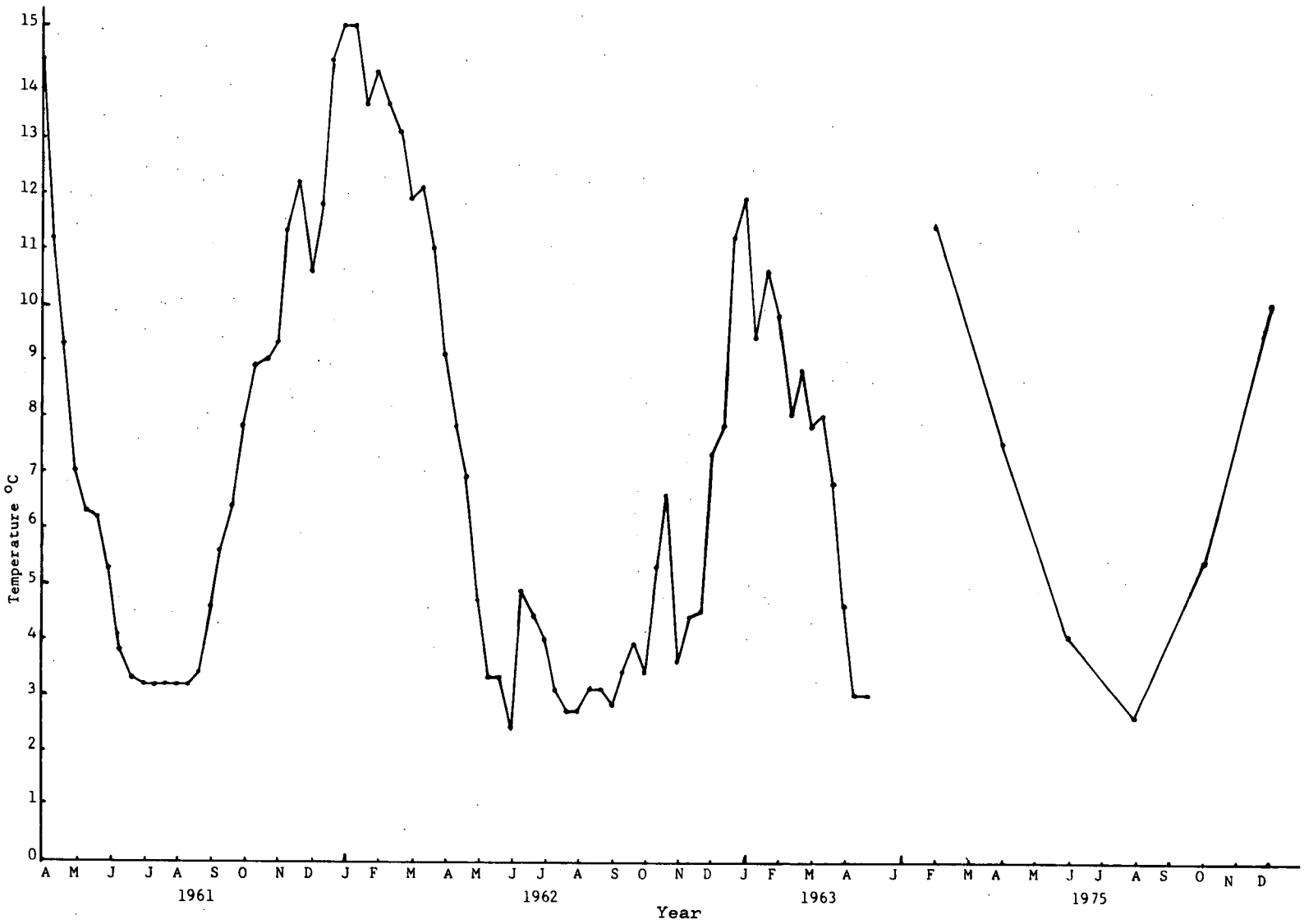


Fig 2.5: Great Lake water temperatures (1961-63 data supplied by HEC)

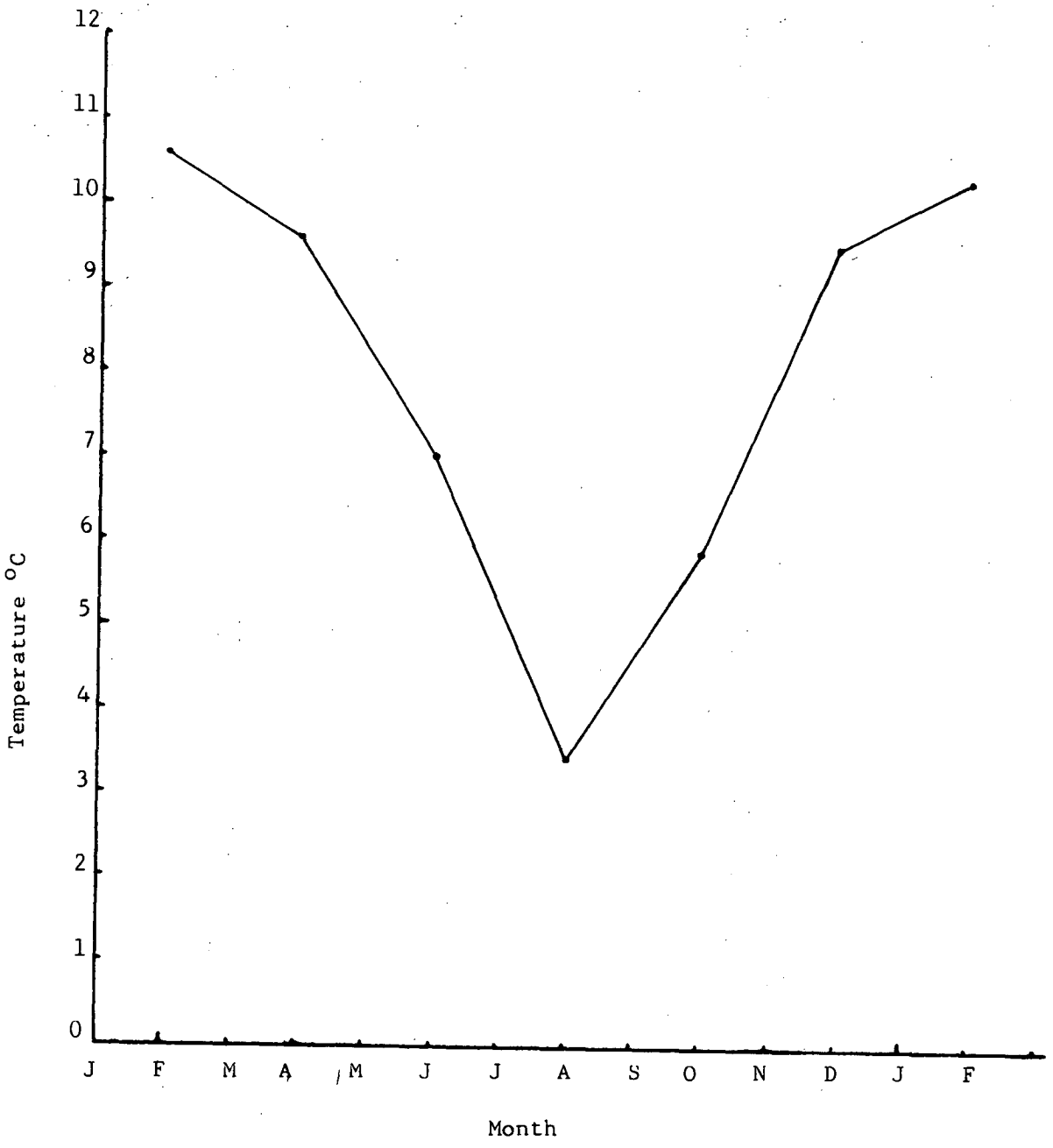


Fig 2.6: Arthurs Lake water temperatures, 1977-78

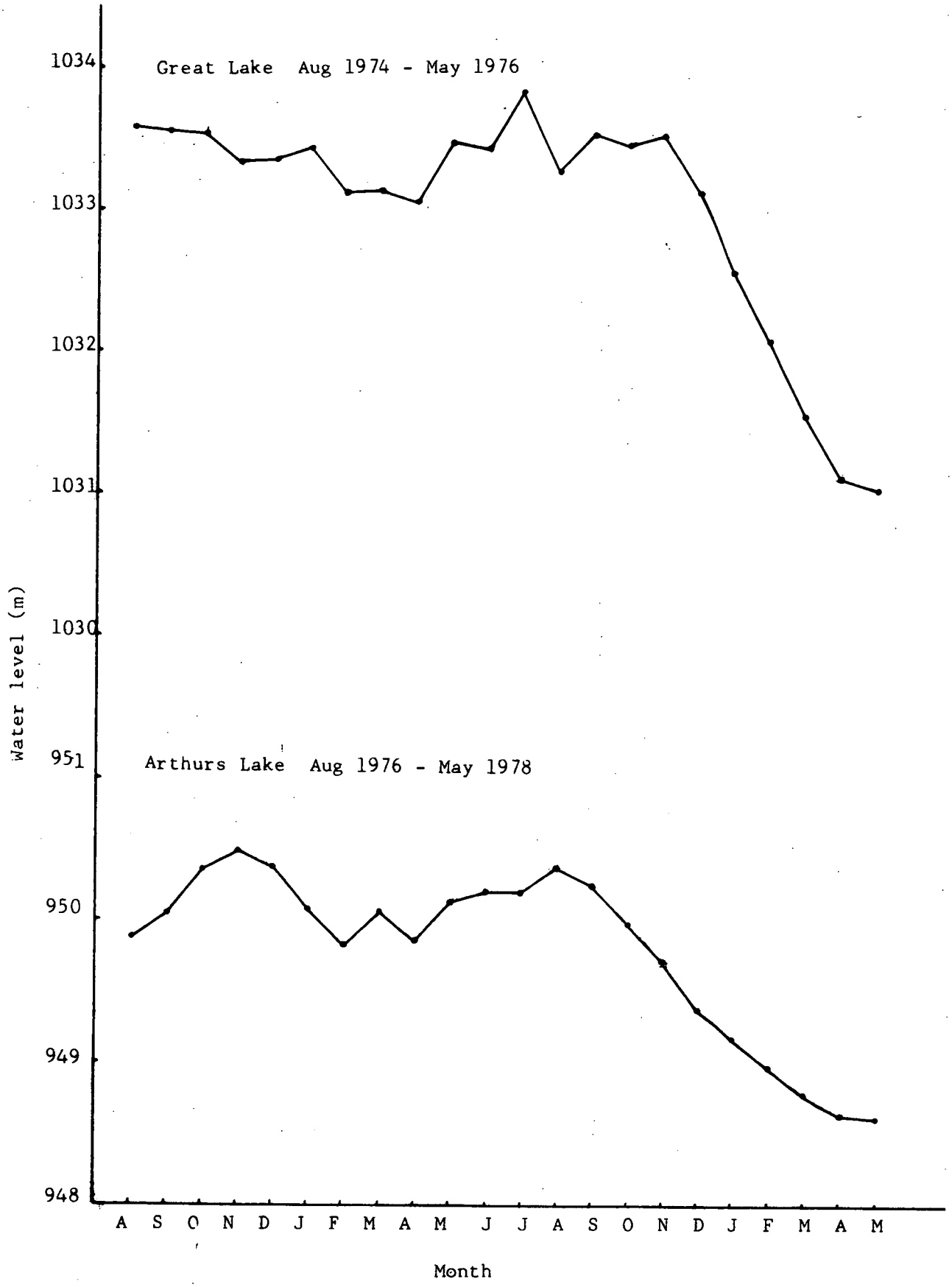


Fig 2.7: Monthly water level fluctuations

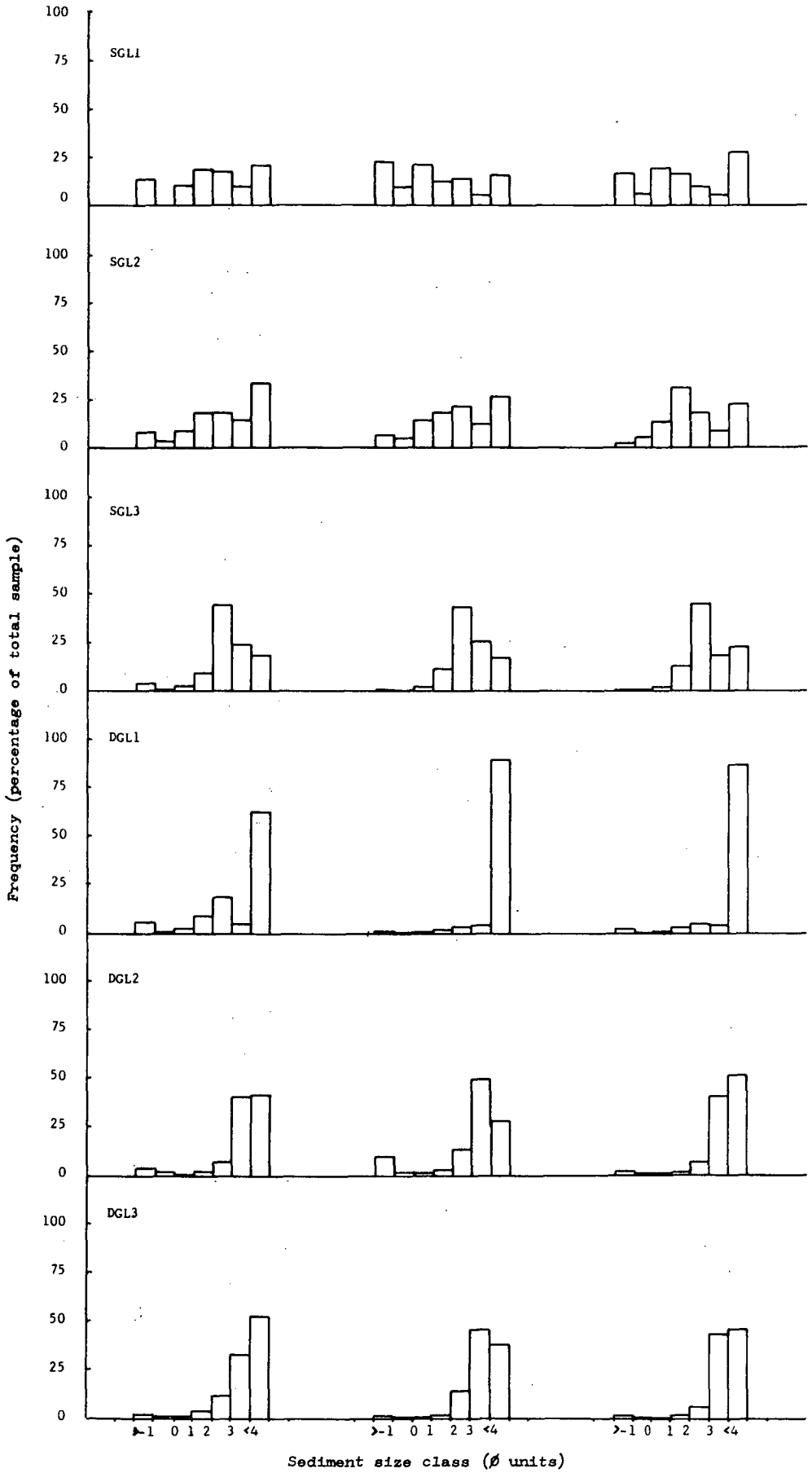


Fig. 2.8a: Size frequency analysis of sediment (three replicates) from Great Lake.

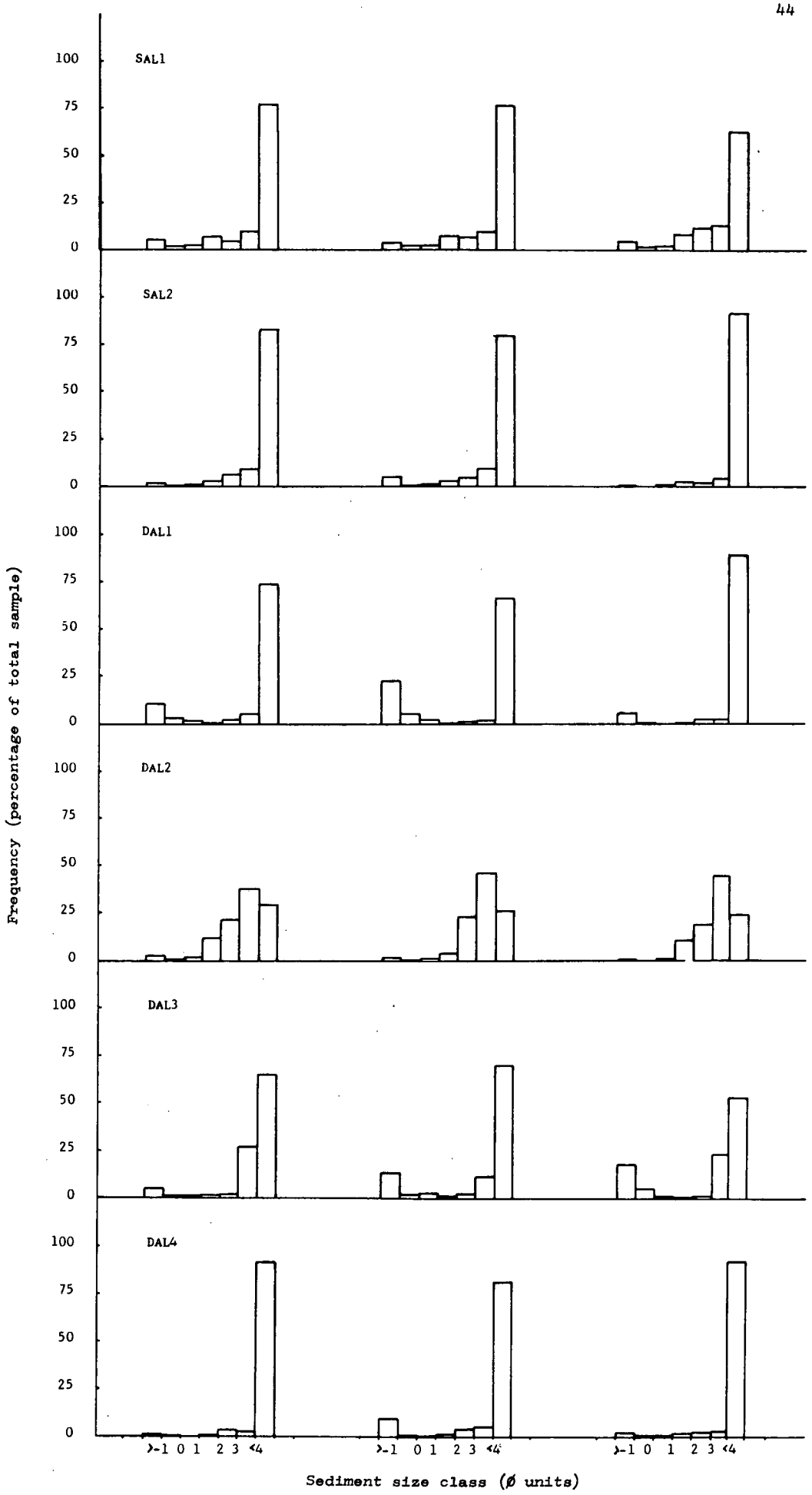


Fig. 2.8b: Size frequency analysis of sediment (three replicates) from Arthurs Lake.

Table 2.4: Organic content of sediments in Great Lake and Arthurs Lake (by percentage loss on ignition at 500°C)

Site	Range (%)	Mean (%)
DGL1	17.1 - 20.8	18.5
DGL2	7.1 - 9.4	8.4
DGL3	5.1 - 12.4	8.4
SGL1	20.2 - 31.0	26.1
SGL2	33.5 - 41.1	37.8
SGL3	14.1 - 15.7	15.2
SAL1	39.1 - 39.9	39.5
DAL2	12.5 - 14.4	13.5
DAL1	5.1 - 6.5	5.6
SAL2	15.1 - 36.3	28.0
DAL3	9.1 - 10.4	9.7
DAL4	13.1 - 27.7	19.8

Brandum Bay level 1, Great Lake (DGL2)

This site was also in the original lake level but in the northern part of the lake. The site was out in the large northern basin of the original lake approximately three kilometres off-shore from Brandum Bay. Site depth was 17 m at NFSL and was the deepest site sampled in either lake.

The sediment had a brown mud layer on the surface with some yellow clayey nodules in it. The nodules ranged in size from very small up to about 2 cm in diameter in some samples. The substrate below was a fine yellow or occasionally blue clay.

Analysis of the sediment showed that it was slightly coarser than that of Swan Bay level 1 with about 40% between 3 and 4 Ø units and about 40% below 4. Organic content was low at around 8%.

Cramps Bay level 1 Great Lake (DGL3)

The third site in the original lake level was near the eastern side of the northern basin of the lake, out from Cramps Bay and about 0.5 km off-shore. It was exposed to the maximum fetch available in Great Lake to the prevailing west to north westerly winds - a distance of about 12 km.

The sediment at this site was usually a yellow sandy clay with numerous small hard clayey particles. The brown mud layer, evident in the other two level 1 sites on Great Lake, was not noticeable at this site.

Analysis of the sediment for particle size gave a similar result to that of DGL2. The organic content was

also similar at 8.4% although slightly less variable.

Swan Bay level 2, Great Lake (SGL1)

This site was situated in a part of Great Lake which was artificially created by the raising of the water level in 1922. It is in a corner of the Swan Bay area known as Dud Bay at a depth of 10 m from NFSL.

The sediment was a dark sandy material with many small clayey nodules. There was usually considerable amounts of fine organic matter on the surface as well as numerous twigs and sticks. An alga (Nitella sp.) was also present in some samples throughout the year.

The analysis of sediment from this site revealed a tri-modal distribution of particle size. The first of these represents about 15-20% of the material. This was retained by the largest sieve (-1Ø units) and contained organic material such as sticks and aquatic plants as well as the larger clay particles. A further 45% of the sediment was between 0 and 3 Ø units representing the sandy part of the sediment. A further 15-25% of the sediment was in the sub-sieve range. Organic content at about 26% was higher than any of the deeper sites in Great Lake, but, as with SGL2, the weed and sticks etc. would give rise to considerable variations in this value.

Brandum Bay level 2, Great Lake (SGL2)

Another site in the artificial part of Great Lake, it was about 0.75 km from the Brandum Bay shoreline and about 100 m to the west of a small island. The depth was 12 m from NFSL. Small sticks and twigs and remains of

rushes as well as the alga (Nitella sp.) were common at this site. The sediment was largely a coarse black granular material similar to the soils around the western shore of the lake. Although the texture of the substrate was quite coarse it appeared to be largely due to aggregation of fine particles.

On analysis there was found to be a spread of material between 0 and 3 ∅ units. About 50-60% of material was retained by sieves in this range. A further 20-30% was in the sub-sieve range. The organic content was higher at this site than any other site in Great Lake. Again the large amount of debris from flooded vegetation would contribute significantly to this.

Cramps Bay level 2, Great Lake (SGL3)

The third of the three sites in the new level was situated at the edge of the dead tree line about 100 metres from shore in Cramps Bay at a depth of 10 m from NFSL. From the nature of the substrate at this site and a similar area further south in Elizabeth Bay compared to SGL1 and SGL2, it appears that there is considerable deposition of lighter material on the windward shores of Great Lake.

The sediment at SGL3 was a brown sandy material, quite uniform in appearance with a layer of fine organic detritus on the surface. Sediment analysis, as shown in Fig. 2.8, shows the uniformity of the sediment, as does the small range in the organic content of 14.1 - 15.7%.

Cowpaddock Bay, Arthurs Lake (SAL1)

The site selected in Cowpaddock Bay was the shallowest

of all the sites in either lake at only 3 m from NFSL. The site was about 100 m from the nearest shore which was to the northeast. The substrate was generally similar in appearance to that of SGL2 except that it was much finer. The sediment was black in colour with numerous sticks and twigs. Also present were large amounts of Canadian pondweed, Elodea canadensis and lesser amounts of Potamogeton tricarinatus and Nitella sp. The amount of weed present varied considerably throughout the year at this site. Further detail of this variation is given in Fig. 2.9.

On analysis the Cowpaddock Bay sediment was found to be quite fine with 60-75% in the sub-sieve grade. It did not appear to be so fine in practice probably due to the formation of aggregates of many small particles. The organic content (39.5%) was the highest for any site in either lake. The seasonal dieback of E. canadensis was probably a major contributor to this.

East Lake North, Arthurs Lake (DAL1)

This site was located in the northern part of what was originally known as 'East Lake' or Sand Lake. It was approximately 1 km from the northern shore at a depth of 9.5 m from NFSL. The substrate at this site was a fine blue clay similar to that encountered at SGL1. There were numerous larger yellow-brown clayey particles scattered through it.

Analysis of the sediment showed that once the large clay particles were removed almost all the sediment was below 4 Ø units in particle size. Organic content was

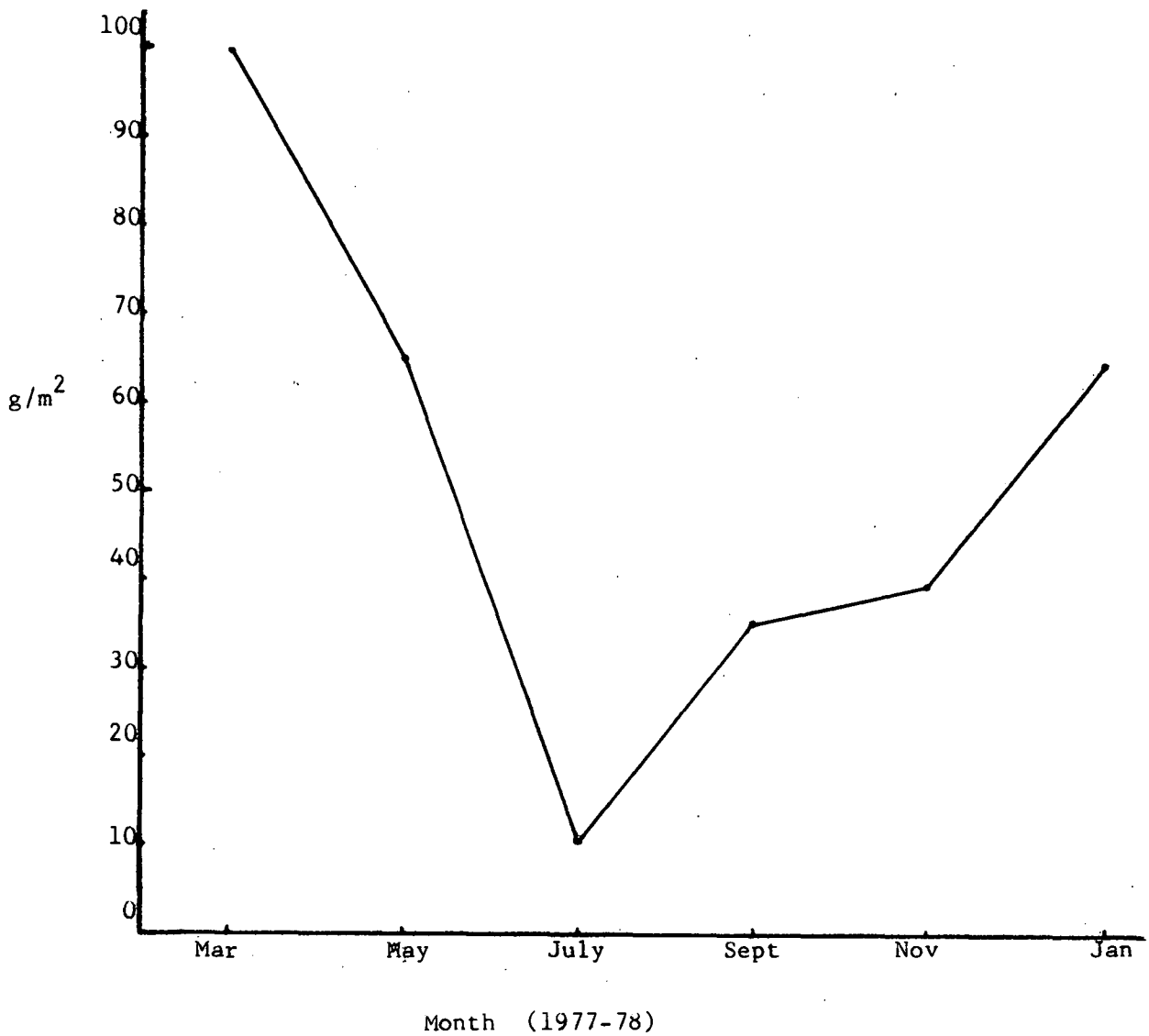


Fig 2.9: Weight of Elodea canadensis in grab samples at one site, SAL 1, Cowpaddock Bay, Arthurs Lake.

moderately high for a deep site at 19.8%.

East Lake South, Arthurs Lake (DAL2)

The second of the two sites in the original East Lake was at the southern end approximately 1 km eastwards from the westernmost point on Neil Island. The depth of the site, 9.5 m was similar to the northern site.

The substrate was sandy in texture with fine brown silt intermixed. Analysis showed that 35 to 45% of material was in the 3-4 Ø range and only about 25% in the sub-sieve range. There were very few large particles at this site but there were occasionally some small pieces of the alga Nitella sp. present. Organic content, (5.6%) was lower at this site than any other site in either lake.

Morass, Arthurs Lake (SAL2)

Before the level of Arthurs Lake was raised the southeastern part of the present lake was dotted with lagoons and the rest was marshland. The Morass site was over this area now at a depth of 6.5 m from NFSL.

The sediment was very fine brown silt usually intermingled with decaying roots and stems of grasses, probably the remains of the original vegetation. During sampling, perhaps three samples in twenty would strike an area virtually devoid of vegetation remains. One of these such samples was used in the sediment analysis hence the wide variation in the organic content from 15.1 to 36.3%. Particle size analysis showed that 80 to 90% of the sediment was sub-sieve size.

The large amounts of organic matter present in these samples made them very tedious to sort as most of this material was retained by the 700 μ sieve used during sorting.

Ti Tree Bay, Arthurs Lake (DAL3)

This site was located in the southern part of the western basin of Arthurs Lake about 1 km from the southern shore. It was the deepest of the Arthurs Lake sites at 14 m from NFSL. It was in part of the original Western Lake.

The substrate contained numerous clayey particles up to about 1 cm in diameter with the remainder of the substrate being blue clay.

Analysis showed that up to about 15% of the sediment was retained by the first sieve with from 50-70% of the material being finer than 4 ϕ units. A considerable portion (15 to 25%) was also between 3 and 4 ϕ units. Organic content at about 10% was roughly comparable with the two deep northern Great Lake sites DGL2 and DGL3.

West Lake North, Arthurs Lake (DAL4)

In the preliminary survey of Arthurs Lake some difficulty was encountered establishing a sample site in the northern part of the western basin. This was due to the hard surface caused by iron and clay concretions which either prevented the penetration of the grab, or jammed the jaws open so that the sample was lost. A reasonable site was eventually found but within this site the problem still arose occasionally. However, once

the initial marker buoy was removed there was some doubt about the continuity of the position of this site.

The substrate was usually a fine yellow clay below with small to large clay and iron concretions on the surface. These ranged in size up to about 7 cm in diameter and were of irregular shape. There was usually a considerable amount of decayed plant material present.

The samples for particle size analysis were comparatively free of large concretions. They showed that 80 to 90% of the material was below 4 Ø units in size whilst the organic content was the highest of any of the deep sites at about 20%.

2.3.1 Discussion: Site Physical and Chemical Relationships

There are only minor differences between the two lakes in relation to water properties and temperature regimes. The general geology of the catchments of the two lakes is also similar. The waters of both lakes are low in dissolved solids and ionic concentrations with Great Lake slightly more so than Arthurs Lake (Table 2.2). Being at a lower altitude and less exposed Arthurs Lake may be slightly warmer than Great Lake overall although no major differences were noted during the surveys.

Both lake systems were originally quite shallow and consisted of several basins or separate lakes which were united when the water levels were raised (Figs. 1.1 & 1.2). The maximum depth of Great Lake was just over six metres whilst Arthurs Lake was no deeper than four metres. The sediments from the three sites in Great Lake and four sites in Arthurs Lake which were located in the original lake basins were all

found to be quite similar in appearance with the possible exception of the sandy DAL2 site in Arthurs Lake. Sediment analysis was not comprehensive but these areas were generally characterised by high levels of silt and relatively low organic levels. (Fig. 2.8, Table 2.4). Large particles were present to varying degrees at some of the deep sites.

The substrates at the two shallow sites in the flooded western side of Great Lake were very similar in appearance consisting of a granular black sediment composed of aggregates of fine particles. Some algal growth (Nitella sp.) was also present. The shallow site in Arthurs Lake (SAL1) was very similar in appearance to these two Great Lake sites with the introduced weed Elodea canadensis probably contributing to the higher organic content, whilst break up of soil aggregates during sieving could have accounted for the observed higher silt content at this site. High organic contents at sites SGL1, SGL2 and SAL2 were probably largely derived from drowned terrestrial vegetation whilst deposition of allocthonous organic matter by wave action could account for the material found at SGL3. Site SAL1 derives a certain amount of its organic matter from drowned vegetation but additional material results from the seasonal dieback of E. canadensis (Fig. 2.9). All northern Arthurs Lake sites may have an additional input of organic material from streams entering the lake in this area.

The Morass site in Arthurs Lake was formerly a grassy marsh at about the same level as the original lakes and it was subject to periodic flooding. The substrate still contains large amounts of decaying roots and grass stems.

2.4 TREATMENT OF DATA

All specimens were identified as far as possible and the number of individuals of each species in each sample at each site and collection date were tabulated. The resulting tables are too bulky to include in full, however a summary table giving the total numbers of each species for each 20 sample series taken from both lakes is given in Appendix 2.

All animals from each sample, (or a reliable sub-sample of them), were weighed for the purpose of estimating total biomass. Excess liquid was removed from these by draining them on filter paper. The wet biomass of the preserved material was used as there was insufficient time available during the initial sorting to calculate live weights. Molluscs and caddis flies were removed from their shells or cases before weighing.

The effects of preservatives on the length and weight of animals have often been documented, particularly the effect of formalin on fish (Parker 1963; Cadwallader 1974). Alcohol also decreases the weight of various invertebrates (see Jonasson 1972; Wiederholm & Ericksson 1977 also Appendix 3). Biomass correction factors calculated from data in Appendix 3 were therefore used in this study. Jonasson (1972) increased the weight of preserved specimens by 33% in his biomass estimates. Where changes due to preservation have occurred the correction factor used has been conservative to avoid any overestimates of total biomass. The biomass estimate method itself is open to considerable error when extrapolating from small samples to

a large surface area. The conversion factors used are therefore considered to be quite within the accuracy limits of such methods. After an initial weight loss in some groups there was a steady, but small weight loss. This may have been due to handling rather than a result of preservation. The adjusted biomass data for each 20 sample series were tabulated and results are given in Appendix 8.

The species diversity data were further analysed using programs for calculating Shannon-Weiner and Pielous evenness indices on the Hewlett-Packard HP 9825A Desktop Computer System, (after Southwood 1971, Pielou 1969 respectively) at the Zoology Department of the University of Tasmania (see Sections 4.2.1.2; 4.2.1.3.1).

Species presence and abundance data for both lakes were punched onto cards and analysed on the CSIRO Cyber 76 computer using a Genstat program after Nelder (1975). This program calculates matrices of similarity between pairs of sites using the Jaccard coefficient of similarity (ignoring 0-0 associations). The Jaccard coefficient, J, is given by:

$$J = \frac{c}{a+b-c}$$

where a = number of species in community A

b = number of species in community B

c = number of species common to both communities

The seventh series of samples at Arthurs Lake was not included in the data set to avoid any seasonal bias which may have occurred had these overlapping samples been used. The data for the remaining dates were then grouped into

sites to give presence - absence for each species at each site. A matrix giving the coefficient of similarity between each pair of sites (or communities) was computed. Three hierarchical clustering strategies, the average linkage, furthest neighbour and nearest neighbour techniques were then performed on this data. Principal coordinates analysis was then performed on this data.

The program was then re-run on the presence - absence data with an instruction to treat any species that had two or less occurrences at a site as being absent from that site. This was an attempt to place emphasis on the dominant species at each site. A similarity matrix was calculated, the same three clustering strategies were used and principal coordinates analysis was also performed.

The data on abundance of each species were then considered. A total number for each species for the first six sample dates at each site was taken. It was transformed into its natural logarithm and this value was used to weigh each species in the Jaccard coefficient calculation.

One was added to each species record to avoid zeroes arising from the $Ln1 = 0$ situation. A similarity matrix was again calculated and cluster analysis as well as principal coordinates analysis were computed as above.

CHAPTER 3

FAUNAL COMPOSITION OF GREAT LAKE AND ARTHURS LAKE

3.1 INTRODUCTION

The fauna of Great Lake and Arthurs Lake has been examined both qualitatively and quantitatively. The state of taxonomic knowledge of various freshwater invertebrate groups was such that specialist help was required for identifications. Fifteen new species have so far been recognised from various taxa collected during the survey.

In this chapter the qualitative faunal differences between the two lakes are examined and discussed in relation to other lakes in Tasmania and south-eastern Australia.

3.2 RESULTS

A list of all species recorded from Great Lake and Arthurs Lake during the survey as well as those obtained from Great Lake in supplementary collections is contained in Table 3.1. This table also gives details of the relative abundance of each species at each of the 12 sites regularly sampled.

The table does not list copepod, ostracod and nematode species which were also occasionally present in the samples. These species were too small to be consistently retained by the sieve used hence they were regarded as microbenthos

Table 3.1

Species list for Great Lake and Arthurs Lake

Abundance key x 1-10/m^2
xx 11-100/m^2
xxx 100-1000/m^2
xxxx >1000/m^2

	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	DAL1	DAL2	DAL3	DAL4	SAL1	SAL2
CRUSTACEA												
Isopoda												
Mesacanthotelson setosus Nicholls				x	xx							
Onchotelson brevicaudatus (Smith)	xxx	x	xxx	xx								
* Onchotelson spatulatus Nicholls												
Uramphisopus pearsoni Nicholls		xx										
Colubotelson sp.							xxx	xxx	xx	xxx	x	xxxx
Heterias sp.				x	x		x	x	x	xx	xx	x
Syncarida												
Paranaspides lacustris Smith				x	x			x				
Amphipoda												
* Austrochiltonia australis (Sayce)								x			xxx	
Neoniphargus ? tasmanicus Smith		xx							xx	xxx		xxx
Neoniphargus sp.		x	x				xxx	xxxx	xxx	xxx		
INSECTA												
Diptera												
Chironomus oppositus Walker		x		x	xx	xxx			x		xxx	x
Crytochironomus griseidorsum (Kieffer)	x	x	x	xx	xx	x		x	x	x	x	x
? Tanytarsus sp.	xx	xx	x	x	xx	xx		x	x	x	xx	x
Polypedilum nr. tonnoiri	x			xx	x	xxx	x		x	x	xx	
? Harnischia sp.	x											
? nr. Harnischia									x			
Dicrotendipes sp.								x			xx	
Cladopelma curtivalva											xxx	
? Parachironomus sp.										x		
Parachironomus ? delinificus												x
Riethia sp.	xx	xx	xx	xxx	xxx	xxx	xx	xx	xx	xx	xxxx	xxx
Coelopynia ? pruinosa Freeman	xx	x	xx	xx	x	x	xxx	xxx	xxx	xx	x	xxx
Paramerina sp.	x		x	x	x	x	x	x	x	x		x
Procladius ? villosimanus Kieffer	x	x		xxx	x	xxx	x	x	x		xxxx	x
Ablabesmyia ? notabilis Skuse			x	x	x	x	xx	x	x	x	x	x
Orthocladiinae Sp.1 (nr. Smittia or Cricotopus)	x			x								
Orthocladiinae Sp.2			x	x	x		x	x	x	x		x
Orthocladiinae Sp.2			x	x	x		x	x	x	x		x
Orthocladiinae Sp.3 (? Cricotopus sp.)		x		x	x							
Orthocladiinae Sp.4 (nr. Eurycnemus)					x							

Table 3.1 continued

	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	DAL1	DAL2	DAL3	DAL4	SAL1	SAL2
Ephemeroptera												
Atalophlebia superba Tillyard								x			xx	
Plecoptera												
also * Leptoperla beroe Newman								x			x	
Trichoptera												
Atriplectides dubius Mosely	xx	x	xx	xxx	xx	xx	xx	xx	x	x	xx	x
Ecnomus tillyardi Mosely				x	x	x					x	
Notalina parkeri Mosely				x	x			x		x	xx	x
Oecetis sp.												x
ACARINA												
Australiobates linderi Lundblad												x
Australiobates longipalpus Lundblad					x							
Oxus meridianus Lundblad	x			x	x						x	
Piona uncatiformis Lundblad				x			x		x	x	xx	x
Arrenurus sp.				x								
Unionicola longiseta Walter										x	x	x
OLIGOCHAETA												
Haplotaxis ornamentus Brinkhurst & Fulton	xxx	xx	xxx	x			xxx	xxx	xxx	xxx		
Haplotaxis heterogyne Benham		x	x				x		x	x		
Phreodrilus magnaseta Brinkhurst & Fulton	x	x	x					x				
Phreodrilus plumaseta Brinkhurst & Fulton		x	x				x					
Phreodrilus palustris Brinkhurst & Fulton	x	xxx	xxx				x	xx	xxx	xx		
Phreodrilus breviatria Brinkhurst & Fulton		xx	x					x	x			
Phreodrilus branchiatus (Beddard)					xx					xx		
Phreodrilus proboscidea Brinkhurst & Fulton				x	xx	xxx					xx	
Antipodrilus plectilus Brinkhurst & Fulton	xx	xxx	x				xxx	xxx	xx	x		
Antipodrilus multiseta Brinkhurst & Fulton		xxx	xx					x				
Telmatodrilus papillatus Brinkhurst & Fulton		x			x					xx		x
Telmatodrilus bifidus Brinkhurst & Fulton	xxx	xxx	xx				xx	xx	xxx	xxx		
Limnodrilus hoffmeisteri Claparede		xx		x	xx	xxx					xx	xx
BIVALVIA												
Sphaerium lacusedes Iredale	x		x	x			xx	xx				
Sphaerium tasmanicum (Tenison-Woods)											x	
Pisidium tasmanicum Tenison-Woods Pisidium sp.	xx	x	x		x	x	xxx	xx		x	x	x

Table 3.1 continued

	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	DAL1	DAL2	DAL3	DAL4	SAL1	SAL2
GASTROPODA												
Beddomeia sp.			x									
Glacidorbis pawpela Smith		x										
Physastra cf. gibbosa											x	
TURBELLARIA												
Romankenkius bilineatus Ball & Tran			x				x	xx	xx	x		x
Spathula ochyra Ball & Tran											xx	
unidentified prorhynchid		x	x				x	x		x		x
NEMERTEA												
Potamonemertes sp.	x	x	x		x	x		x	x	x		x
PORIFERA												
unidentified sponge	x				x				x	x	x	x
HYDROZOA												
unidentified hydroid								x	x		x	

* Indicates species collected only in additional samples in Great Lake

and therefore outside the scope of the survey.

Small forms of some other groups such as the early instar chironomid larvae also may have passed through the sieve but they were not noticed in any large numbers.

Small fish of the genus Paragalaxias were caught on several occassions in both lakes but they were not recorded with the invertebrate fauna.

A total of 51 separate species of invertebrates was collected from Great Lake during the main survey whilst another 3 species were added to the list in additional sampling (see Appendix 2). The oligochaetes (13 species) and chironomids (15 species) alone accounted for over half this number. Crustaceans were represented by five species of isopods, three species of amphipods and one species of syncarid.

Five species of molluscs, four species of mites, three species of trichopterans and two turbellarians were also found. The remaining groups, the plecopterans, nemerteans and poriferans were represented by single species only.

The Arthurs Lake fauna was of basically similar composition with a slightly greater diversity. A total of 56 species was recorded. The same 13 species of oligochaetes as found in Great Lake were also present in Arthurs Lake and 16 species of chironomids were also found, the majority of which were common to Great Lake. In Arthurs Lake, the crustacean group was slightly different in composition and far more abundant than that of Great Lake with two species of isopods, one species of syncarid and three species of amphipods. There were

only slight variations in the occurrence in Arthurs Lake of species of the remaining groups recorded from Great Lake. However, one species each of Ephemeroptera and Hydrozoa were additional records for Arthurs Lake.

The numbers of each species collected at each date at each site in both lakes are given in Appendix 2. These figures are for each 20 sample series and should be multiplied by 2.15 to convert to numbers per square metre of lake bed. The total number of individuals/m^2 for each date at each site in both lakes is given in Table 3.2. The contents of the additional samples from Great Lake are listed in Appendix 2.

CHIRONOMIDAE: In total numbers present, the chironomid group was the dominant element of the fauna of Great Lake but took second place to the Crustacea in Arthurs Lake. Riethia sp. was the single most abundant species of chironomid in both lakes. This was most marked in Great Lake where it was also the most widespread species. The dominance of this species in Arthurs Lake was largely due to its abundance at the Cowpaddock Bay site. Two other of the more abundant species of chironomid in Arthurs Lake were largely concentrated at the Cowpaddock Bay site also. These were the large species Procladius villosimanus and Chironomus oppositus, both of which were among the more common species in Great Lake as well. Another very common and widespread species in both lakes was Coelopynia pruinosa. This species displayed a regular distribution for several sample series in Arthurs Lake and closely approached such a distribution many times in both lakes.

Table 3.2: Number of animals per square metre of bottom for each sample date at each site in Great Lake and Arthurs Lake. (Samples taken at end of month indicated).

Month \ Site	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	SAL2	DAL1	DAL2	DAL3	DAL4
1	464	1017	768	931	432	1916	2047	1974	1926	1817	847	1260
3	1453	1357	581	899	563	2313	2924	1656	2290	2146	1441	860
5	641	1662	611	750	1023	2866	3029	1952	2279	2578	1563	1163
7	890	1318	576	1888	753	2509	6478	1269	2090	2511	2384	1307
9	836	1548	572	2208	890	3367	2814	1140	2101	1782	1204	1604
11	744	1002	660	1640	839	2363	2662	1322	1187	3335	1281	2253
1							2939	1357	1933	2853	1015	916
Mean no. /m^2	839	1318	628	1387	750	2556	3328	1552	1978	2361	1453	1408

Other species of chironomids which were common to varying degrees were Tanytarsus sp. and Polypedilum tonnoiri in Great Lake and Cladopelma curtivalva at Cowpaddock Bay in Arthurs Lake. All of these were small species, the first two of which were also present in Arthurs Lake whilst C. curtivalva was not found outside Cowpaddock Bay. The remaining chironomid species varied in their abundance from a couple of hundred specimens down to one or two only from all samples.

Ten species of chironomids were common to both lakes whilst only one of the more abundant species, C. curtivalva, was confined to one lake only.

OLIGOCHAETA: The oligochaetes were clearly the second most abundant group in Great Lake but were a close third in Arthurs Lake in terms of individual numbers. In number of species the group took second place in both lakes.

Four species were especially common in Arthurs Lake whilst the same four along with another three species were also common in Great Lake with over 500 individuals of each species being collected during the survey.

Only one of the more abundant oligochaete species, Limnodrilus hoffmeisteri (Great Lake only) was previously known to science whilst only two other species had previously been recorded elsewhere. In all, 10 new species were found, five in the family Phreodrilidae, four in the family Tubificidae and one in the family Haplotaxidae (see Brinkhurst & Fulton 1979, 1980). The largest of the common species was Haplotaxis ornamentus. It was extremely abundant at the deeper sites especially in

Arthurs Lake where it was the major contributor to the biomass of that lake.

Two other large species, Phreodrilus palustris and Antipodrilus multiseta were common in Great Lake with the latter species only also common in Arthurs Lake. Another very common species in some parts of both lakes was the tubificid, Antipodrilus plectilus. This species was sometimes found clustered in tangled knots of more than fifty specimens, especially at Brandum Bay level 1. A further tubificid species Telmatodrilus bifidus was particularly common at all of the deep Great Lake sites and four of the Arthurs Lake sites. A small phreodrilid, Phreodrilus proboscidea was abundant at the shallow sites only in both lakes.

Although most of the oligochaete species found in Great Lake and Arthurs Lake were previously undescribed it is probably a result of taxonomic neglect of this important faunal group rather than their own scarcity. Oligochaetes have usually been lumped together in faunal surveys in Australia (e.g. Timms 1974b,1978 in part; Knott et al. 1978; King 1979) both in consideration of actual numbers and in biomass estimates. Many of the species found are of particular interest both taxonomically and zoogeographically.

CRUSTACEA: The next most important component of the fauna in terms of numbers in Great Lake was the crustacean group. In Arthurs Lake two species of crustaceans were the two most abundant species. In Arthurs Lake, crustacean fauna was dominated by the phreatoicid Colubotelson sp. which

was the most abundant of all species in the lake. It was found to varying degrees at all sites but was especially common at Morass Bay and East Lake South. Surprisingly, this species was not a part of the benthic fauna of Great Lake where several other endemic forms were recorded. The most common of these was the large species Onchotelson brevicaudatus. The distribution of phreatoicids in Great Lake was disjunct and certain species appeared to be confined to definite areas. One species O. spatulatus was collected only from Elizabeth Bay, Great Lake during the additional survey. Prior to this it had not been recorded since its original description (Knott pers. comm.).

The amphipod fauna of Arthurs Lake was of major importance numerically with one species Neoniphargus sp. being the second most abundant animal recorded in the survey. Amphipods generally were widespread in Arthurs Lake with some differences in occurrence at various sites. The distinctly different Cowpaddock Bay site contained the species Austrochiltonia australis whilst the other two species, Neoniphargus sp. and N. tasmanicus, were more widespread and, at some sites, overlapped in their distribution. In contrast the Great Lake amphipod fauna was depauperate containing the same three species, none of which were at all common.

An isopod species of the genus Heterias was present at several sites in both lakes. Its distribution was sporadic but it was most frequently collected at the shallow Cowpaddock Bay site in Arthurs Lake.

The endemic syncarid Paranaspides lacustris was found in low numbers at two sites in Great Lake and also

from one site in Arthurs Lake. This species may be capable of actively avoiding the grab thus resulting in an underestimate of its abundance or else it may only be present in low numbers as has been reported in the literature (see Williams 1965).

TRICHOPTERA: The only other groups present in any quantity were the trichopterans and the bivalves. Four species of trichopterans were found in Arthurs Lake, three of which were also present in Great Lake. Only one of these species, Atriplectides dubius was at all common. It was collected in varying quantities from all sites in both lakes and was one of only three species found with such a distribution during the survey (the others both being chironomids). A. dubius was most abundant at the shallower sites in both lakes.

OTHER INSECTA: Atalophlebia superba was the only mayfly species recorded during the survey. It was only found in Arthurs Lake and was only common at Cowpaddock Bay. The stonefly species, Leptoperla beroe was not common at any site and only a few specimens were recorded from Arthurs Lake during the main survey.

MOLLUSCA: The bivalves were most frequent in Arthurs Lake where Sphaerium lacusedes, S. tasmanicum and two species of Pisidium, one of which is an undescribed species (J. Kuiper pers. comm.), was collected. The known species is P. tasmanicum Tenison-Woods. Great Lake contained S. lacusedes and two species of Pisidium, but they were less abundant there than in Arthurs Lake.

Gastropod molluscs were rare in both lakes. However a new species, Glacidorbis pawpela, was recognised by Smith (1979) from two specimens only collected from Cramps Bay level 1 during the routine sampling. Further specimens were collected during the grid survey and at a later date from Elizabeth Bay for the taxonomic description (Smith 1979).

ACARINA: A total of six species of mites were recorded, four from each lake with two species common to both lakes. Only one of these, Piona uncatiformis, occurred with any regularity.

TURBELLARIA: Three species of turbellarians (two triclads and one alloeocoel) were found, three from Arthurs Lake and two of the same species in Great Lake. All three species were previously unknown but the two triclads have since been described by Ball and Tran (1979). One of the planarians was reasonably common in Arthurs Lake but was only found at one site in Great Lake. The second species, Spathula ochyra, was found in Cowpaddock Bay only. The alloeocoel (family Prorhynchidae) was found at two deep sites in Great Lake and four in Arthurs Lake but was not abundant at any of them.

NEMERTEA: A new species of nemertean (Hickman pers. comm.) was found sporadically at four sites in both lakes. It may have been more abundant than noted but could have been missed due to their habit of disintegrating when disturbed.

PORIFERA: Colonies of sponges were recorded from two sites in Great Lake and four sites in Arthurs Lake. Numbers recorded are for separate colonies. They occurred at all sample dates at Morass Bay and most times at the West Lake North site in Arthurs Lake.

HYDROZOA: Isolated colonies of a species of hydroid were also collected from three sites in Arthurs Lake with the major concentration being at the sandy East Lake South site.

3.3 DISCUSSION

CHIRONOMIDAE: The dominant chironomid species in Great Lake and Arthurs Lake, Riethia sp., Procladius villosimanus and Coelopynia pruinosa are also major components of the benthos of seven other Tasmanian lakes (Timms 1978) whilst most other common species found in Great Lake and Arthurs Lake were also recorded by Timms in at least some of the lakes he studied. Riethia (probably the species R. plumosa Freeman and/or R. strictoptera Kieffer) appears to be a widespread genus in larger freshwater lakes in Tasmania and it is also abundant in Lake Tali Karng, the only deep highland lake in Victoria, (Timms 1974a) and Lake Eucumbene in New South Wales (R. Farragher pers. comm.).
P. villosimanus is also abundant in Lake Tali Karng (Timms 1974a) and in three volcanic lakes in South Australia. (Timms 1974b) as well as in some of the Kosciusko glacial lakes (Timms 1980b). The large species Chironomus oppositus also shows a similar distribution to the latter species.

TRICHOPTERA: Atriplectides dubius, a trichopteran, was particularly widespread and at times common in both lakes and occurred at all sites. This species appears at home in a benthic habitat or in streams and occurs throughout Tasmania and in Victoria (Neboiss 1977a). It was recently placed in a separate family, the Atriplectididae (Neboiss 1977b), of which it is presently the only member. It is not known if this species or the other less common species found in Great Lake and Arthurs Lake are present in the benthos of other Tasmanian lakes as Timms (1978) did not identify his species past the family level. However Neboiss (1977a) recorded Ecnomus tillyardi from many areas around the state and Notalina parkeri from several other central plateau areas.

OTHER INSECTA: Plecoptera were not common in either lake whilst Ephemeroptera were numerous only at one site in Arthurs Lake. Only one species, Atalophlebia superba, was found. This species was not recorded by Timms (1978) but he did record other species of the genus. This was also the case with the stonefly genus Leptoperla. Tillyard (1936) found A. superba in abundance around the Great Lake area and he also dredged it from the bottom.

OLIGOCHAETA: From what is presently known 10 of the 13 species of oligochaetes collected are endemic to the two lake systems. As indicated earlier this may well merely reflect a neglect of this group elsewhere in the state as well as on the mainland. However of the 13 species collected, only one (Limnodrilus hoffmeisteri) is at all widespread being common throughout the world (Brinkhurst &

Jamieson 1971). Phreodrilus branchiatus has only been recorded outside Tasmania from southern Chile (Beddard 1891) and a further species which, if it proves to be Haplotaxis heterogyne as suspected by Brinkhurst (pers. comm.), has not previously been collected since its original description by Benham (1903) from New Zealand material. The dominant oligochaete, Haplotaxis ornamentus is considered to be most closely related to several species found in Europe (Brinkhurst & Fulton 1980). The remaining endemic species are all in either of the families Tubificidae or Phreodrilidae. The family Phreodrilidae exhibits a Gondwanaland distribution pattern. One of the tubificid genera, (Antipodrilus), is found also on mainland Australia and New Zealand. The other genus, (Telmatodrilus), is more widespread but poorly known.

This group could be of considerable value zoogeographically as they have relatively low mobilities. However the state of their taxonomy makes comparisons with other Tasmanian or Australian works difficult.

The named species found in other Tasmanian lakes by Timms (1978) (with the exception of P. branchiatus and L. hoffmeisteri) do not overlap with those found in Arthurs Lake or Great Lake. However his Haplotaxis sp., Phreodrilus sp. and Peloscolex sp. may be conspecific with some of the new species described. It remains to be seen if any of these endemic species are represented in the fauna of other Tasmanian lakes.

CRUSTACEA: The crustacean group is also of considerable interest zoogeographically but again the field is limited

by poor taxonomic knowledge, particularly in the amphipod group. The phreatoicid group has been studied by Knott (1975) but as yet his taxonomic revisions have not been published. Consequently the names used are those that are valid at present. Knott (pers. comm.) could not uphold the validity of some of the species described by Nicholls (1943, 1944) from Great Lake whilst some of those he considered to be valid (namely Mesacanthotelson tasmaniae (Thomson) and Colubotelson sp.) were not recollected from that lake during the survey. The fate of these species is unknown along with the amphipod Gammarus ripensis (Smith 1909c) whose equivalent does not appear to have been collected during the survey.

The major qualitative difference between the two lakes is in the phreatoicid faunas but the reason for this is unclear. The Arthurs Lake species Colubotelson sp. is present in shallow tarns and creeks around Great Lake and has been recorded around the shoreline of the lake but it does not occur in its deeper areas which contain possibly four endemic (to Great Lake) species. This high degree of endemicity is unparalleled by the group at a single location elsewhere (Knott pers. comm.). Such endemicity is,however, apparent in Great Lake in other groups e.g. paragalaxiid fishes (McDowall & Fulton 1978).

In contrast to the Great Lake phreatoicids the Arthurs Lake species (Colubotelson sp.) is found over much of Tasmania with the exception of the west coast and an area extending through the midlands to the south-east corner of the state (Knott 1975). Within the above region Timms (1978) recorded Colubotelson sp. from the

benthos of Lakes St. Clair, Dove and Crescent and it is also found in the highlands of south-eastern mainland Australia (Timms 1974a; Knott 1975).

The amphipod fauna is only important in Arthurs Lake where the dominant form is a species of Neoniphargus. The genus is plentiful in Tasmania but its taxonomy is under review at present. Timms (1978) tentatively identified two other species of this genus in his study of seven Tasmanian lakes but only one of these (Neoniphargus cf. exiguus Smith) was common and this was at one site only. The species Neoniphargus ? tasmanicus was formerly listed as common in Great Lake (Smith 1909a) but it was only abundant in parts of Arthurs Lake during this survey. Austrochiltonia australis, a widespread species in south-eastern Australia (Timms 1974b, 1978; Williams 1974), was common at the shallow site in Arthurs Lake only.

Other crustaceans encountered less frequently during the survey were an isopod of the genus Heterias and the syncarid Paranaspides lacustris. The isopod is similar to, but probably not conspecific with H. petrensis from Lakes Sorell and Crescent (Roberts 1975). The latter species was not collected from either of those lakes by Timms (1978). P. lacustris was found in both lakes studied thus extending the known range of this species. It has not been recorded from any other Tasmanian lakes with the exception of two artificial storages downstream from Great Lake, and Woods Lake, (Fulton unpublished) which is connected via the Lake River to Arthurs Lake.

MOLLUSCA: Molluscs are not strongly represented numerically in Great Lake but some species are more frequent in Arthurs Lake. The bivalves Sphaerium lacusedes and members of the genus Pisidium were the main contributors. Smith and Kershaw (1979) have recognised only one species in each genus (S. tasmanicum and P. cas͡ertanum) both of which are widespread in south-eastern Australia. However Kuiper (pers. comm.) has prepared a revision of the sphaeriids of Australia in which he records Sp͡aerium lacusedes, S. tasmanicum, Pisidium tasmanicum and a new species of Pisidium from Great Lake and Arthurs Lake collections. Timms (1978) recorded sphaeriids from all the lakes he studied.

In Lake Leake, Timms (1978) found the gastropod Physastra attenuata (= Physastra gibbosa) which was present but rare in Arthurs Lake. I have seen specimens of this species from Great Lake although it was not found in this survey.

A new species of gastropod, Glacidorbis pawpela, (Smith 1979) collected from Great Lake during this survey has not been recorded elsewhere. The freshwater "limpet" Ancylastrum cumingianus, once quite common in Great Lake (Evans 1939b,1942), was not recorded during the survey but it is not likely that its normal habitat was sampled.

TURBELLARIA: The Tasmanian turbellarian fauna has also lacked detailed taxonomic study until recently (Ball 1974; Ball & Tran 1979). The latter paper described two of the three species recorded during the survey (family Dugesiidae)

whilst the remaining species is a member of the family Prorhynchidae and may be an undescribed species (J. L. Hickman pers. comm.). Timms (1978) recorded unidentified planaria from five of the seven Tasmanian lakes he studied. Ball & Tran (1979) suggested that the new species Romankenkius bilineatus may be the same as the unidentified striped species collected by Leonard and Timms (1974) from Lakes Sorell and Crescent, but the confirmed distribution for this species remains as Great Lake and Arthurs Lake with the genus being endemic to Tasmania.

The second new species, Spathula ochyra, has only been recorded from one shallow site in Arthurs Lake, however the genus is also found in south-eastern Australia and New Zealand. (Ball 1977; Ball & Tran 1979).

The family Prorhynchidae was recorded from Tasmania by Hickman (1934) when he described the species Prorhynchus tasmaniensis from the Lake Fenton area. It is not known where the present species fits into the family. It was not particularly common in either lake studied and there are no published records of occurrence of the group elsewhere in the state.

NEMERTEA: According to Williams (1980) only one species of nemertean is known from freshwater in Australia. The new species collected during this survey has been tentatively placed in the genus Potamonemertes (J. L. Hickman pers. comm.) along with a previously described New Zealand species (Moore & Gibson 1973). The new species was widespread but not common in Great Lake and Arthurs

Lake and was difficult to detect in the samples. It was also difficult to preserve without causing it to eject its proboscis and contract into a tight ball.

ACARINA: Water mites were sporadic in occurrence and, with the exception of one site in Arthurs Lake where Piona uncatiformis was relatively common, they were not a significant part of the fauna. An unidentified species of mite was recorded from three Tasmanian lakes by Timms (1978), whilst several species, including two from Shannon Lagoon, were recorded from Tasmania by Lundblad (1941, 1948). Both the Shannon Lagoon species were recollected during the survey. Szalay (1953) lists 27 species from Tasmania and this list included all the identified species from Great Lake and Arthurs Lake collected during the survey with the exception of Piona uncatiformis which was previously known from Victoria and New South Wales (Lundblad 1948). Viets (1975, 1976, 1978a, b) has recently described some new species from Australia including Tasmania but none of these are known from the Central Plateau.

PORIFERA: A freshwater spongespecies was present in both lakes, being more widespread and slightly more abundant in Arthurs Lake than Great Lake. A number of species of sponges have been recorded from Australia (Racek 1969) but mainly from New South Wales and Queensland. Only two species, Heterotula nigra, and H. multidentata have been recorded from Tasmania (Flynn 1922; Racek 1969). The species collected during this survey has not been identified.

HYDROZOA: The remaining group, the Hydrozoa was represented in Arthurs Lake by one unidentified species. Flynn (1922) recorded specimens of the genera Cordylophora and Hydra from Northern Tasmania but there do not appear to be any other published records of hydroids from Tasmania.

CHAPTER 4

QUANTITATIVE FAUNAL VARIATION OF GREAT LAKE AND ARTHURS LAKE

4.1 INTRODUCTION

The benthic fauna of a lake may be examined quantitatively basically in two ways: in terms of numbers of individuals, or in terms of weight (biomass and/or production). Variation in numbers can be further broken into various component parts.

The species numbers and biomass of both lakes are examined and compared in this chapter with special emphasis on the differences between sites in each lake. Analysis of spatial distribution within a small area would require many more samples than were taken in this survey, therefore little emphasis is placed on this topic. Considerable data on seasonal variation and therefore life history of various species were collected during the survey and these aspects are briefly discussed. However, the study was primarily concerned with identification and quantification of the fauna, consequently this area is more closely examined.

4.2 RESULTS

4.2.1 Faunal Variation

In the analysis of faunal variation numerous mathematical models and methods may be applied and the one selected may be chosen, to a certain extent, to give the "required" result. However the survey was not initiated for the purpose of testing models or as an exercise in ecological theory hence the analysis in some areas proceeds very little beyond direct visual appraisal of the tabulated results.

The presentation of the data is a problem in itself as the records of occurrence of 50 taxa in each of 1560 separate samples cannot be reproduced in an easily useable form. Hence a summary of each 20 sample series was used (see Appendix 2). Inevitably some information may have been lost but the data could not easily have been processed otherwise.

Three main areas of faunal variation were expected and these are designated as:

1. Within series variation
2. Seasonal variation
3. Inter-site variation

The majority of the analysis was related to the variation between sites both within one lake, and between the two lakes studied, as this was where most of the variation was evident both in species present, and numbers of individuals.

4.2.1.1 Within series variation

Within series variation, i.e. the variation between each grab sample at a particular date and site, was not analysed very extensively. The main purpose of such analysis was firstly to establish the sampling procedure, and later to check that it was achieving its objective.

The preliminary samples referred to in Section 2.2 were briefly analysed for such variation by plotting a cumulative mean number of organisms against sample number in order to determine the required number of samples per series to adequately represent the population. Improved efficiency in grab use and sorting techniques during the preliminary sampling program increased the number of species and individuals detected. Graphs of mean number of animals with each successive sample (Figs. 4.1 & 4.2) for the first series of samples taken in Great Lake show similar results to those obtained from the preliminary sampling at SGL2 (Fig. 2.1).

Further support to the sampling strategy as well as data on the uniformity of the fauna is given by examining the total number of different species present with each successive sample. This was done for the first sample in Great Lake (Figs. 4.3 & 4.4) but similar results were also obtained in Arthurs Lake. In most cases over 95% of the total species collected occurred in the first 15 samples. Based on variance to mean ratios the spatial distribution of individual animals within a site was generally contageous to varying degrees i.e. variance > mean. Some species, notably the oligochaetes Haplotaxis ornamentus and Telmatodrilus bifidus, the

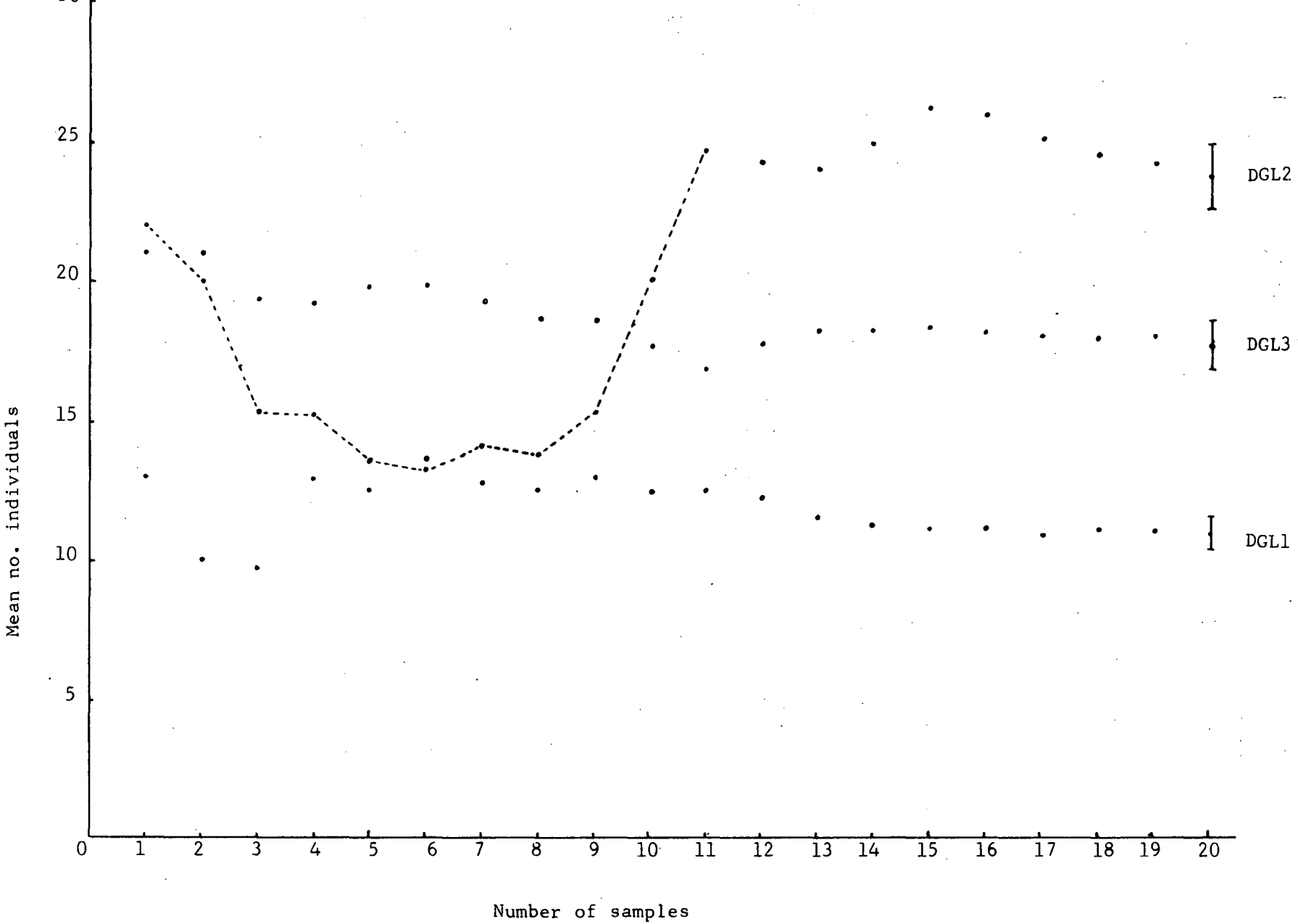


Fig 4.1: Mean number individuals with increasing number of samples, Great Lake level 1 (I shows 5% limits of mean).

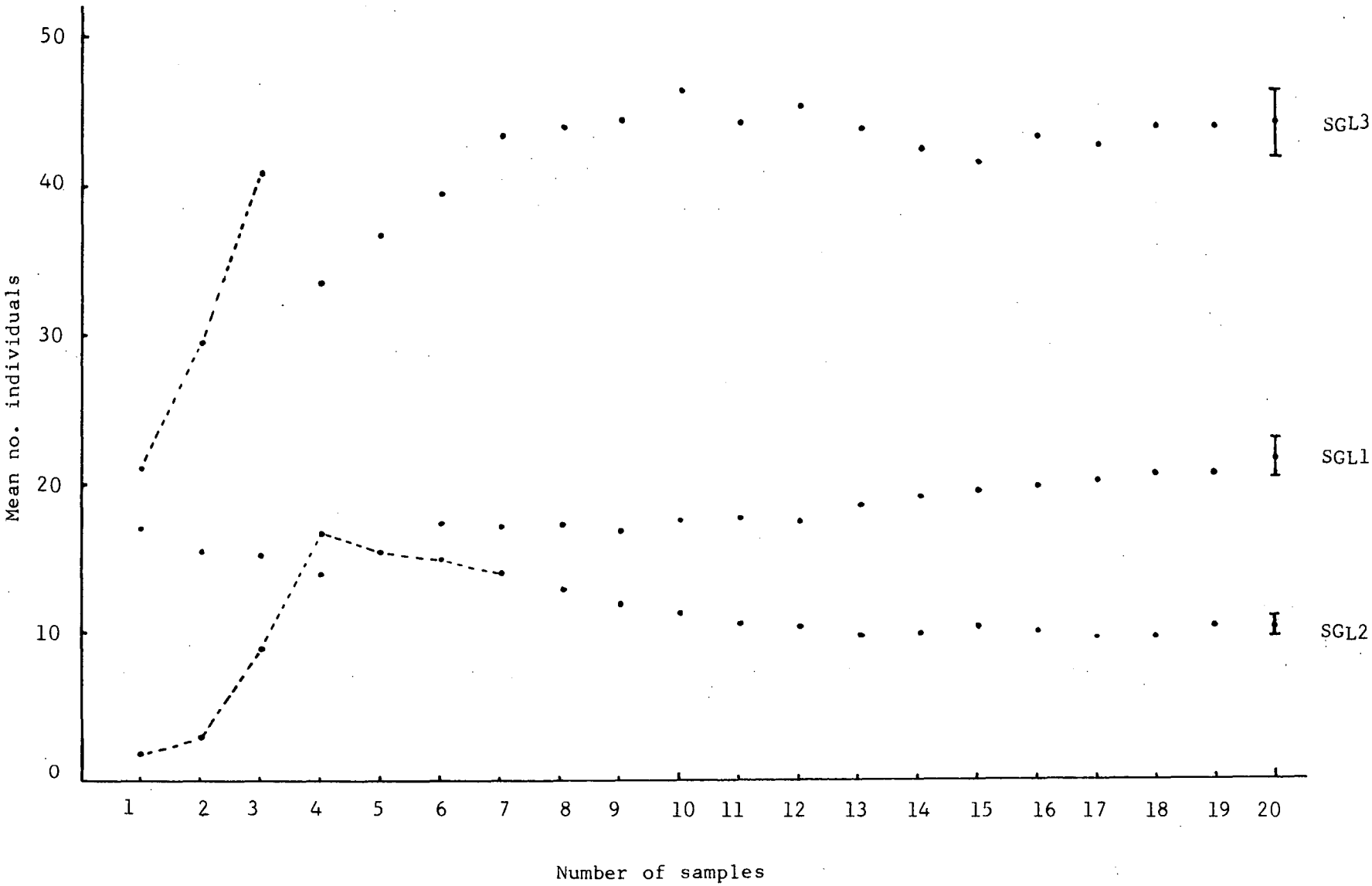


Fig 4.2: mean no. individuals with increasing number of samples, Great Lake level 2

(I shows 5% limits of mean).

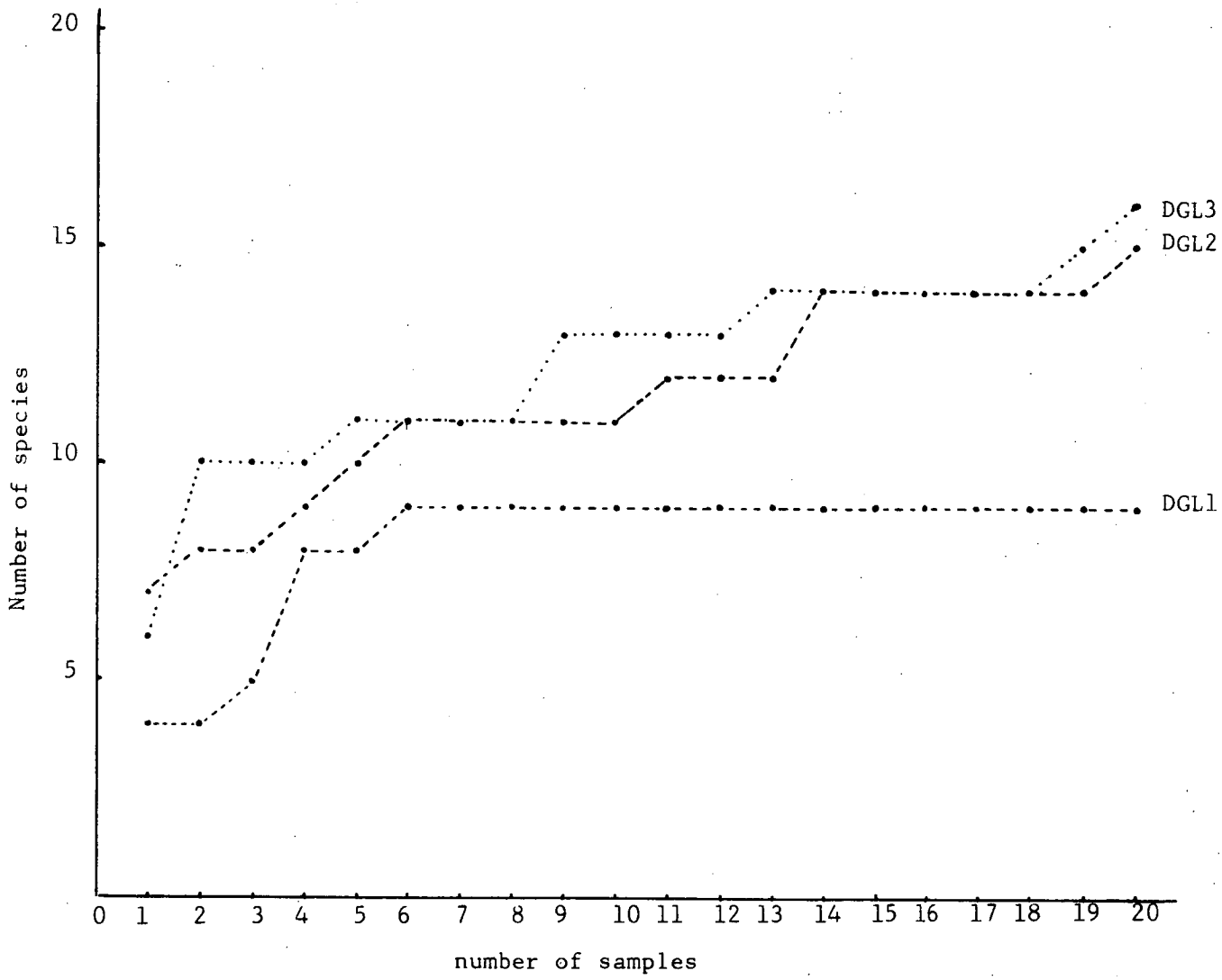


Fig 4.3: Total number of species present with each sample taken, Great Lake level 2, January 1975.

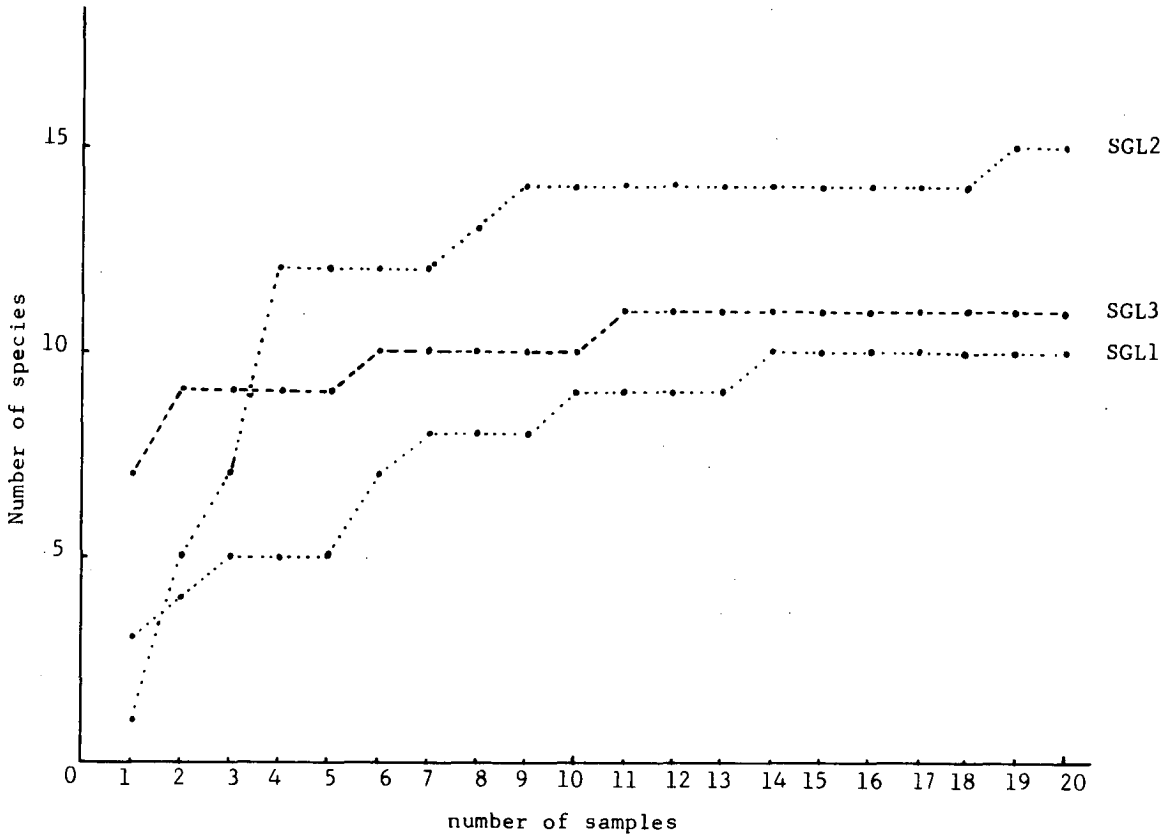


Fig 4.4: Total number of species present with each sample taken, Great Lake level 1, January 1975.

chironomid Coelopynia pruinosa, and the trichopteran Atriplectides dubius displayed random distributions (after Elliot 1971) at various dates and sites. In a couple of cases only, the distribution of H. ornamentus was found to be regular.

The degree to which species showed contageous distributions varied considerably both within and between taxa. The within species variation was most noticeable in some chironomid species, particularly Riethia sp. as well as in the phreatoicids and amphipods of Arthurs Lake and the bivalves wherever they occurred. The common oligochaete species generally were random, or approaching same, in distribution with the possible exception of the tubificid Antipodrilus plectilus which periodically occurred in interwoven clumps of up to about 50 individuals.

4.2.1.2 Seasonal variation

Patterns in the seasonal abundance of individual species were very difficult to detect. There were no consistent peaks in any group when various sites were compared. There were variations in numbers of individual species throughout the year at a particular site but these peaks were often inconsistent between sites.

Naturally, such seasonal variations should be closely allied to the life history of the species concerned. In the case of the chironomid Riethia sp. which exhibits a life cycle of one years duration (section 4.2.2) definite abundance peaks occurred and these can be seen in Fig. 4.5. Another chironomid Procladius villosimanus also appears to show a similar peak in

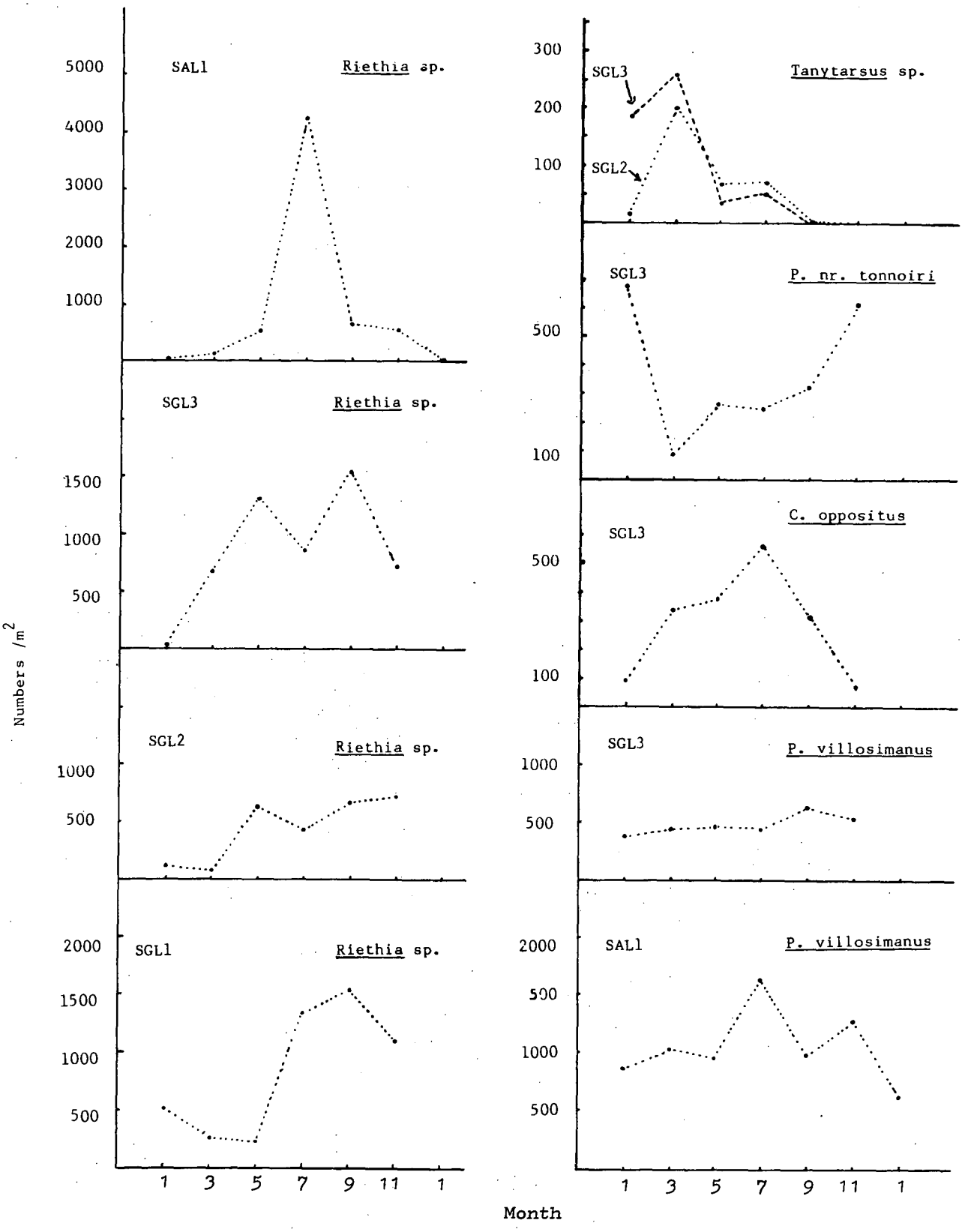


Fig 4.5 : Seasonal variation of numbers of various chironomid species from Great Lake (1975) and Arthurs Lake (1977-78).

Arthurs Lake but it was not common enough at other sites for comparisons to be made (Fig. 4.5). The occurrence of Tanytarsus sp. was markedly seasonal with peak occurrences usually in early March at all sites where it occurred (Fig. 4.5).

In some of the species with life cycles lasting longer than one year there is a tendency for a masking of abundance peaks, caused by an influx of young of the year, by variations in adult numbers. Whether these variations are due to normal mortality or migrations of adults at that time, or possibly to sampling procedures, is unknown. Peaks in the number of phreatoicid juveniles and also their effects on total numbers are shown in Fig. 4.6. These data clearly show the rise in the number of juveniles in the December samples and in Arthurs Lake, where a late January sample was taken, a subsequent drop in juvenile numbers.

The oligochaete group does not show any marked seasonal variations which are at all consistent throughout the sites. The large species H. ornamentus appears to be more common in the autumn-winter samples (Fig. 4.7) but this may be attributable to chance.

The inconsistency of seasonal samples within sites is emphasised when the overlapping January 1977 and 1978 samples from Arthurs Lake sites are examined. Shannon-Weiner diversity indices were calculated for each site at each date (Table 4.1). This index has two components. It varies with the number of species present and also the abundance of each species in relation to the total number of individuals in the community. The maximum index

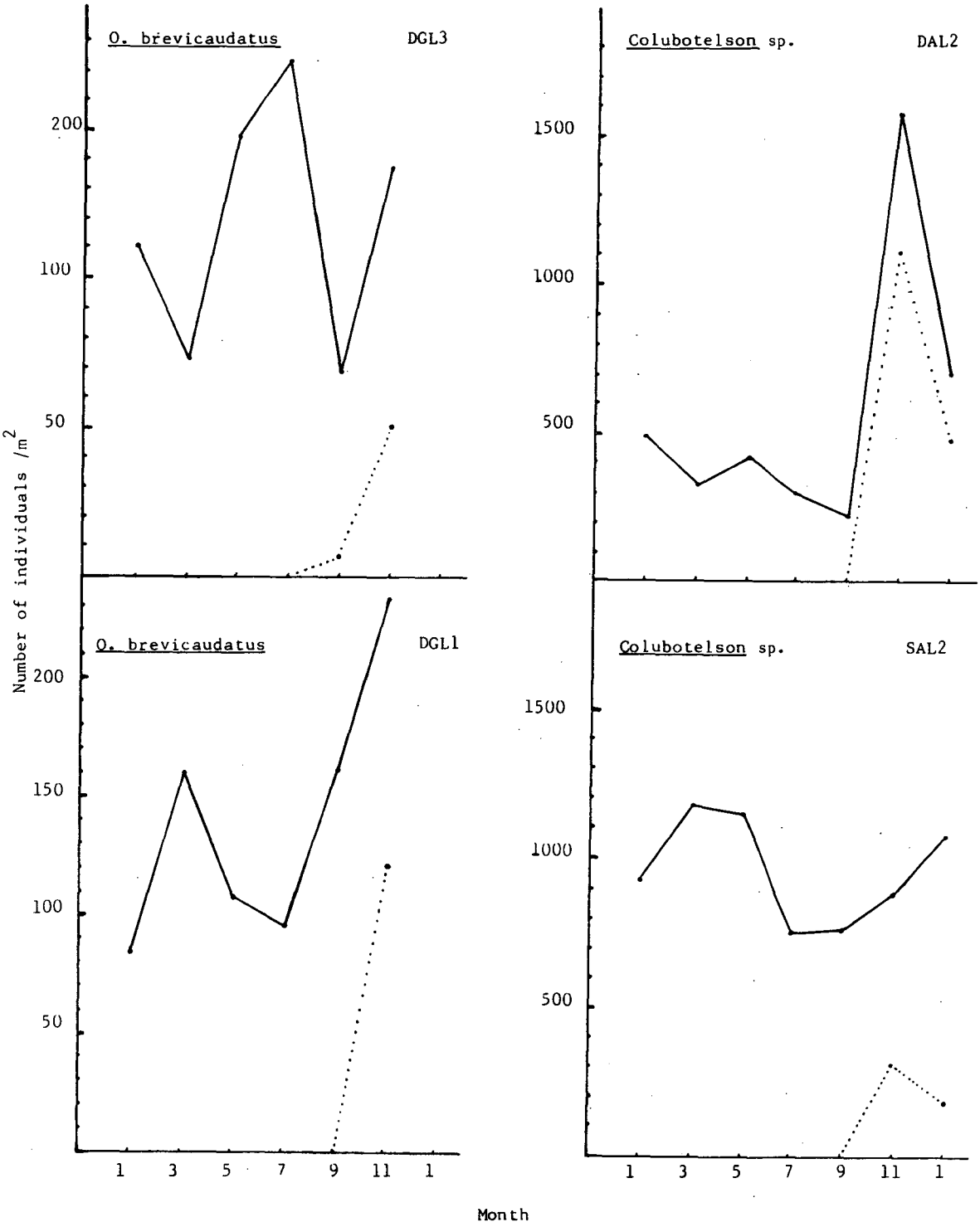


Fig. 4.6 : Variation in total numbers of phreatoicids present at various sites in the Great Lake (1975) and Arthurs Lake (1977-78). (.... indicates number of juveniles in the total).

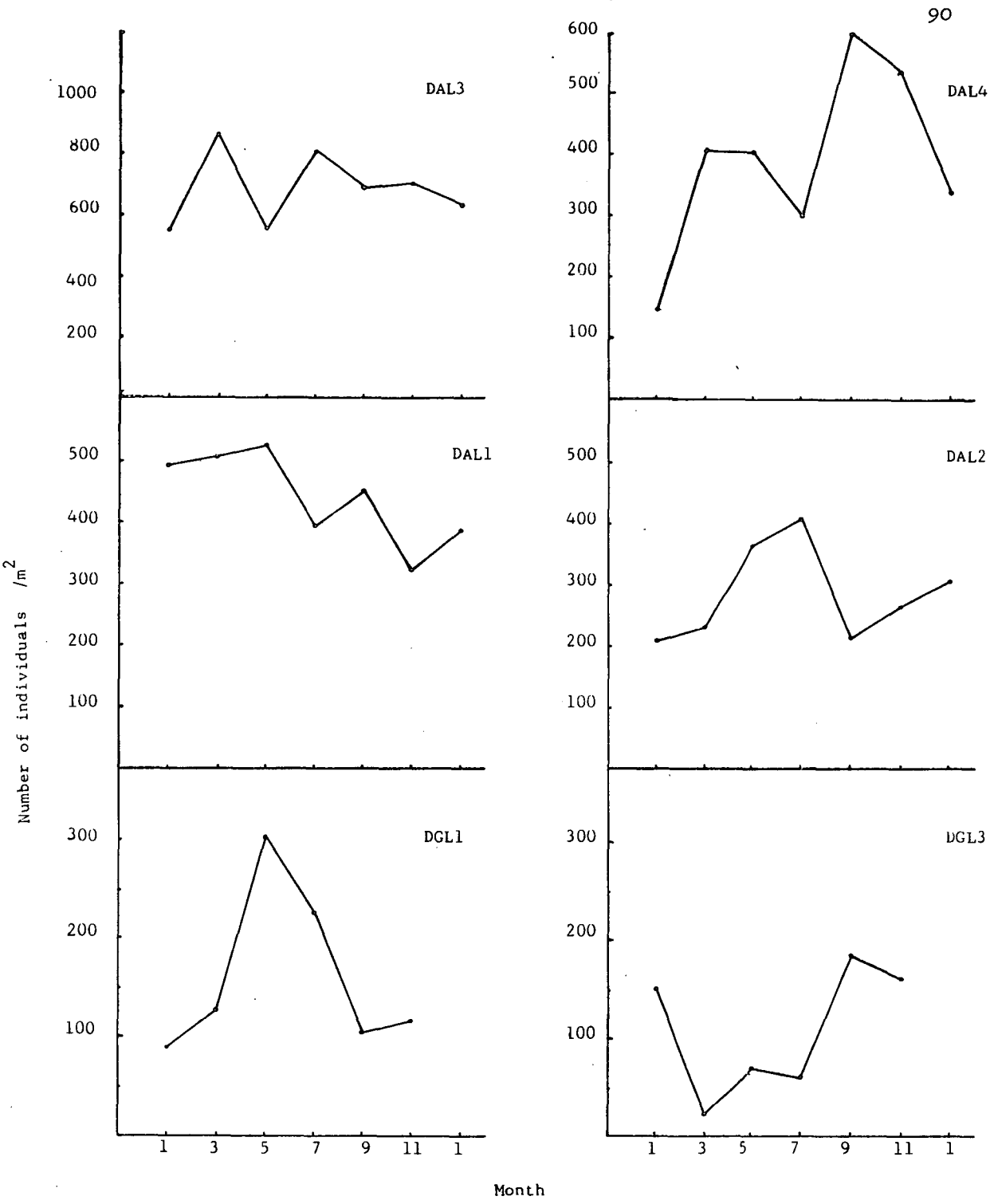


Fig 4.7 : Numbers of H. ornamentus present at various sites in Great Lake (1975) and Arthurs Lake (1977-78).

Table 4.1: Diversity indices for each site from Great Lake and Arthurs Lake.

Site	Sample date	Total individuals	Total spp.	Shannon-Weiner	Pielou's Eveness
DGL1	1	216	9	1.7476	0.7954
	3	676	11	1.7410	0.7261
	5	298	12	1.6235	0.6533
	7	414	12	1.9166	0.7713
	9	389	10	1.7152	0.7449
	11	346	14	1.6727	0.6338
DGL2	1	473	14	1.5576	0.5902
	3	631	17	1.8226	0.6433
	5	773	16	1.1234	0.4052
	7	613	17	1.6926	0.5974
	9	721	18	1.4484	0.5011
	11	469	17	1.9114	0.6746
DGL3	1	357	17	2.1733	0.7671
	3	270	13	2.0931	0.8161
	5	284	17	2.0653	0.7289
	7	268	18	2.0673	0.7152
	9	264	15	2.1291	0.7862
	11	309	14	1.9325	0.7323
SGL1	1	433	10	1.3660	0.5932
	3	418	18	2.1191	0.7332
	5	348	19	2.0926	0.7107
	7	879	15	1.0802	0.3989
	9	1027	17	1.1258	0.3974
	11	763	13	1.3031	0.5080
SGL2	1	201	15	2.0928	0.7728
	3	262	15	2.0006	0.7388
	5	476	19	1.6074	0.5459
	7	350	15	1.5277	0.5641
	9	414	18	1.1798	0.4082
	11	390	17	0.7910	0.2792
SGL3	1	891	11	1.5809	0.6866
	3	1076	11	1.6184	0.7029
	5	1333	10	1.4029	0.6385
	7	1167	12	1.5536	0.6479
	9	1566	11	1.3688	0.5944
	11	1099	10	1.4590	0.6640

Table 4.1 continued

Site	Sample date	Total individuals	Total spp.	Shannon-Weiner	Pielou's Eveness
SAL1	1	952	19	1.8937	0.6431
	3	1368	21	1.9083	0.6268
	5	1409	23	1.9764	0.6303
	7	3013	18	1.0524	0.3641
	9	1309	20	1.7935	0.5987
	11	1238	18	1.4421	0.4989
	1	1367	19	1.6709	0.5675
SAL2	1	918	13	1.3354	0.5206
	3	770	11	0.9922	0.4138
	5	908	15	1.1808	0.4360
	7	590	14	1.2929	0.4899
	9	530	10	1.0673	0.4635
	11	619	13	1.2273	0.4785
	1	631	13	1.0948	0.4268
DAL1	1	896	15	1.8626	0.6878
	3	1065	13	1.7756	0.6922
	5	1060	14	1.6317	0.6183
	7	972	13	1.6762	0.6535
	9	977	13	1.7730	0.6913
	11	552	10	1.7295	0.7511
	1	899	12	1.8551	0.7466
DAL2	1	845	19	1.6781	0.5699
	3	998	15	1.7163	0.6338
	5	1199	14	1.7565	0.6656
	7	1168	14	1.9877	0.7532
	9	829	19	1.9324	0.6563
	11	1551	21	1.6225	0.5329
	1	1327	23	2.0136	0.6422
DAL3	1	394	12	1.1503	0.4629
	3	672	14	1.4427	0.5467
	5	727	13	1.7795	0.6938
	7	1110	15	1.7655	0.6519
	9	560	15	1.4887	0.5497
	11	596	15	1.5743	0.5813
	1	472	14	1.3493	0.5113
DAL4	1	586	17	1.9998	0.7058
	3	408	17	1.8424	0.6503
	5	541	17	1.8275	0.6450
	7	608	17	2.0591	0.7268
	9	746	16	1.8032	0.6504
	11	1048	17	1.8546	0.6546
	1	426	15	1.9359	0.7149

for a given number of species is obtained when all species are equally represented.

The differences between each index were tested for significance using a 't' test as described by Poole (1974). The within site analysis compared the results for each date at the one site (see Table 4.2 and Appendix 4). A significant difference at the 0.001 level of probability was recorded for three of the six sites when the January 1977 and January 1978 samples were compared.

The use of the Shannon-Weiner diversity index within each site could give some indication of the seasonal variation apparent, but it does not necessarily indicate peaks. This method may be useful in this case, as, within one site, the fauna present (at least the dominants) is relatively constant in composition throughout the year. Therefore, the differences in the diversity index for each date could be largely due to variations in abundance only. The number of significantly different comparisons ($p < .001$) of pairs of sample series for each site (from 't' test for differences between pairs within sites - Table 4.2 and Appendix 4) therefore becomes a crude comparative measure of seasonal variation exhibited by each site (see Table 4.3). This table broadly indicates that the shallow sites are subject to the greatest variation in seasonal abundances.

4.2.1.3 Inter-site variation

4.2.1.3.1 Diversity indices

The Shannon-Weiner indices were used to compare samples taken from all the sites at the same time of year. Significance tests for differences between each pair of

Table 4.2: Tests for significance between Shannon-Weiner diversity indices for each sample series from DAL1 Arthurs Lake.

Month	N	S	H	J	E(H)	Var(H)
1	896	15	1.8626	0.6878	1.8547	0.0007
3	1065	13	1.7756	0.6922	1.7699	0.0010
5	1060	14	1.6317	0.6183	1.6255	0.0009
7	972	13	1.6762	0.6535	1.6701	0.0008
9	977	13	1.7730	0.6913	1.7669	0.0010
11	552	10	1.7295	0.7511	1.7213	0.0011
1	899	12	1.8551	0.7466	1.8490	0.0006

Table of 't' values:

1	2	3	4	5	6	7	month
	2.142	5.819	4.788	2.217	3.159	0.209	1
		3.332	2.338	0.058	1.014	2.012	2
			1.071	3.290	2.193	5.791	3
				2.290	1.212	4.732	4
					0.962	2.088	5
						3.057	6
							7

Table of degrees of freedom:

1743	1764	1778	1749	1704	1789
	1795	1788	1797	1791	1699
		1795	1796	1779	1726
			1790	1765	1747
				1789	1706
					1651

Where: N = total number of individuals
S = number of species
H = S-W index
J = Pielou's eveness index
E(H) = expected value of H
Var(H) = variance of H

Tables for all other sites are included in Appendix 4

Critical 't' value 3.291 for probability < 0.001

Table 4.3: Number of significant differences between pairs of sample series within each site in Great Lake and Arthurs Lake.

no. significant differences	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Site	DGL3		DAL1	DGL1			SAL2	DAL2		SAL1	SGL1		SGL2	
				DAL4			SGL3			DGL2			DAL3	

indices were again made for each of the sites for all groups of two monthly samples. (The January 1978 Arthurs Lakes series were not included). Tables similar to those shown in Table 4.2 and Appendix 4 resulted but with more comparisons (Table 4.4 and Appendix 5). The pairs which did not show significant differences at the 0.001 level were recorded i.e. the sites most similar. After the data for each of the six dates were compared a table showing the number of times each site was grouped with each other site was drawn up (Table 4.5). This analysis did not group any two sites on all occassions. Site DGL1 was linked with sites DAL1, DAL2, DAL4 and SGL3 on five occas~ions. Further cross linkages were made at the next level. On the other end of the scale site SAL2 was linked least with the other sites.

The conclusions which can be drawn using diversity indices are limited largely by the absence of taxonomic data. Similar indices may arise irrespective of the composition of the fauna i.e. in a hypothetical case a community consisting of 10 species from the one genus could have the same diversity index as one consisting of 10 species from separate phyla. It was therefore considered that the diversity indices of the chironomid or oligochaete groups could provide useful comparisons. However the diversity indices were not further examined as a form of cluster analysis using presence and abundance data for each species was considered more appropriate.

4.2.1.3.2 Cluster analysis

The results obtained from cluster analysis of the

Table 4.4: Tests for significance between Shannon-Weiner diversity indices for each site for month 1 in Great Lake and Arthurs Lake.

Site	N	S	H	J	E(H)	var (H)
DGL1	216	9	1.7476	0.7954	1.7291	0.0022
DGL2	473	14	1.5576	0.5902	1.5439	0.0021
DGL3	357	17	2.1733	0.7671	2.1509	0.0018
SGL1	433	10	1.3660	0.5932	1.3556	0.0023
SGL2	201	15	2.0928	0.7728	2.0580	0.0042
SGL3	891	11	1.7654	0.7362	1.7598	0.0007
SAL1	952	19	1.8937	0.6431	1.8842	0.0014
DAL1	896	15	1.8626	0.6878	1.8547	0.0007
DAL2	845	19	1.6781	0.5699	1.6675	0.0010
SAL2	918	13	1.3354	0.5206	1.3289	0.0010
DAL3	394	12	1.1503	0.4629	1.1363	0.0034
DAL4	586	17	1.9998	0.7058	1.9861	0.0015

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	2.891	6.720	5.725	4.311	0.331	2.426	2.151	1.156	7.368	8.013	4.141	DGL1
		9.760	2.885	6.701	3.896	5.609	5.740	2.012	3.992	5.480	7.294	DGL2
			12.604	1.033	8.098	4.882	6.197	8.647	15.865	14.163	2.991	DGL3
				9.014	7.331	8.659	9.149	5.124	0.539	2.871	10.284	SGL1
					4.660	2.642	3.285	5.503	10.514	10.800	1.226	SGL2
						2.768	2.615	1.885	10.571	9.627	4.960	SGL3
							0.675	4.010	11.396	10.699	1.944	SAL1
								4.004	13.047	11.178	2.918	DAL1
									6.999	7.599	5.897	DAL2
										2.813	13.328	SAL2
											12.120	DAL3
												DAL4

Table of degrees of freedom:

1171	1163	1171	1062	1052	1126	919	1125	1016	1119	1137
	1165	1171	1058	1057	1129	923	1128	1021	1115	1140
		1159	1013	976	1155	967	1155	1065	1077	1162
			1073	1041	1117	908	1117	1004	1128	1129
				866	944	769	943	837	1157	960
					1148	1113	1148	1167	925	1138
						1036	1171	1124	1009	1171
							1037	1139	812	1020
								1124	1009	1170
									892	1111
										1026

Tables for all other sample series are included in Appendix 5.

Critical 't' value 3.291 for probability < 0.001

Table 4.5: Frequency of insignificant differences between site pairs from comparisons of Shannon-Weiner diversity indices for the six sample dates (Table 4.4 and Appendix 5).

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	site
	2	1		1	5	2	5	5		2	5	DGL1
		1	1	3	3	1	3	2	1	2	2	DGL2
			2	2		1	1	2			3	DGL3
				2		3			3	1		SGL1
					3	2	4	1	2	2	3	SGL2
						2	5	3		3	1	SGL3
							3	1		1	4	SAL1
								3		3	4	DAL1
										1	4	DAL2
												SAL2
											1	DAL3
												DAL4

data are given in dendrogram form in Figs. 4.8 - 4.10 whilst the similarity matrices for each arrangement of the data are included in Appendix 6.

The results of these analyses are quite consistent for each arrangement of the data. In each case the nearest neighbour technique tended to hasten the clustering of groups whilst the furthest neighbour technique prolonged the groupings. The nearest neighbour technique also has the tendency to cluster in a single linkage pattern rather than form groups. The average linkage method appears to be slightly favourable although all three methods gave quite consistent results for the significant groupings within each set of data.

Some differences in groupings, although minor, were obtained between the three arrangements of the data. The main change observed was that sites DAL1 and DAL3 were most closely related when species presence only was considered (Fig. 4.8) but when the rare species were excluded (Fig. 4.9) and also when species abundance was included (Fig. 4.10) the groupings altered to produce slightly different arrangements of the deep sites.

The first cluster analysis technique which was a grouping based on species occurrence only (Fig. 4.8) highlighted the independant nature of most sites. On this basis the closest grouping was between two deep Arthurs Lake sites from separate basins in the lake. The first grouping between lakes was between site DAL2 and DGL3. There was, however, a consistent split between the shallow sites and the deep sites with the intermediate SAL2 site generally grouping with the shallow sites.

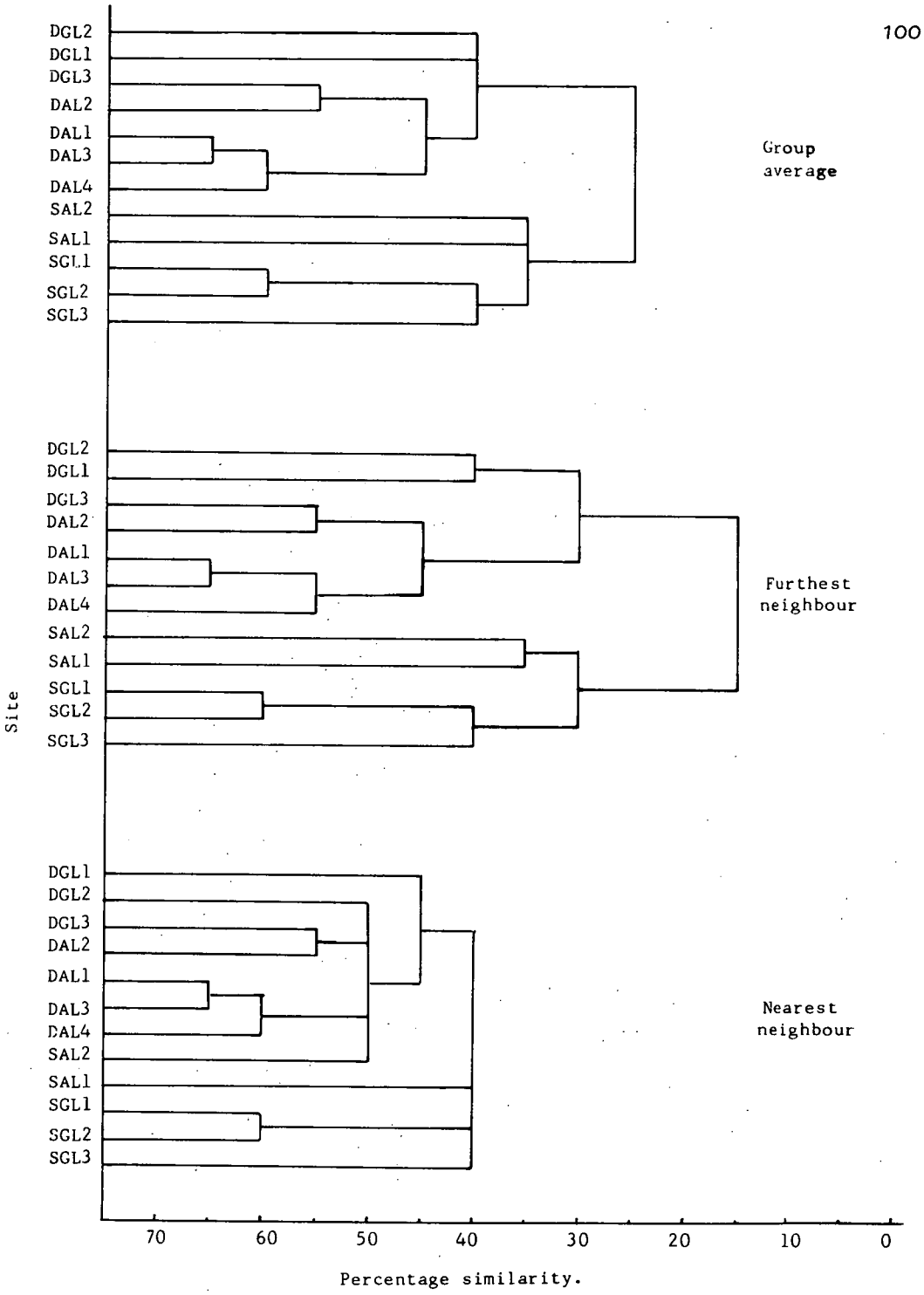


Fig. 4.8 : Cluster analysis groupings for all sites in Great Lake and Arthurs Lake using presence/absence data only.

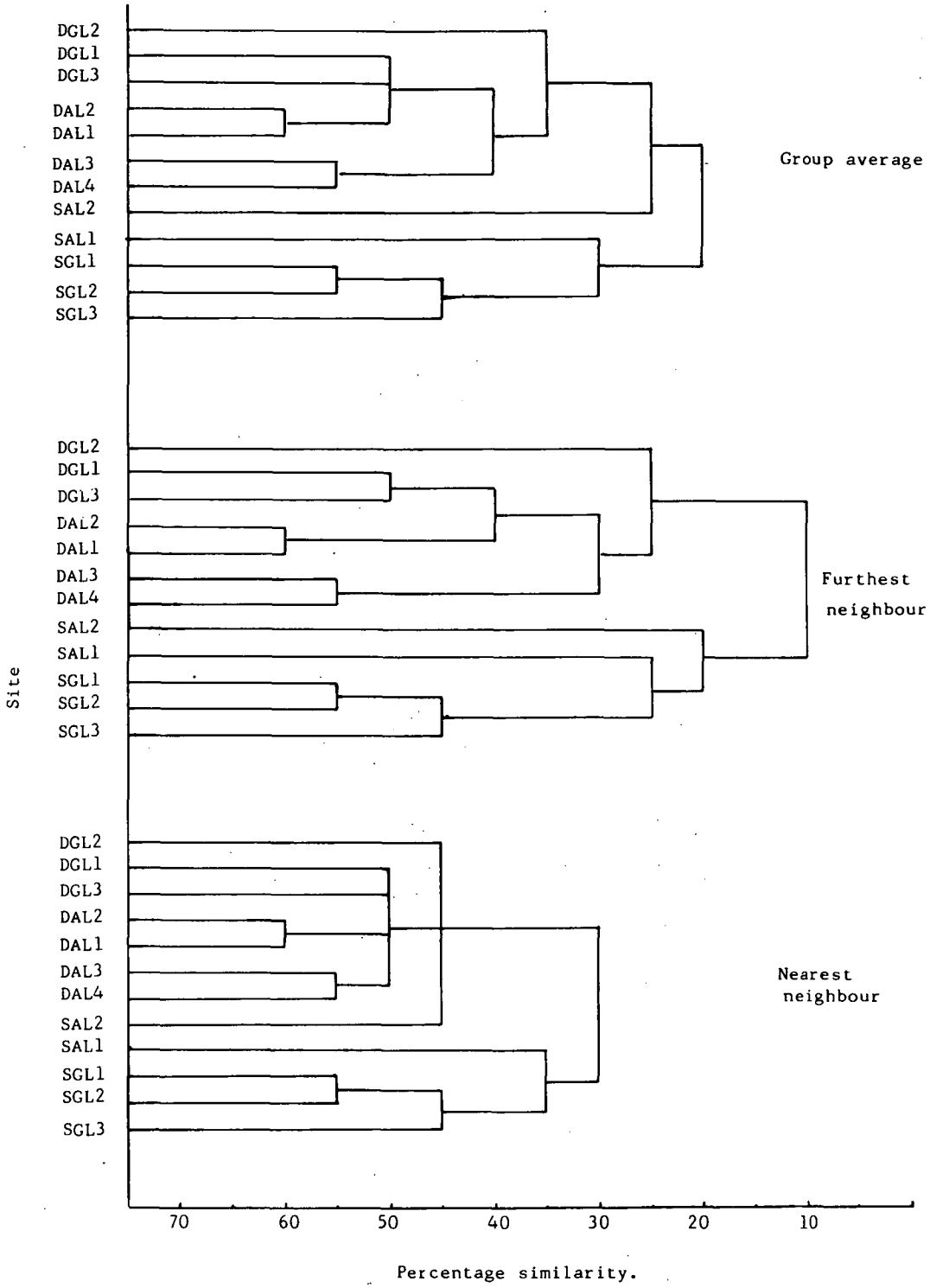


Fig. 4.9 : Cluster analysis groupings for all sites in Great Lake and Arthurs Lake excluding rare species data.

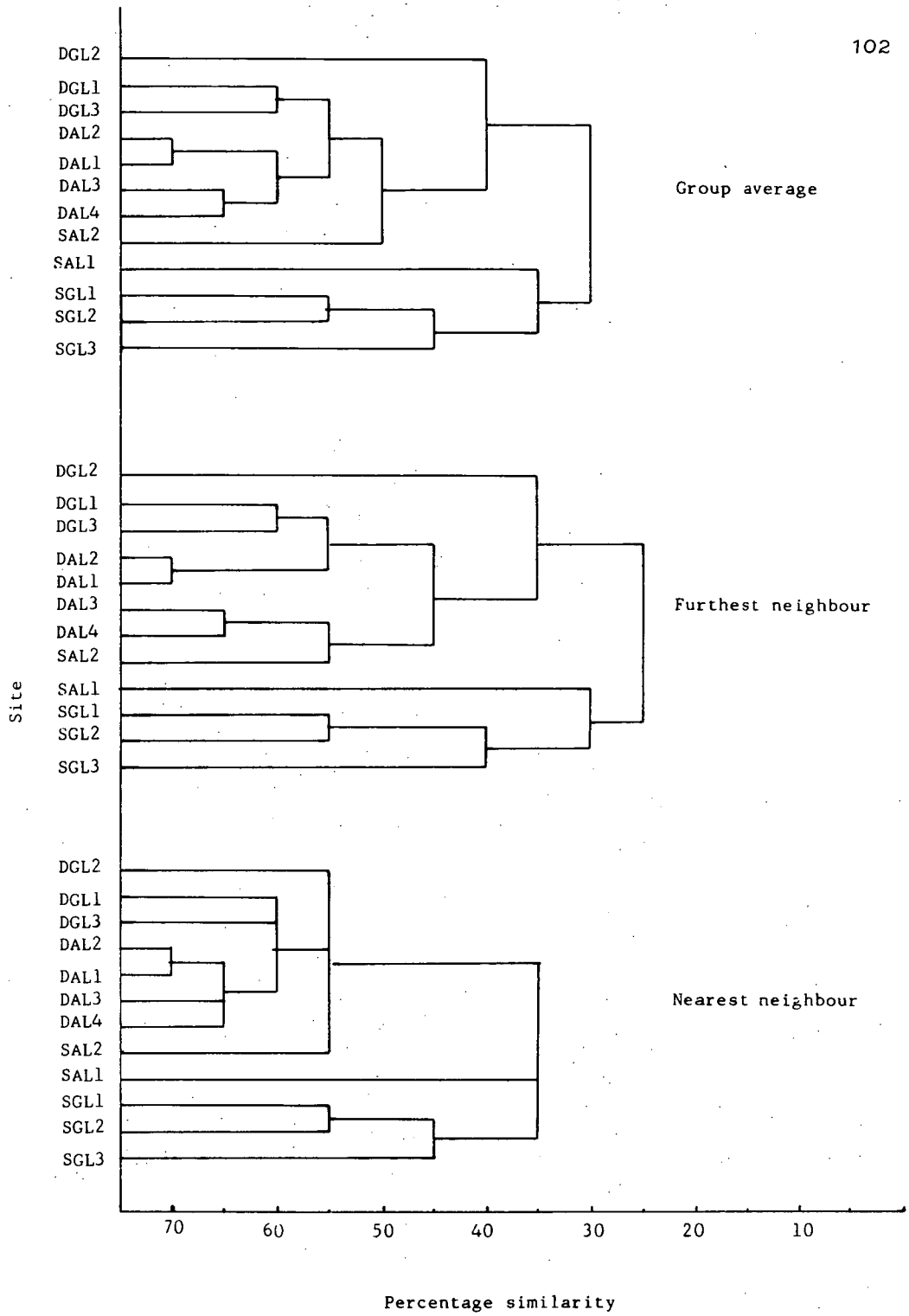


Fig. 4.10 : Cluster analysis groupings for all sites in Great Lake and Arthurs Lake including all species and abundance data.

The cluster analysis excluding species with only two occurrences (Fig. 4.9) gave essentially similar primary clusters (with slightly lower levels of association) to that obtained when abundance data were included (Fig. 4.10).

The three deep Great Lake sites do not unite as a group above the 50% level of association with or without consideration of abundance data. One of these sites, DGL3, usually associates with DGL1 and then with the deep Arthurs Lake sites before the deep Brandum Bay site DGL2. However, of the deep Great Lake sites the greatest qualitative faunal similarities are probably between sites DGL1 and DGL2 although this is at quite a low level (see Fig. 4.8).

No two sites were grouped at any greater than a 70% level of similarity by any arrangement of the data or clustering strategy. The groupings generally arrived at throughout by the 50% level of similarity are that the four deep Arthurs Lake sites (DAL1, DAL2, DAL3, DAL4) have associated in some way either altogether or via other groupings. The two shallow western Great Lake sites (SGL1, SGL2) associate with each other at the 55% level or above in each case. Other groupings are usually consistent in direction throughout although they may be at variable (usually lower than 50%) levels of significance. Nevertheless, the unions are of interest.

The first site to join the SGL1, SGL2 group is always site SGL3, the third shallow Great Lake site, whilst the shallow Arthurs Lake site SAL1 invariably joins this group before, or at the same time as it is united with the deeper

sites. The three deep Great Lake sites (DGL1, DGL2, DGL3) group in pairs, with each other, or, with the deep Arthurs Lake sites, but total union of these three sites is always at less than 45% similarity.

The three clustering strategies always group the shallow sites from both lakes together and the deep sites from both lakes together at, or before uniting all sites regardless of the arrangement of the data with the exception of site SAL2. This site is intermediate in depth between the newly flooded and original lake areas of Arthurs Lake. It is placed in various positions by the sorting strategies employed usually with the deep sites but occassionally with the shallow sites at a low level of similarity.

The grouping of the fauna of the various sites by cluster analysis has therefore been approached in nine different ways: (three data arrangements and three sorting strategies, Figs. 4.8, 4.9, 4.10).

4.2.1.3.3 Principal coordinates analysis

Principal coordinates analysis (PCA) examines the variation between sites in terms of its component parts or latent vectors, and it is possible, if warranted, to label the component parts contributing most to the division. This analysis was performed on the same three arrangements of the data used in the cluster analyses. The contribution by the first vector in each analysis (Appendix 7) was only about 20% of the total variation and subsequent vectors only added slowly to these levels. The PCA grouped the fauna in a basically similar fashion to the cluster analyses. Once again, the shallow sites

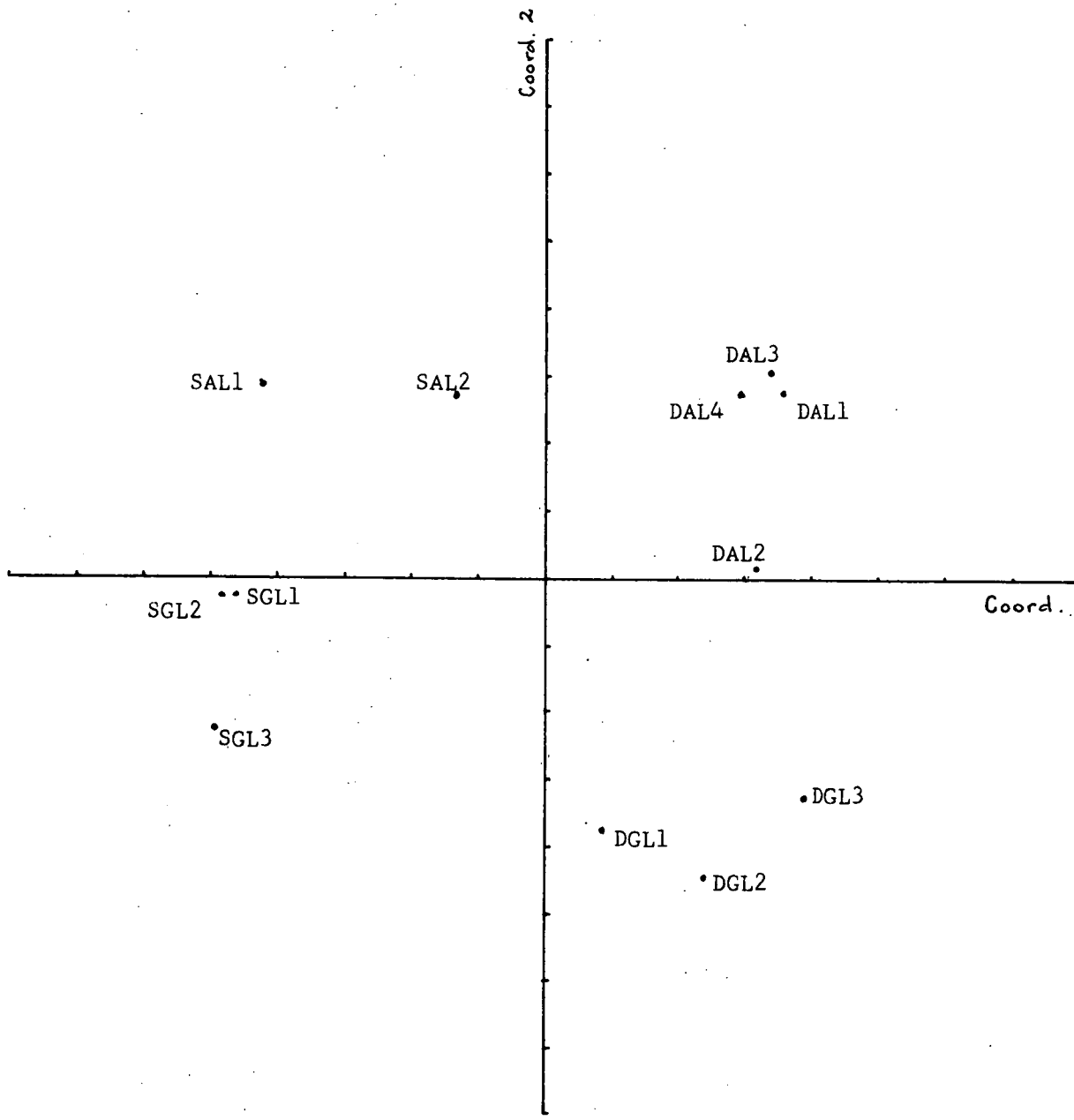


Fig. 4.11 : Plot of first two latent vectors from PCA using species presence/absence data only from all sites in Great Lake and Arthurs Lake.

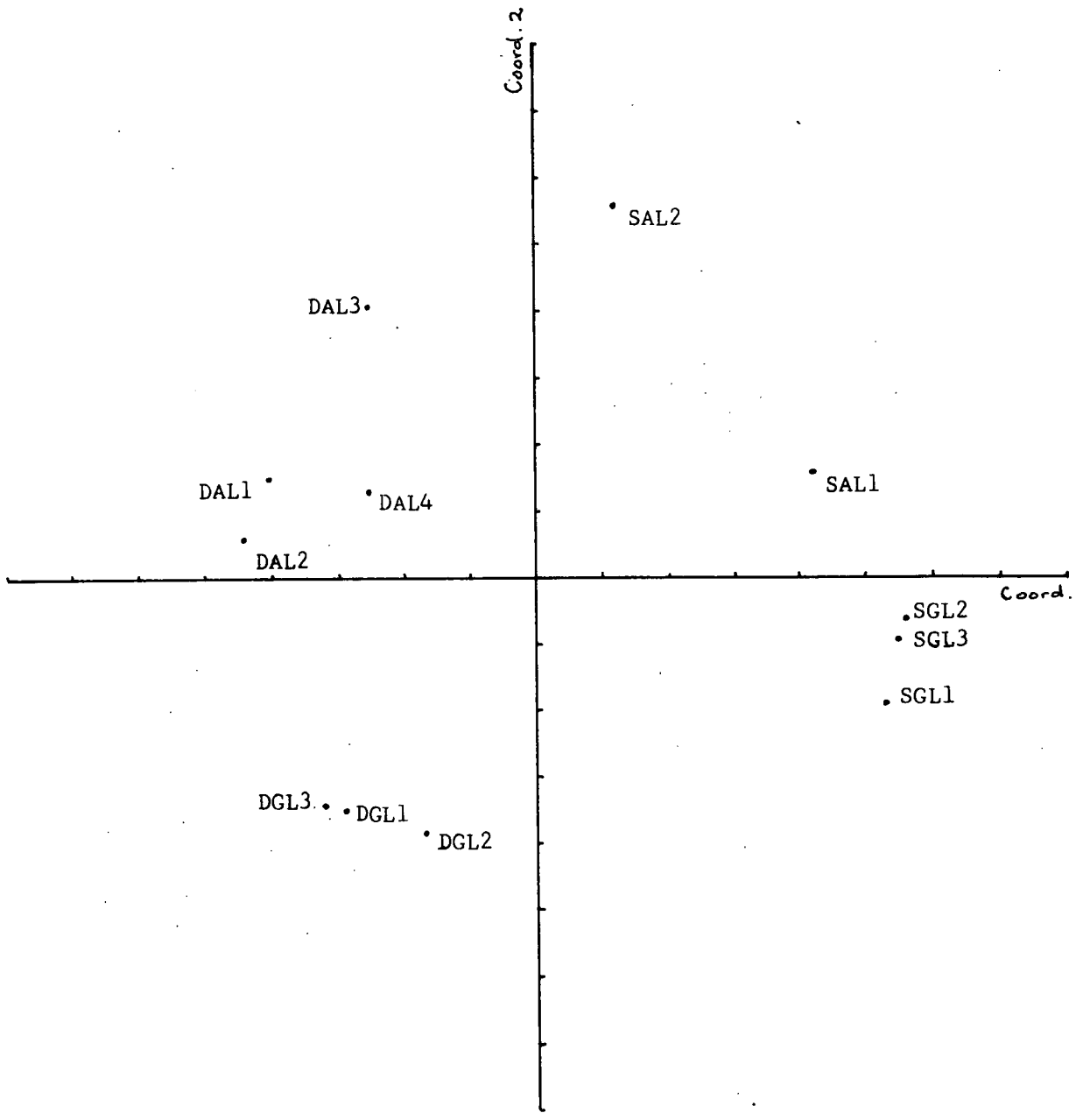


Fig. 4.12: Plot of first two latent vectors from PCA using abundant species data only from all sites in Great Lake and Arthurs Lake.

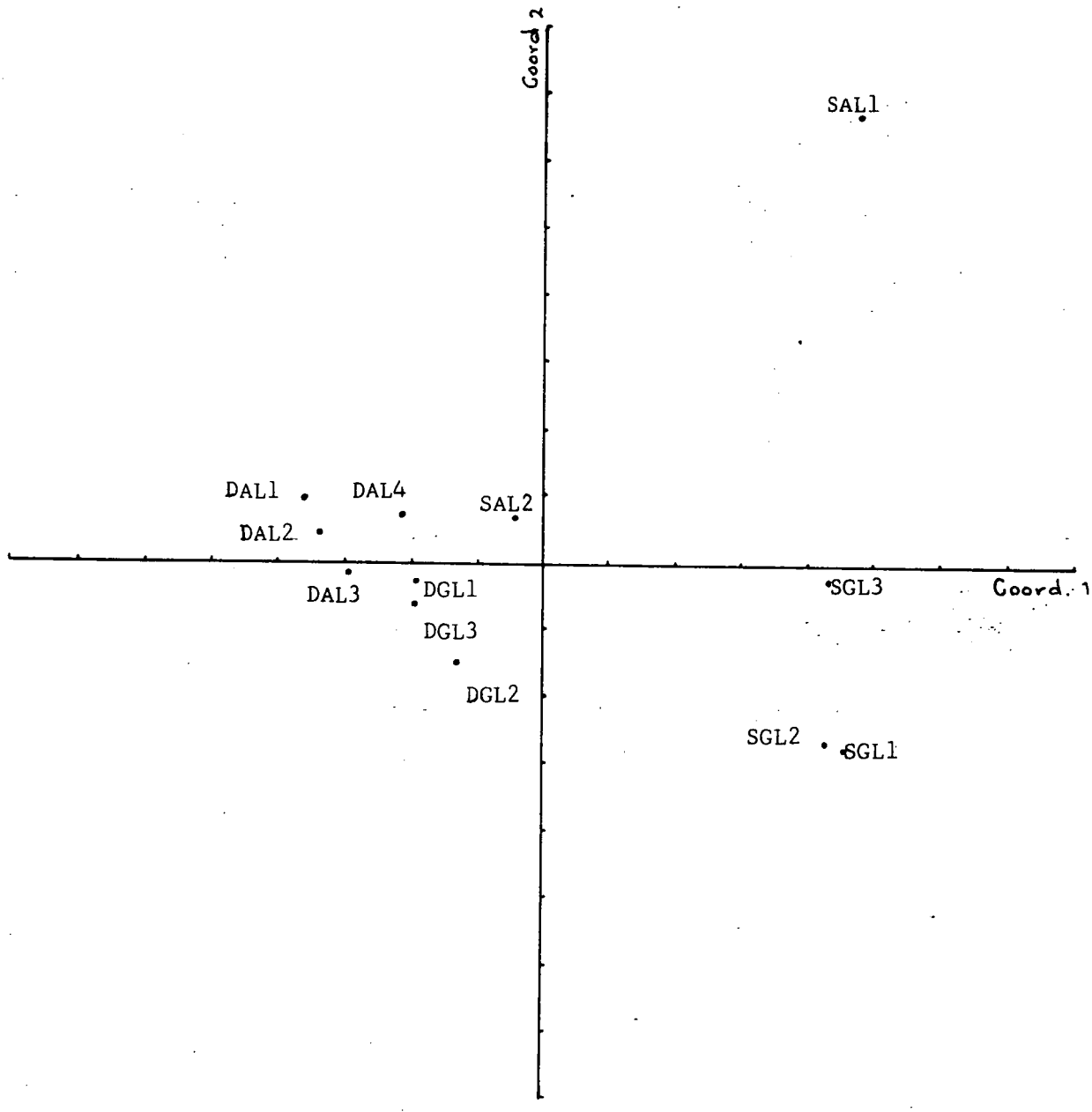


Fig. 4.13 : Plot of first two latent vectors from PCA using all species and abundance data from all sites in Great Lake and Arthurs Lake.

and the deep sites form groups under the various data arrangements when values for the first two vectors are plotted against each other (Figs. 4.11, 4.12, 4.13).

Although the variation between sites is apparently quite subtle it is sufficient to separate the shallow and deep sites in both lakes and give consistent groupings of these when applied to each arrangement of the data.

4.2.1.3.4 Site faunal relationships

Some relationships between sites are clearly established from the treatment of the data. The deep sites of both lakes show overall similarities to each other whilst the two shallow Great Lake sites SGL1 and SGL2 are consistently closely associated. The third shallow Great Lake site, SGL3, is more loosely joined to the latter group, as in turn is the shallow Arthurs Lake site SAL1. The Morass Bay site in Arthurs Lake, SAL2, is intermediate between both groups showing tendencies towards each in some respects. Further examination of the deep sites divides them into two groups on an Arthurs Lake - Great Lake basis with a closer union within a group between the four Arthurs Lake sites than between the three Great Lake sites.

Some further relationships between the deep sites are suggested from the analyses. The deep Arthurs Lake sites tend to group in pairs with an East Lake - West Lake distinction. There is a tendency for site DAL2 to show variability in some respects in the grouping. The three deep Great Lake sites are probably weaker in their association to each other or to any other site than the Arthurs Lake basins are to each other.

The major sources of variation between the shallow sites (SAL1, SGL1, SGL2, SGL3) and deep sites (DAL1, DAL2, DAL3, DAL4, DGL1, DGL2, DGL3) would appear to be easily explained as major qualitative differences in the oligochaete and crustacean faunas as well as some qualitative and quantitative differences in the chironomids. The differences are readily apparent from examination of Table 3.1 and Appendix 2.

The Cowpaddock Bay site (SAL1) differs from the shallow Great Lake sites in the crustacean group i.e. a different phreatoicid and the presence of Austrochiltonia australis. The presence and abundance at SAL1 of the chironomids Cladopelma curtivalva and Dicrotendipes sp. and the increased abundance of Procladius villosimanus are also important. The presence of Ephemeroptera, Plecoptera, increased numbers of mites and the planarian Spathula ochyra at this site also contribute to its distinction from shallow Great Lake sites.

The Cramps Bay level 2 site (SGL3) differs in turn from the other two shallow Great Lake sites primarily by the absence of crustaceans, and generally higher chironomid numbers. The differences between SGL1 and SGL2 are considerably less marked and relate more to certain species rather than whole groups. The phreatoicid Onchotelson brevicaudatus is absent from SGL2 whilst the oligochaete Phreodrilus branchiatus and the nemertean were not found at SGL1. Abundance differences are also apparent in the chironomid species Tanytarsus sp., Polypedilum nr. tonnoiri and P. villosimanus as well as in the trichopteran Atriplectides dubius and the oligochaetes

P. proboscidea and, to a lesser extent, Limnodrilus hoffmeisteri.

The Morass Bay site (SAL2) is probably separated from the deep sites because of the absence of the typical deep water oligochaetes. It is separated from the shallow sites by the lack of the typical shallow water chironomids, the Chironominae.

The deep Arthurs Lake and Great Lake sites may be distinguished by their crustacean faunas which, as mentioned earlier, are the major differences between the two lakes. Phreatoicids are common in both lakes but the species are different. The amphipods are very abundant in Arthurs Lake but are rare in Great Lake. The remainder of the fauna, with the exception of isolated species, does not show any distinct consistent differences between the two lakes but does serve to distinguish between individual sites.

Within Great Lake the three deep sites show several qualitative cross linkages which are difficult to distinguish in order of importance. The phreatoicid Uramphisopus pearsoni was only found at DGL2 as was the oligochaete L. hoffmeisteri. The abundance of the species C. pruinosa, A. dubius, A. plectilus and A. multiseta is also at variance with sites DGL1 and DGL3. These factors probably set this site slightly further apart from the other two deep Great Lake sites. The Swan Bay site differs mainly in the oligochaete group in that A. multiseta is absent whilst abundances of H. ornamentus, P. palustris and A. plectilus are considerably different to those at sites DGL2 and DGL3. No amphipods were recorded from this site either.

The third deep Great Lake site, DGL3, differs from DGL1 and DGL2 mainly in the abundances of various species. There do not appear to be any major qualitative differences between the faunas of these sites.

In Arthurs Lake the observed differences between the two deep basins could be a result of the absence of the amphipod Neoniphargus tasmanicus and the bivalves from the western basin (sites SAL3 and DAL4) as well as the lower numbers of phreatoicids. The presence of the oligochaetes P. branchiatus, A. multiseta and T. papillatus at site DAL4 and not at DAL3 may account for some of the differences within the western basin. The two deep sites in the eastern basin (DAL1 and DAL2) differ mainly in the virtual absence of P. palustris and perhaps R. bilineatus from DAL1 as well as differing abundances in the crustacean group between the two sites.

Site SAL2 is not only intermediate in depth between the shallow and deep sites in Arthurs Lake, it is also intermediate in position between the two basins. It has some faunal elements not present in both basins as it shares the amphipod N. tasmanicus and the sponge species with the western basin whilst it shares high phreatoicid numbers with the eastern basin.

Finally, Table 4.6 has been compiled from various sources throughout the results. This table further illustrates the independant nature of the various sample sites. It is shown that the fauna is spread around the lakes and that several sites as well as seasonal sampling are required to adequately evaluate that fauna.

Table 4.6: Numbers of species collected at each site in Great Lake and Arthurs Lake.

Site	Mean no. spp.	Max no. at one date	Total no. spp.	Max for lake at one date
DGL1	11	14	21	
DGL2	16	18	28	
DGL3	16	18	25	38
SGL1	15	19	27	
SGL2	17	19	26	
SGL3	11	12	15	
SAL1	20	23	30	
SAL2	13	15	25	
DAL1	13	15	21	42
DAL2	18	23	32	
DAL3	14	15	27	
DAL4	17	17	30	

Total species GL = 50 AL = 54

4.2.2 Life History Data

Although elucidation of life histories was not a major objective of the survey some data are naturally available from the samples taken.

The phreatoicid group was one of the few groups which showed a more or less uniform reproductive cycle. In Great Lake the large species Onchotelson brevicaudatus exhibits a life cycle lasting at least two years. The young are present in samples taken at the end of November (Fig. 4.6). The brood pouch was evident in females in each of the three samples from the end of May until the end of September at Swan Bay level 1. Although large specimens were still present after the appearance of the young it appears unlikely that they remain to reproduce a second time. They did not appear to reproduce in their first year. Most of the Great Lake phreatoicid samples were too small for size frequency analysis but some detail is given for O. brevicaudatus from site DGL3 in Fig. 4.14.

Juveniles of another Great Lake species, Mesacanthotelson setosus, were present in samples taken in early December hence a similar breeding time is suggested for this species. Another species present in Great Lake, Uramphisopus pearsoni, may reproduce slightly earlier, as small juveniles of this species were first found in samples taken near the end of October. However, local conditions at the time may have been responsible for such variations, as only a short delay in release from the brood pouch could result in their non-appearance until the next sample time two months later.

The Arthurs Lake phreatoicid, Colubotelson sp., also appears to have a two year life cycle although, being a smaller species, the cohorts are more difficult to follow. Specimens of Colubotelson sp. were quite numerous in Arthurs Lake and details of their growth are given in Fig. 4.15. Juveniles were first found in samples in early December at all sites. Paired males and females were observed at Morass Bay at the end of July and brood pouches were evident in samples of females taken in late July and particularly in late September. Hence an extended breeding season is suggested. There appear to be considerable differences in the maximum size attained by Colubotelson sp. between sites in Arthurs Lake. The size factor appears to be inversely related to numbers present with the largest specimens being found at Ti Tree Bay whilst the maximum size of adults was much less at the Morass site. Specimens at other sites were intermediate in size between these extremes. Evidence of this may be seen from the modal size of adults from different sites in Fig. 4.15.

Although amphipods were very numerous in Arthurs Lake it was not possible to produce any data on their life history from the samples taken. More frequent samples would probably help as it appears that more than one brood is produced each year.

Some of the more common chironomid species were examined. These were Riethia sp., Procladius villosimanus, Chironomus oppositus, Tanytarsus sp., Polypedilum nr. tonnoiri and Coelopynia pruinosa.

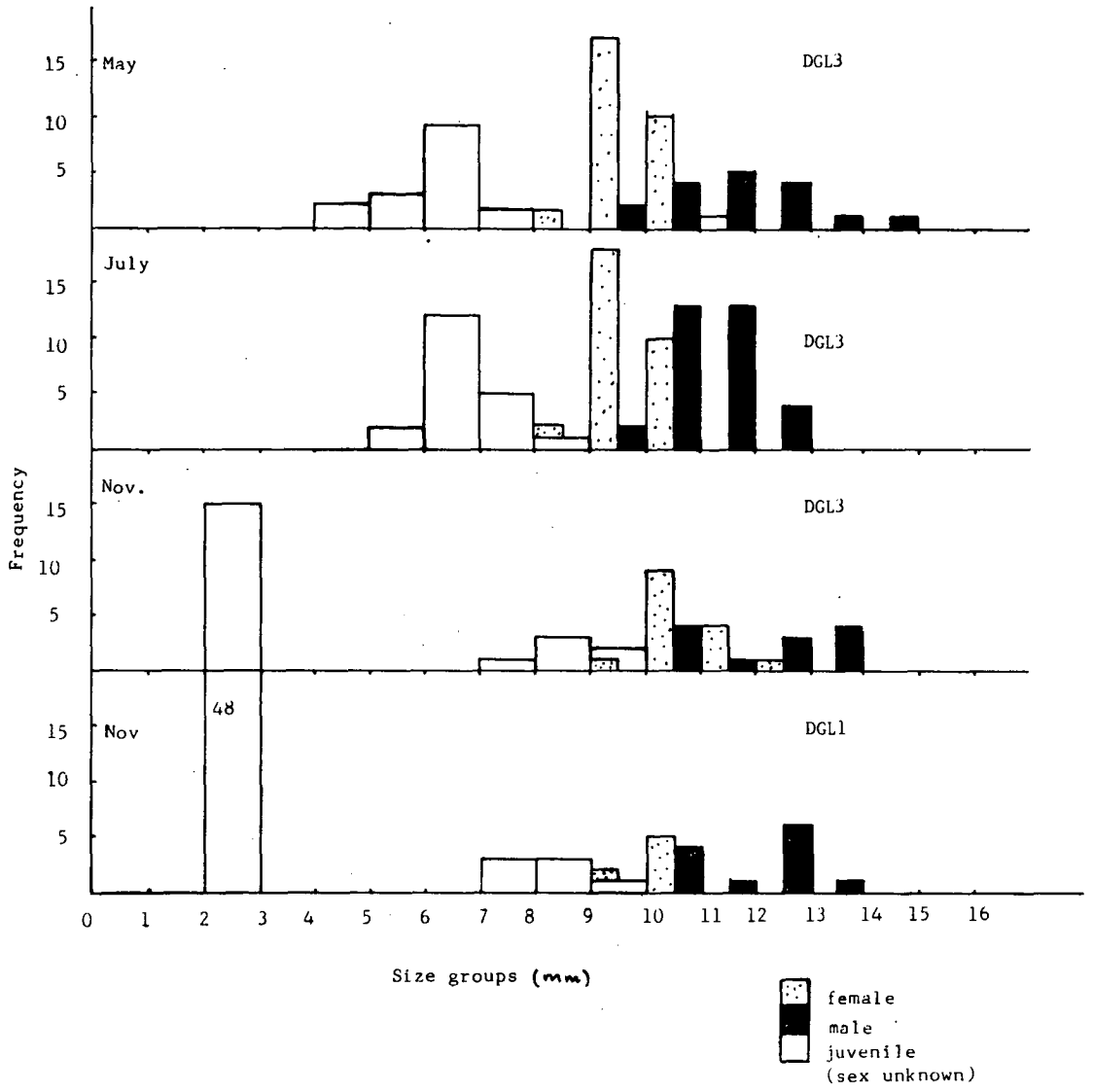


Fig 4.14 : Size frequency histogram for O. brevicaudatus at various sites in Great Lake (samples taken near end of month indicated).

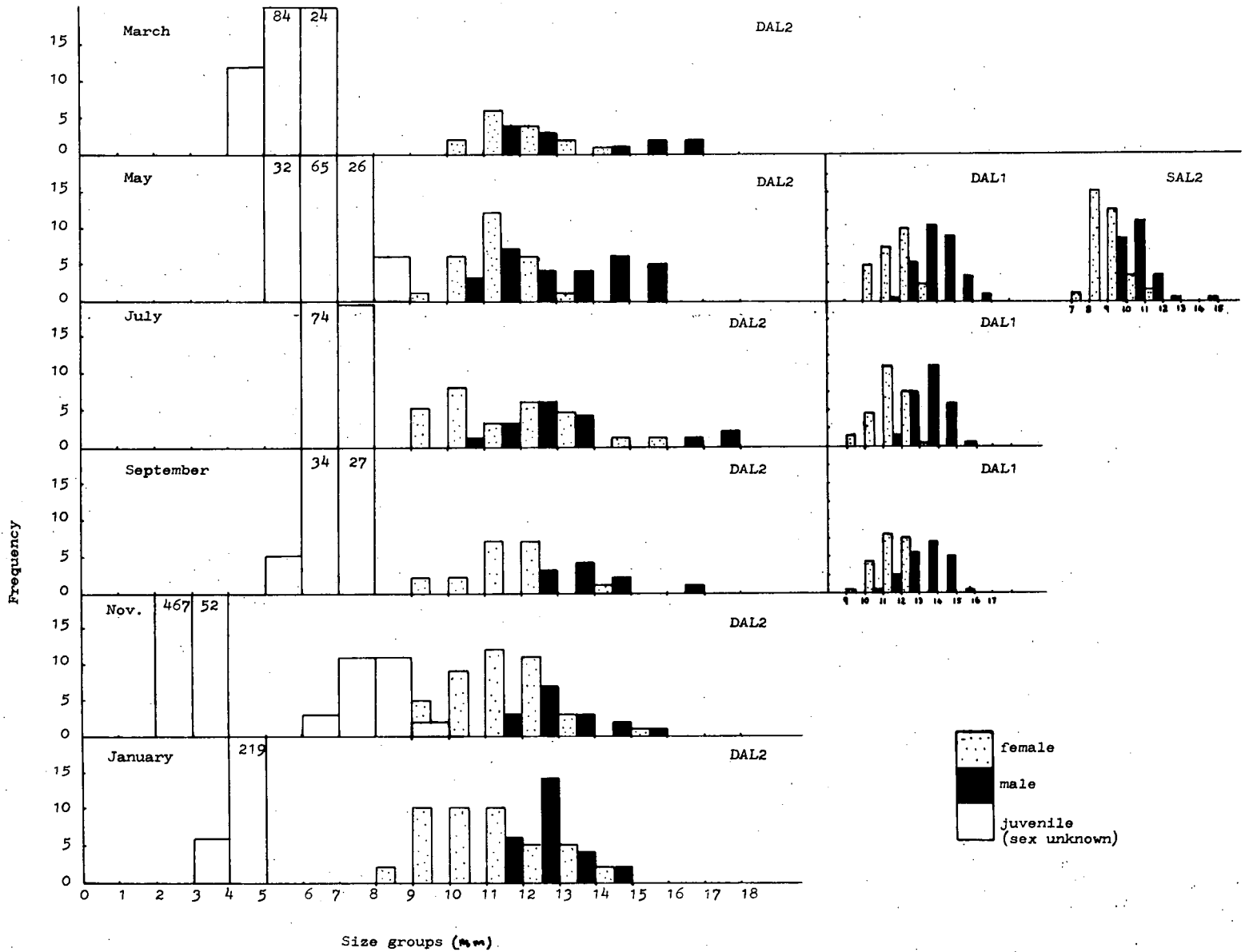


Fig. 4.15: Size frequency histogram for Colubotelson sp. at various sites in Arthurs Lake (samples taken near end of month indicated).

Riethia sp. was the most common chironomid in both lakes. It was found to have a life cycle of one year with peak numbers generally recorded in late winter-spring samples. The maximum size was generally reached after the end of November with a few large fourth instar larvae still present in January samples especially in Great Lake. Only a few third instar larvae of this species were collected and growth through the first three instars is apparently quite rapid. All larvae were into the fourth instar, although quite small, by mid-autumn. Some data on the frequency distribution of developmental stages are given in Table 4.8. Emergence is probably over a period from December through to late January.

P. villosimanus was also found to have a one year life cycle in both lakes. Emergence in this species probably takes place predominantly in late spring to early summer in the lakes studied with a few large fourth instar larvae still being present in the late January samples. The third instar larvae appeared in large numbers in the late January samples i.e. the next sample after the major hatch (Table 4.7). This gave the effect of smoothing out the occurrence peaks in this species (see numbers for this species at SGL2, SGL3 and SAL1 in Appendix 2) compared with Riethia sp. which usually does not reappear in the following sample.

Another large species, C. oppositus, shows a similar one year life cycle to the above two species (Table 4.7). Emergence mainly takes place in late spring, with a predominance of third instar larvae in the late January samples. Although data from Arthurs Lake only have been

Table 4.7: Frequency of occurrence of instars of three chironomid species throughout one year. (Samples taken near end of month indicated).

Site	SAL1		SGL3		SAL1		SAL1		
Species	*Riethia* sp.		*Riethia* sp.		*P. villosimanus*		*C. oppositus*		
Instar	3	4	3	4	3	4	2	3	4
Jan.	3	6	-	13	342	51	3	107	4
Mar.	2	53	43	370	2	465	6	106	10
May	-	265	-	580	-		-	-	160
July	-	1920	-	380	12	740	-	1	14
Sept.	-	295	-	690	3	445	-	4	247
Nov.	-	250	-	320	45	540	-	-	3
Jan.	1	1			220	56	5	570	27

tabulated for the above three species a similar pattern was observed in Great Lake. Many of the early Great Lake samples were used for taxonomic purposes and some others accidently dried out.

The small Chironominae species Tanytarsus sp. and Polypedilum nr. tonnoiri also have one generation per year as with the preceding large species. However, these species show later emergence times and apparently very little growth over winter. Emergence in P. tonnoiri takes place in late-summer whilst Tanytarsus sp. emerges in late autumn. Frequency distribution of developmental stages of these two species is given in Table 4.8. Seasonal fluctuations in numbers of some species are shown in Fig. 4.5.

Coelopynia pruinosa did not appear in such abundance at any one site as did the previous species but it was perhaps more evenly distributed. The life cycle in this species is more complicated in that samples from Great Lake indicated that emergence took place predominantly in February-March whereas samples from Arthurs Lake (not in the same year however) indicate that emergence may also occur after winter (see Table 4.9). It is possible that this species may produce two generations per year with emergence in summer and again in spring. It is probably more likely that emergence is over an extended period with a consequent extended recruitment time thus staggering the numbers in each instar at any one time.

Other chironomid species were rarely numerous enough to afford satisfactory data for life history study. Collection of earlier instars, particularly of C. pruinosa,

Table 4.8: Frequency of occurrence of instars of two chironomid species throughout one year. (Samples taken near end of month indicated).

Site	SGL3		SGL3	
Species	P. tonnoiri		Tanytarsus sp.	
Instar	3	4	3	4
Jan.	3	280	2	80
Mar.	26	5	-	115
May	73	30	-	18
July	100	44	-	20
Sept.	97	44	-	-
Nov.	15	240	-	-

Table 4.9: Frequency of occurrence of instars of C. pruinosa from various sites in Great Lake and Arthurs Lake. (Samples taken near end of month indicated).

Site	SAL2			DAL1			SGL1	
Instar	2	3	4	2	3	4	3	4
Jan.	-	48	111	-	43	62	8	49
Mar.	-	42	60	-	69	76	-	7
May	1	29	47	1	75	74	9	15
July	-	50	16	-	57	77	55	34
Sept.	-	37	14	-	71	64	14	19
Nov.	13	64	12	2	56	51	-	20
Jan.	-	34	26	-	5	78		

is also desirable to fully determine the life history of the species studied.

The life cycle of the trichopteran species Atriplectides dubius was briefly examined. This species was relatively common only at Swan Bay level 2 in Great Lake. The samples could be grouped into two size groups in March samples whilst three size groups were present later in the year. Pupating adults were present in samples taken from November to January and large larvae were retained alive and reared to adults after approximately one month from samples collected in early October. When pupating, A. dubius larvae detach about 5 mm of the posterior end of their case and position this transversely at the other end to seal off the case.

Only one generation per year with an extended emergence time is suggested by the time of appearance of the small larvae in the samples. Some small larvae were collected in the late January samples whilst others appeared in the late March and late May samples.

The life histories of any of the oligochaete species were not closely investigated. In all species, with the exception of the large Haplotaxis ornamentus, juveniles entering the population were not easily recognisable. Without microscopic investigation size classes could not be recognised and the fragmentation which occurred in these species would have rendered such a task very time consuming.

Cocoons containing single eggs of H. ornamentus were collected during the mid year samples from both Great Lake and Arthurs Lake. Unfortunately the identity of these

was not immediately recognised hence little information was gained from them at the time. Young H. ornamentus were collected in small numbers only during the latter half of the year but at no time did the juveniles constitute a major part of the fauna. It appears that this species may live for at least three years.

4.2.3 Biomass Estimates

Applying the correction factors where applicable as determined in section 2.4 an estimate of the total biomass for each site at each date was made by summing the individual species components as set out in Appendix 8. These values are given in Table 4.10 and their variation with season is presented graphically in Fig. 4.16. There does not appear to be any definite seasonal trend in the biomass levels at the deep sites but seasonal peaks are apparent at the shallow sites. There is also a tendency for the beginning and end of year samples to be about equal in most cases hence the last Arthurs Lake sample has not been included in the calculation of the annual mean values as this would introduce a seasonal bias in that lake.

The magnitude of seasonal variation is usually less than three fold with only one exception and that was at site SAL1 (Cowpaddock Bay) where a nine fold difference between minimum and maximum values was observed.

The variation at any one site is usually attributable to variation in one particular group of animals e.g. oligochaetes, chironomids etc. and in many cases may be further defined to one species only. The percentage

Table 4.10: Biomass totals for each site on each collection date in Great Lake and Arthurs Lake (Arthurs Lake mean value excludes second January sample). Values are in g/m^2.

Month \ Site	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4
1	15.31	12.60	24.82	4.51	3.08	5.37	3.19	70.55	13.08	10.38	61.24	14.17
3	30.94	14.29	8.18	5.38	1.48	5.29	8.94	110.25	13.69	17.14	91.61	41.56
5	55.04	8.48	13.98	2.61	3.73	11.15	13.09	90.24	41.14	14.98	56.10	46.32
7	49.92	10.46	10.85	5.98	1.73	11.77	28.77	66.80	42.91	8.62	73.68	39.01
9	23.32	4.53	14.33	7.90	3.81	13.93	16.13	84.90	16.72	8.50	73.48	56.72
11	20.04	11.18	24.22	6.25	3.98	9.59	9.74	54.13	33.31	8.82	64.31	59.60
1							5.17	73.47	37.18	13.29	61.82	45.05
Mean	32.43	10.26	16.06	5.44	2.97	9.52	13.31	79.48	26.81	11.41	70.07	42.89

Integrated value GL = 13.9 g/m^2 AL = 35.9 g/m^2

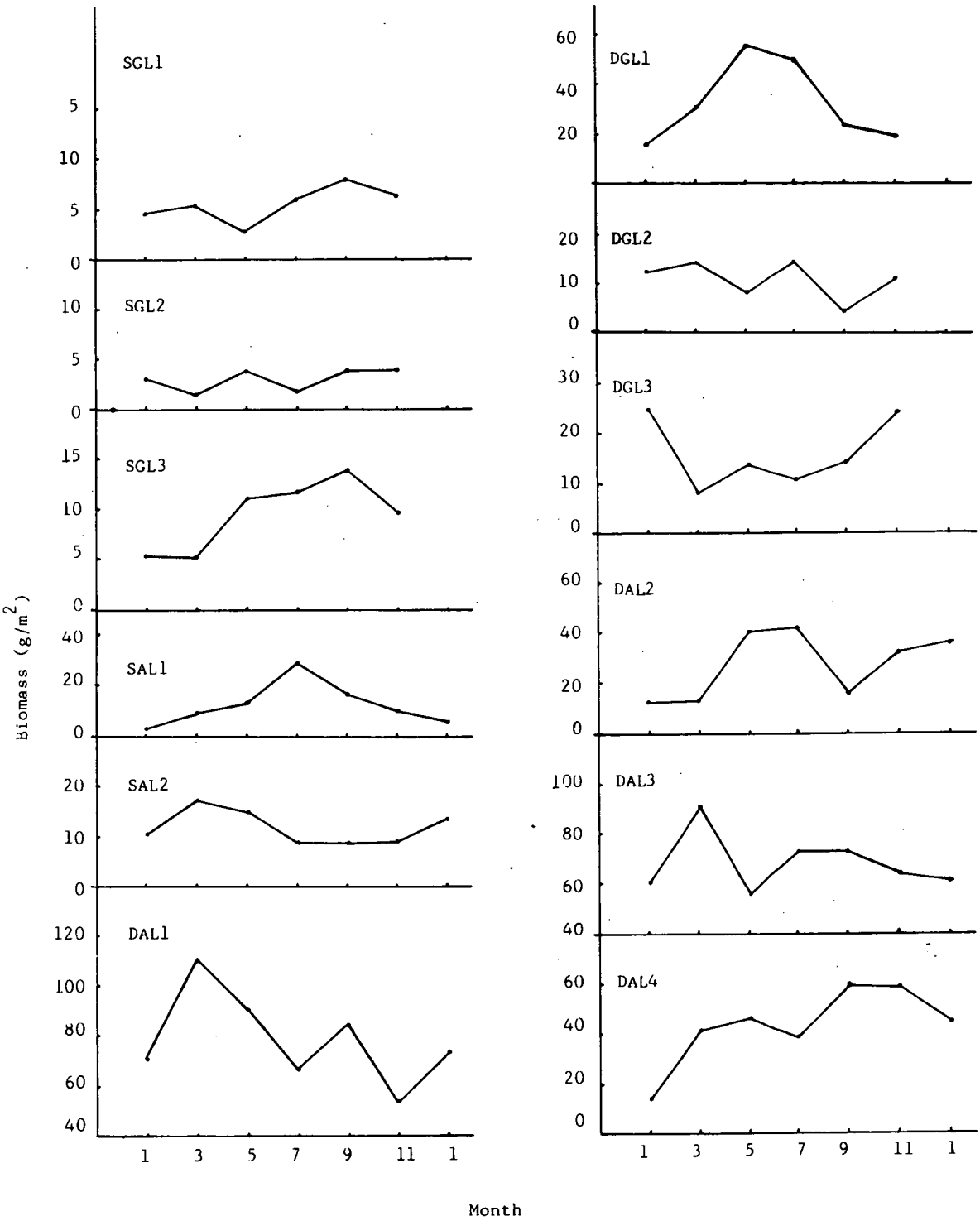


Fig. 4.16 : Yearly variation in biomass for each site in Great Lake (1975) and Arthurs Lake (1977-8).

contribution over the year to the total biomass by each species group is given in Table 4.11 whilst the seasonal variation of the dominant species groups at each site is given in Fig. 4.17. The contribution by each individual species can be calculated from data in Appendix 8.

From these tables it is seen that the oligochaete group accounts for by far the major part of the standing crop at all deep sites throughout the year. The level varies between about 77% and 98% of the total biomass. In all cases the majority of the total biomass at these sites is attributable to a single species (Haplotaxis ornamentus) and therefore the biomass of these sites relates closely to the fluctuations in numbers of this species (see Fig. 4.7). At the deep Great Lake sites DGL2, and to a lesser extent, DGL3, other larger oligochaetes, Antipodrilus multiseta and Phreodrilus palustris, as well as the small but numerous A. plectilus, assumed some importance in biomass totals at certain times of the year. However, taken overall the percentage contribution of the oligochaete group to the total biomass of the deep sites was quite consistent throughout the year and fluctuations up to only about 10% around the mean value for the year were observed (see Fig. 4.17).

After the oligochaetes the crustaceans were the next most important contributor to biomass totals at the deep sites in both lakes. This contribution was almost entirely due to phreatoicid isopods in Great Lake with only very minor contributions by amphipods. In Arthurs Lake much larger contributions were made by amphipods,

Table 4.11: Percentage contribution to total biomass of each species group at each site (mean of seasonal values, excluding second January sample in Arthurs Lake).

LAKE	GREAT LAKE						ARTHURS LAKE					
SITE	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	SAL2	DAL1	DAL2	DAL3	DAL4
Isopoda	6.6	2.3	13.3	17.0	23.9		2.8	84.5	11.6	15.6	*	7.6
Syncarida				*	1.1					*		
Amphipoda		*	*				5.2	2.8	*	3.7	*	1.7
Diptera												
Chironomidae	1.6	1.6	2.7	65.8	57.4	83.3	84.2	7.3	*	2.0	*	*
Ephemeroptera							1.9			*		
Plecoptera										*		
Trichoptera	*	*	*	15.7	9.9	3.6	2.5	1.6	*	*	*	*
Acarina	*			*	*		*	*	*			
Oligochaeta	90.4	95.7	83.0	*	6.9	13.1	2.4	3.4	86.5	76.7	98.3	90.0
Mollusca	*	*	*	*	*	*	*	*	*	1.2		*
Turbellaria		*	*				*	*	*	*	*	*
Nemertea	*	*	*		*			*	*	*	*	*
Porifera	*			*			*	*			*	*
Hydrozoa							*			*	*	

* contributes less than 1% to the total

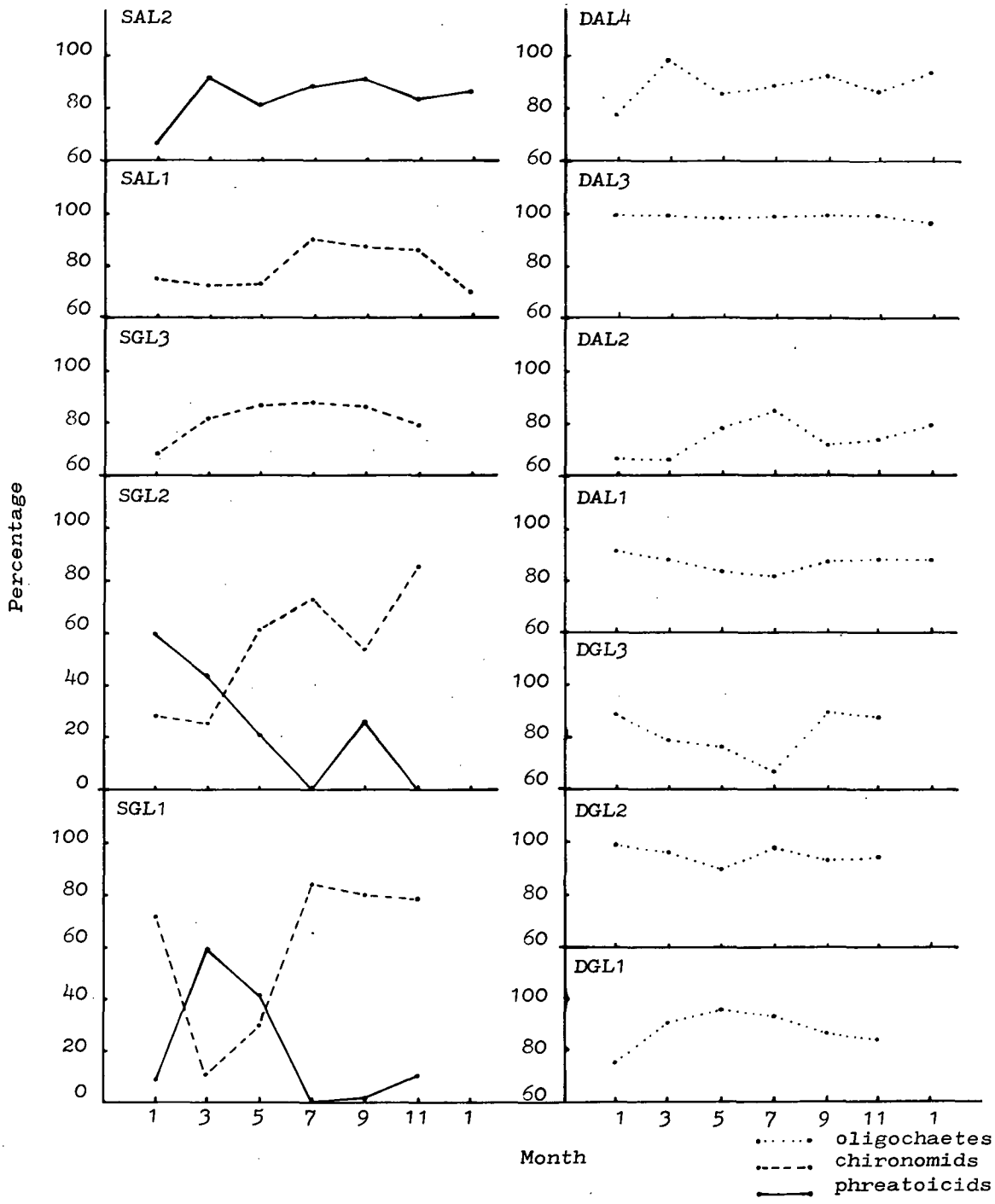


Fig. 4.17: Percentage contribution throughout the year to total biomass by dominant species at each site in Great Lake (1975) and Arthurs Lake (1977-8).

however the phreatoicids were still the most important crustacean.

The chironomid group is of minor importance only at the deep sites. It represents about 2% of the total biomass at the three deep Great Lake sites but achieves this level at only one of the deep Arthurs Lake sites.

The oligochaete, crustacean and chironomid groups, as well as the 1.2% level for the molluscs (principally the bivalve Sphaerium tasmanicum) at site DAL2, are the only groups to contribute more than 1% to the total biomass of any of the deep sites over the whole sampling year. Of this total a single oligochaete species contributes well over 60%.

The biomass of the shallow sites of both lakes was usually dominated by the chironomid group (Table 4.11). However the phreatoicid isopods were also important and were the dominant group at all seasons at site SAL2. The trichopterans were also of some significance in Great Lake but at no stage were they the major biomass contributor.

The chironomid group constituted 57-85% of the biomass of the three shallow Great Lake sites and to the shallow Arthurs Lake site SAL1. The majority of this total was made up by Riethia sp. with other occasional major contributions by Procladius villosimanus and Chironomus oppositus at some sites.

The chironomid biomass was subject to seasonal peaks and the sample most affected, particularly by the fluctuations in numbers of Riethia sp. was the late January sample. As mentioned earlier, this species has

a one year life cycle in which larvae at their maximum size emerge in summer. Hence depending on local conditions large Riethia larvae may or may not be present at this time of year. Such seasonal abundances in other chironomid species may be masked to a certain extent by having longer life cycles and extended breeding seasons, but last instar larvae of the larger species are usually of sufficient size to have some effect when weight not numbers is considered. Following this, chironomid biomass usually reaches a peak in mid year and decreases towards summer as mature specimens hatch (see Fig. 4.18).

The phreatoicid biomass figures do not show any marked seasonal trends. At the one site where they were the major contributor to total biomass (SAL2) a peak value was observed in autumn and this peak was also observed at DAL1 which had the next highest phreatoicid biomass total. However these animals have at least a two year cycle with at least two generations present at most times. These peaks may, therefore, merely reflect the abundance data rather than represent actual peak levels for individuals of the species.

The amphipods contributed more to the crustacean biomass than phreatoicids at site SAL1 only. The trichopteran group also becomes an important contributor to the biomass of the shallow sites especially in Great Lake whilst two other groups only, make contributions of more than 1% to the total on single occasions. These are the ephemeropterans (1.9%) at SAL1 and syncarid crustaceans (1.1%) at SGL2. The latter occurrence is of considerable interest and was achieved by the presence of only four specimens of Paranaspides lacustris.

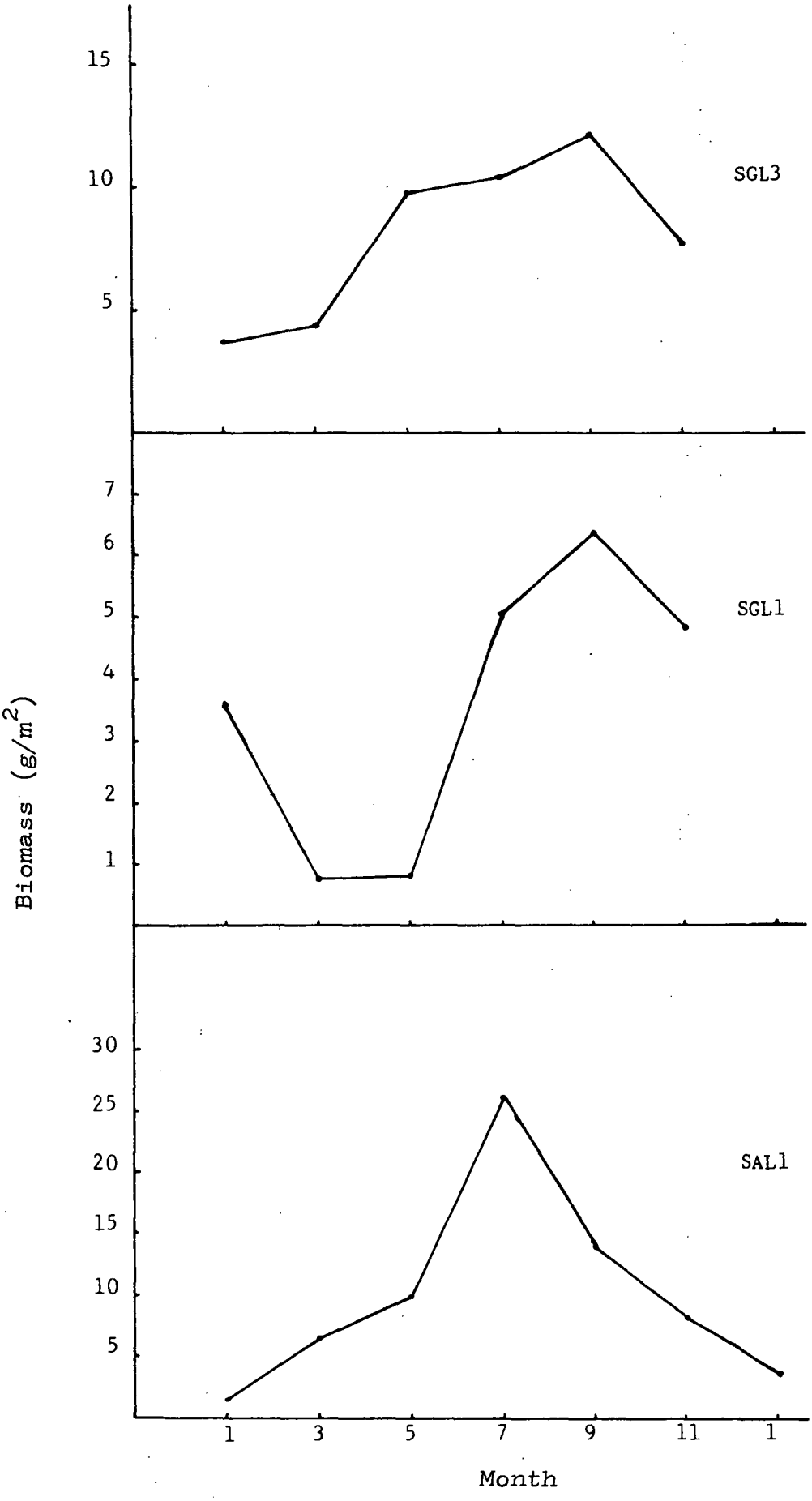


Fig. 4.18: Chironomid biomass at various sites in Great Lake (1975) and Arthurs Lake (1977-78).

For the purpose of comparing biomass levels in Great Lake and Arthurs Lake with values calculated for Tasmanian and other lakes a mean weighted biomass value for both lakes was calculated. This was based on a mean yearly value for each site, taking the value for each site or pair of sites as the overall biomass level for its basin and thus calculating the value for the total lake at normal full supply level.

The mean weighted biomass values for each lake are included in Table 4.10.

4.2.4 Instaneous Growth Rates and Production Estimates

Quotation of a section from Chapter 7 of Edmondson and Winberg (1971) is considered appropriate at this stage.

> ".... before setting out to estimate the production of a particular species, the investigator must obtain information about the distribution, specific features characteristic for stages of development as well as the age structure and the generation time. It is also important to have information on the reproductive cycle of each species. The above data are essential, in order to determine the changes in the number of specimens and the standing crop of each of the age groups".

From these requirements it is apparent that insufficient prior data were available to make valid estimates of benthic productivion in Great Lake and Arthurs Lake. Estimates usually rely upon the recognition of cohorts throughout the year when calculating production from biomass differences and estimates of the biomass of the eliminated individuals (see Edmondson & Winberg 1971). Whilst cohorts could be recognised in some of the more common species of chironomids and phreatoicids they generally did not start and end in coincidence with the twelve month sampling program.

The use of size frequency group methods such as proposed by Hynes and Coleman (1968) and modified by Hamilton (1969) were considered, particularly for the oligochaetes. However as this group was prone to fragmentation during the collection, sorting, identification storage process, it proved to be virtually impossible to use this method.

It is possible to calculate the instantaneous growth rates (G) of various species using the equation.

$$G = \frac{\ln W_2 - \ln W_1}{t}$$

where W_2 is the mean individual weight at end of t days and W_1 is the initial mean individual weight. The time period t varied between species and although there was considerable uniformity between species it was not considered justifiable to extrapolate the time period to give an annual production estimate (P) using the equation

$$P = G\bar{B}$$

where $\bar{B}$ is the mean annual biomass of the species (after Johnson & Brinkhurst 1971). However estimates of P for the period under consideration have been included in Table 4.12.

Instantaneous growth rates were calculated for the chironomids Riethia sp. and Procladius villosimanus, which exhibit a one yearly life cycle. The instantaneous growth rates of phreatoicids in Great Lake and Arthurs Lake were also examined. The results of all calculations of G are listed in Table 4.12.

Table 4.12: Estimates of instantaneous growth rates (G) and production (P) for various species from Great Lake (1975) and Arthurs Lake (1977-8).

Species	Site	Period (inclusive)	Group	$\bar{B}$ (g/m^2)	G (g/day)	P (g/m^2)
Riethia sp.	SAL1	Aug-Nov	4th instar	8.1	1.03×10^{-3}	1.07
	SGL2	Aug-Nov	4th instar	4.84	1.06×10^{-3}	0.66
	SGL3	June-Nov	4th instar	5.31	1.49×10^{-3}	1.22
P. villosimanus	SAL1	Feb-Nov	4th instar	4.52	4.0×10^{-3}	5.39
O. brevicaudatus	DGL1	Oct-Nov	1st year		6.03×10^{-3}	
	DGL1	Oct-Nov	2nd year		5.62×10^{-3}	
	DGL3	Aug-Nov	2nd year		8.8×10^{-3}	
Colubotelson sp.	DAL1	Feb-Mar	1st year	0.59	19.9×10^{-3}	0.75
	DAL2	Feb-Mar	1st year	0.65	19.6×10^{-3}	0.80
	DAL2	Aug-Oct	1st year	0.85	12.5×10^{-3}	0.79

4.3 DISCUSSION

The major emphasis in this study has been placed on the faunal variation between sites rather than variation within a site or on a seasonal basis. In the following discussion, brief reference has been made to other works in relation to the latter two areas. However, the discussion of inter-site variation in this chapter is restricted to data from Great Lake and Arthurs Lake. Other Australian and overseas lacustrine benthic faunas are considered in the following chapter.

4.3.1 Faunal Variation

4.3.1.1 Within series variation

As stated earlier (Section 4.2.1.1) the analysis of within-series variation was primarily to validate the sampling procedure. From this work it is clearly evident that sample series containing only one or two samples would not have given an adequate quantitative or qualitative estimate of the fauna of Great Lake or Arthurs Lake at any of the sites chosen. A pattern of samples within a defineable zone, as suggested by Brinkhurst (1974), was used instead of a transect line. The restriction of sites in this way may have resulted in a qualitative underestimate of the fauna of the lake as a whole, especially in Great Lake, which appears to have a number of discreet basins, each with some separate faunal elements. Nevertheless, the procedure achieved its objectives at the sites sampled, and

although considerable further analysis could be performed on spatial distribution of the benthos within a site this was not attempted. It has been investigated for benthic fauna by Miller (1941), Raverra (1966) and Alley and Anderson (1969).

4.3.1.2 Seasonal variation

Predictably, the seasonal variation in abundances was most apparent in the more common insect groups such as the chironomids, and in particular those species with a single generation per year. It was also observed in other groups with a single period of population increase during the year, such as the phreatoicids.

Much of this variation is covered in analysis of the life history of the various species (Section 4.2.2). It has also been shown that the influx of young of the year is not always apparent in total numbers as the large numbers of adults present tend to mask changes due to recruitment in those species with extended life cycles.

The numbers of oligochaetes present were relatively constant throughout the sampling periods. Any peaks that did occur appeared in individual samples without any regular build up or decline. Deevey (1941) recorded stable numbers of oligochaetes in his study of seasonal variation in Connecticut lakes. Further, in a European study of the tubificid Potamothrix hammoniensis in Lake Esrom over four years, Jonasson and Thorhauge (1972) did not demonstrate any repeated abundance peaks. Jonasson (1972) did record peaks of abundance in summer in Lake Esrom for the tubificid Ilyodrilus hammoniensis (also the bivalve Pisidium casertanum). Timms (1973a) reported peaks

in abundance of oligochaetes in seasonal samples from two Victorian lakes but his investigation as with this survey, only covered one year. Table 3.2 shows that maximum total numbers of animals occurred at different times of the year, depending on the site, in Great Lake and Arthurs Lake, with no apparent relationship between deep and shallow sites or between lakes.

In the absence of faunal data from several consecutive seasonal cycles it is difficult to detect the consistent variations in numbers of the permanent bottom dwelling species. The overlapping summer samples in Arthurs Lake have provided some valuable life history data but otherwise have not been totally coincident with the previous years levels. It is also probably pointless comparing any observed peaks in Great Lake and Arthurs Lake to those observed in most European and American works as well as the Victorian systems studied by Timms (1973a) because of the stresses imposed on most of those systems by stratification and consequent degrees of anoxia in the profundal areas. Such stresses do not occur in the polymictic Tasmanian central plateau lakes where the only major variable throughout each season is temperature.

The use of the Shannon-Weiner diversity index in relation to seasonal variation (Table 4.3) suggests that such variation is largely due to the high, but generally stable oligochaete, and in Arthurs Lake, crustacean numbers at the deep sites. The shallow sites generally lack these groups and are in turn dominated by relatively high but seasonally variable numbers of chironomids. The stability of the SGL3 site is probably due to a compensatory

effect of the abundance peaks of different species of chironomids present at that site. However, the intermediate depth SAL2 site has very high consistent phreatoicid numbers and a stable chironomid fauna more akin to the deeper sites.

The assumption that the diversity index is indicating seasonal abundances relies upon the uniformity of the sample site. If there is a change in the uniformity of the substrate between samples or series of samples then the number of microhabitats could change. This may be reflected by changes in the diversity index associated with the collection of a different fauna or different numbers. The shallow sites SGL1, SGL2 and SAL1 did show the greatest potential for varied microhabitats with the presence of Nitella sp. or Elodea canadensis as well as coarse and fine particulate organic matter.

In conclusion, consistent seasonal peaks in numbers are not apparent when considering the fauna of either lakes as a whole. However, they are clearly evident when individual species are examined. Such variations are largely functions of the life histories of the species concerned and mortality does not appear to occur at any clearly defined point in time.

4.3.1.3 Inter-site variation

4.3.1.3.1 Diversity indices

The Shannon-Weiner diversity index becomes less useful for comparisons between sites as it cannot allow for differing faunal components.

This method nevertheless, roughly grouped the deep sites in both lakes and also isolated the intermediate SAL2 site. It also grouped site DGL1 with SGL3 on all but one occasion which is a confusing result.

Diversity indices appear to be more usually applied to a riverine situation to detect changes in species occurrence often associated with sources of pollution (Hawkes 1972; Hellawell 1977). When used to compare the faunas of two lakes (Mason 1977) it was found that "Species richness alone provided a more consistent difference between the two sites".

4.3.1.3.2 Cluster analysis

The three arrangements of the data used in the cluster analysis have resulted in some differences in the site groupings as shown in the results. The groupings achieved can be considered in relation to the effects of the particular data arrangement as well as in regard to the implications of the groupings. For instance, the exclusion of the rare species (Fig. 4.9) was, in effect, placing more emphasis on the more abundant species at each site without actually introducing abundance data. Hence it was observed that the clusters achieved from the exclusion of rare species and the inclusion of abundance data were basically similar. Nevertheless, to achieve a high degree of similarity when rare species were excluded the sites still required a considerable common faunal element.

The close association of deep sites in separate basins of Arthurs Lake was achieved when all species were considered, but the basins separated when the major species

and abundance data were considered. The basins are therefore showing similar diversity in their rare species but differ slightly in the presence of abundant species.

The distinction between deep and shallow sites is independant of data arrangement and is therefore of major significance. These sites also cover virtually the full range of total numbers found in the two lakes which suggests distinction largely based on qualitative faunal dissimilarities.

The Arthurs Lake deep sites are generally grouped together with site DAL2 showing some divergence, probably due to the differing nature of its substrate (see Chapter 2).

Even though the cluster analyses has given essentially consistent groupings of sites, it is apparent that there are certain fundamental differences between all sites. The fact that no two sites show any more than a 70% level of similarity by any data arrangement or sorting strategy supports this statement.

4.3.1.3.3 Principal coordinates analysis

This technique gives perhaps more distinct splits between the sites before the abundance data are included. With these data included the deep sites all tend to group together, as do the shallow Great Lake sites. However, site SAL1 is distinctly separated which is probably a result of the higher species abundances at this site when combined with the already apparent faunal differences. These results may indicate that the sites are distinct faunistically but the abundances do not always follow along similar lines.

Although the percentage contribution to total variation by the first two latent vectors in the PCA was not very high the groupings achieved are quite consistent for all three arrangements of the data. This indicates that whilst the differences between the sites are not absolute, they are relatively consistent and independant of the analysis technique. This conclusion could also be drawn from the cluster analyses results, bearing in mind that studies of ecological data rarely produce clear cut and indisputable conclusions.

4.3.1.3.4 Site faunal relationships

In the consideration of the distinction between sites some allowances are made in order to compensate for the objective nature of cluster analysis and PCA groupings. For example, the presence of small numbers of certain species (e.g. some chironomids) may not be as important as the presence of similar numbers of other species (e.g. some oligochaetes), even though they would have the same ranking in an objective method of analysis.

The data analyses techniques used have served to identify the degree of association between the various sites. This has been interpreted in the form of qualitative and quantitative faunal differences in Section 4.2.1.3.2. These differences may be summarised to give a generalised fauna for the deep and shallow sections of both lakes. The 'deep' fauna is characteristic of the original lake areas and is dominated by the oligochaetes and crustaceans. The 'shallow' fauna is characteristic of the newly flooded areas and is dominated by the chironomids.

A generalised deep water fauna in both lakes would include a species of phreatoicid (and in Arthurs Lake at least one amphipod), a chironomid fauna particularly consisting of Coelopynia pruinosa and Riethia sp., usually small numbers of the trichopteran A. dubius and some turbellarians. Also a varied and numerous oligochaete fauna dominated by the large species Haplotaxis ornamentus, but also usually containing Phreodrilus palustris, Antipodrilus plectilus and Telmatodrilus bifidus.

Similarly, a generalised shallow water fauna for both lakes would consist of a varied and abundant chironominid fauna including large numbers of Riethia sp., substantial numbers of the trichopteran A. dubius and an oligochaete fauna with the species P. proboscidea and L. hoffmeisteri common.

In Great Lake at least there is reason to further separate the shallow areas into "windward" and "leeward" shore elements. This effect was markedly apparent in the appearance of the substrate, with sites SGL1 and SGL2 having black sediments with Nitella sp. present and large pieces of decaying roots and other vegetation. Canal Bay 2 (1 & 2), Little Lake Bay 2 (2) and Elizabeth Bay 2 (1) from the supplementary survey (Fig. 2.3 and Appendix 2) also showed these tendencies. In contrast, site SGL3, and also Elizabeth Bay 2 (2) and Little Lake Bay 2 (1) had brown sandy sediments with a fine organic material probably deposited as a result of water movements induced by the prevailing west to north-westerly winds. Some evidence of faunal differences on a similar basis are

present in the Great Lake data. Thus it is suggested that position in relation to prevailing winds may be having some effects on the fauna of Great Lake at least. The different areas have been considered when estimating a mean biomass figure for each lake as a whole (see Section 4.2.3).

The reasons for the observed faunal differences are more difficult to explain. The depth factor, whilst it would probably be the primary reason in the explanation of larval insect distribution, is not necessarily of major importance in other groups. Most chironomids were more abundant at the shallow sites, the exception being C. pruinosa. The same was true for the trichopterans in both lakes and the Ephemeroptera and Plecoptera in Arthurs Lake. The Ephemeroptera are probably present at SAL1 because of the large quantity of Elodea canadensis present at this site. The chironomid C. curtivalva is usually found only in association with aquatic vegetation (Martin pers. comm.). In turn, the extent of the vegetated area is related to depth.

High organic levels (Table 2.4) could account for the high numbers of chironomids at the shallow sites but this in turn is largely related to depth as indicated by the terrestrial origin of most of the organic matter (see Section 2.3).

The oligochaete and phreatoicid faunas in particular are more abundant in the original lake-bed areas. This is not a depth preference as these species certainly pre-date the raising of water levels in both lakes and

therefore they would have originally inhabited water of a depth similar to that which now covers former high ground. There is a distinct shallow water oligochaete, P. proboscidea. The reason may be related to sediment type which varies between sites (see Chapter 2). The deep sediments are basically blue clays with minor variations in composition. Site DAL2 is an exception being quite sandy and similar to site SGL3. The shallow sites SAL1, SGL1 and SGL2 are fine black soils exhibiting varying degrees of aggregation. The oligochaetes may prefer the clay sediment, or else their restriction to these areas could be due to a very low mobility. The presence of the successful cosmopolitan species L. hoffmeisteri in deep and shallow areas tends to support the latter suggestion.

An interesting distribution pattern is shown by another oligochaete P. branchiatus. In Great Lake this species was only found during the main survey at the shallow Brandum Bay site SGL2 in the northern part of the lake. In the supplementary survey (Appendix 2) P. branchiatus was quite common at sites in Little Lake Bay further to the north (see Fig. 2.3). It was also recorded in Arthurs Lake from site DAL4 which is nearest the main human habitated areas of that lake. It could be that such a distribution is the result of recent introductions.

Although there are some absentees from certain basins of both lakes among the oligochaete fauna it is not possible to show that there is or ever was any endemicity to certain areas within a lake in this group.

The same 13 species are represented in both lakes and their absence from some basins is more likely related to local bottom conditions. Nevertheless, some distribution patterns appear to have resulted from isolation in areas that have since become confluent. Both lakes have been formed by the damming of water to unite several separate bodies of water. More widespread sampling within each basin may extend the known range of some species.

Some phreatoicid species appear to be restricted to certain basins within Great Lake as well as to a particular level. O. brevicaudatus appears to be the widespread species but it is not as common in the Brandum Bay basin (see Fig. 1.3) to which U. pearsoni appears restricted. O. brevicaudatus may perhaps be a recent immigrant to this area. Another species, M. setosus, is present at the similar shallow SGL1 and SGL2 sites but not at SGL3. A further phreatoicid, O. spatulatus, was only collected from Elizabeth Bay (Appendix 2), formerly Lake Elizabeth (Fig. 1.3), and although this area is now a part of Great Lake this species has not apparently expanded its range. The distribution of a further species, M. tasmaniae (not collected during the survey), could provide further information on this theory.

The mollusc Glacidorbis pawpela was quite common in Elizabeth Bay (Appendix 2) but only two specimens were recorded from nearby Cramps Bay during the main survey. With this exception, there is little further evidence to support or refute such a theory. Other groups which lack the motility necessary to quickly colonise an area were not generally abundant enough to provide sufficient evidence either way.

The major differences between the two deep Arthurs Lake basins are not easily explained. The amphipod N. tasmanicus should not lack the motility to colonise the western basin and conditions appear suitable. Similarly, the sediment and organic contents of DAL1 and DAL4 appear similar enough to support bivalves which at present are only numerous in the eastern basin.

On the basis of sediment size-frequency and organic content analyses one would expect the deep sites to show relationships in the following ways. In Great Lake DGL2 and DGL3 should be very similar, with DGL1 the odd one out. In Arthurs Lake DAL1 and DAL4 should be closely linked, with DAL3 also fairly similar. DAL2 should be quite separate due to the sandy substrate and low organic content. Apparently the sediment differences are not sufficient to result in separate faunas directly related to these differences.

Considering the faunas of the two lakes as a whole it can be seen from Table 4.6 that there is little difference in the mean number of species present at each site. However, Arthurs Lake sites individually show a generally greater species diversity than Great Lake sites. With the total number of species not greatly different between the two lakes this could be interpreted as indicating slightly stronger faunal similarities between the Arthurs Lake sites than those of Great Lake.

The differences between the lakes as a whole therefore appear to be largely quantitative (also see Biomass section). Only one Great Lake site has higher mean annual numbers than any of the six Arthurs Lake sites

(Table 3.2). The deep sites of Arthurs Lake have almost twice as many individuals present on average than the deep sites in Great Lake, but it should be considered that the depth of the deep Arthurs Lake sites, especially in the eastern basin, is closer to the depth of the Great Lake shallow sites (Table 2.1) than to the deep Great Lake sites with a similar faunal composition.

The reasons for such differences in numbers are not known. There are no major differences in the sediments or organic contents of the two lakes and the dissolved ion levels do not suggest that there should be two-fold differences in abundances. Some elements of the fauna, particularly the crustaceans and the oligochaete H. ornamentus, appear to be contributing most to the abundance differences and further study of their requirements could shed some light on this question.

In concluding the discussion of faunal variation it is worthwhile to consider the data in Table 4.6. No more than 60% of the total species in either of the lakes were collected at any one site and the total number of species known from each site was never collected in any 20-sample series throughout the year. Hence, a number of sites in each lake are required as well as seasonal sampling (the number of samples in a series has been discussed earlier) in order to adequately collect a representative qualitative sample. The size and history of Great Lake and Arthurs Lake have made these requirements perhaps more obvious and necessary than is usual with smaller, unaltered lakes.

4.3.2 Life History Data

There is no published information on the life history of the Great Lake phreatoicids O. brevicaudatus, M. setosus and U. pearsoni. However, the life history of these species briefly proposed in Section 4.2.2 of this study is basically similar to that of the Arthurs Lake species, Colubotelson sp. also recorded in that section. The latter species was studied by Engemann (1963) and later by Knott (1971) who studied coastal populations in the Hobart and nearby southern areas. The findings of this study coincide with those of Knott except that he recorded a slightly larger adult maximum size. As indicated in the results (Fig. 4.15) there was some variation in the modal size of Colubotelson sp. in Arthurs Lake which was possibly related to population density.

Knott (1971) suggested a two year life cycle for this species and this appears to be supported by the Arthurs Lake data. Engemann (1963) had suggested a three year maturity time but his data were questioned by Knott (1971).

It appears that most, if not all, animals die after reproducing. However, further study of the Arthurs Lake material is required to confirm that no specimens survive after two years as a few large adults which do not conform to the size frequency patterns were recorded.

In the only other known study of this group, Barnard (1927) examined the life history of a South African phreatoicid, Mesamphisopus capensis. He also found that this species matured in two years.

The life cycles of the chironomids Riethia sp., C. oppositus and P. villosimanus appear to be simply of

one years duration with a late spring emergence period. Timms (1973a) also found that P. villosimanus had one generation per year in Lake Purrumbete. However, Timms records that the emergence period was later than in the Tasmanian lakes studied here.

The life cycle of a species of Tanytarsus, (T. barbitarsis), has been studied in Australia (Paterson & Walker 1974). This study took place in the small, shallow, highly saline Lake Werowrap in Victoria. T. barbitarsis produced about seven generations per year in that situation with a turnover time of about 30 days in spring-summer. A similar life cycle was found for this species in nearby Lake Gnotuk by Timms (1973a).

The Tanytarsus sp. present in Great Lake and Arthurs Lake produced only one generation per year. Since it generally emerged in autumn, slow winter growth of early instars of this species resulted in it not usually being found in the following spring or early-summer samples.

Polypedilum nr. tonnoiri emerged later than the larger species but earlier than Tanytarsus sp. Early instars of this species showed sufficient growth before winter to reach the 3rd instar by which time they were of sufficient size to be retained by the sieve used. Very little growth is then shown by this species until spring.

The life history of C. pruinosa is not quite so clear. Considerable numbers of third instar larvae are present at various times of the year, and it is possible that this species may have two generations per year. Large fourth instar larvae are present over an extended period. Timms (1973a)found that this species only appeared

to have one generation per year in Lake Purrumbete in Victoria. It could be that this species has a longer third instar duration than the other three large species studied. This could lead to the conclusion of two generations per year when compared to the other more clear cut examples.

With the exception of P. villosimanus, in which the next generation is collected in the samples immediately following emergence, and C. pruinosa whose life cycle is not adequately known, the emergence time of each chironomid species is marked by a significant reduction in numbers in the following samples. This is clearly illustrated in Fig. 4.5.

Caddis fly life histories have not been investigated in Tasmania and the profundal benthos is not usually a major habitat of this group elsewhere. The common species in the two lakes studied, Atriplectides dubius appears to have only one generation per year. Two generations per year may occur but more pupating adults would have been expected in the spring samples. One generation every two years, as is the case in some cold lakes in the Northern Hemisphere, appears unlikely.

The absence of any marked seasonal fluctuations in oligochaete numbers and the lack of an identifiable major influx of young worms of any species makes life history analysis of this group very difficult. The cocoons of Haplotaxis ornamentus found during winter and small specimens of this species collected later in the year are the only data collected on life history in this group.

4.3.3 Biomass and Growth Rates

The highest biomass levels in both lakes are found in the original lake areas. This is primarily (75% or more) due to oligochaetes and usually the species, Haplotaxis ornamentus. The life history of H. ornamentus does not show seasonal peaks in numbers or size which are consistent between sites, consequently the total biomass of the deep sites does not show consistent trends (Fig. 4.16, Table 4.10). If the oligochaete portion of total biomass of these sites is subtracted the remainder approximates the levels of the shallow Great Lake sites.

The biomass levels of the shallow sites do show some consistent seasonal trends with peaks generally occurring around spring at the chironomid dominated sites. This is consistent with the life history of chironomids which tend to show greatest numbers at this stage and, particularly the common Riethia sp., are also approaching maximum size.

The biomass at site SAL2 shows a peak in late summer concurrent with high phreatoicid numbers. The young phreatoicids first enter the population in early summer and show rapid early growth. The following decline in biomass could be a result of losses through winter as a drop in numbers was evident at this stage.

The reason for the observed high numbers of H. ornamentus, and hence high biomass, at the deep sites is probably related to a combination of fine sediments and high organic content. In Great Lake the finest sediments and highest organic content occurred at site

SGL1 as did the highest H. ornamentus numbers and consequently biomass. In Arthurs Lake the greatest H. ornamentus biomass was found at site DAL3. However, individual animal weight was lower at sites DAL3 and DAL2 than at DAL1 in particular. Organic content was also lower at these two sites. The high H. ornamentus population at site DAL3 may have resulted in a depletion of organic material. The more northern sites DAL1 and DAL4 are closer to major inflowing streams which could be providing them with greater quantities of organic material than site DAL3.

Organic content levels may also explain the biomass differences at the shallow sites. There is no means of measuring what proportion of the organic material at SGL1 and SGL2 was readily useable by the benthos. However, it appeared that the fine particulate material at site SGL3 would be more easily utilised than the large pieces of root and other recogniseable pieces of decaying plants which comprised a large proportion of the organic matter at sites SGL1 and SGL2. In Arthurs Lake sites SAL1 and SAL2 had considerable amounts of material in both forms.

It is not known how H. ornamentus (or any of the other benthic animals) utilises organic matter in the substrate, so further discussion would be inappropriate.

It appears that some differences between sites within one lake may be related to the particle size and organic content of the substrate. However, the overall differences observed between the two lakes are not simply a function of these variables. The deep sites of both

lakes show a similar range of values for these two variables, yet Arthurs Lake has a considerably higher standing crop overall. The mean weighted biomass value for each lake also illustrates this.

These biomass levels (Great Lake 13.9 g/m^2, Arthurs Lake 35.9 g/m^2) may have some inherent errors in their calculation. The small areas of these lakes which are subject to fluctuating water levels have probably received an inflated biomass value. However, this value is low compared to the lake average as it is equivalent to the shallow site value. In Great Lake the area affected is only a small proportion of the total surface area. A mean yearly value is used which is representative for the oligochaete dominated biomass of the two lakes as this group does not show seasonal peaks. However, the biomass values of the benthos of lakes with a chironomid dominated fauna would be distorted if samples were only taken in spring/early summer.

There is a considerable difference in the standing crop of the two lakes which is largely due to higher numbers and greater biomass in the oligochaete group. Higher biomass levels in Arthurs Lake may be further related to greater numbers of H. ornamentus at the deep sites. As there do not appear to be any consistent differences in sediment type or organic content other sources of variation must be examined. Dissolved oxygen content would not appear to be limiting as both lakes are polymictic and regular wind action maintains near full saturation oxygen levels. Arthurs Lake may experience a slightly warmer temperature regime overall but this

should not be sufficient to account for the three fold standing crop difference.

Although both lakes were not sampled in the same year it appears unlikely that the differences in climatic conditions between the two sampling periods would be sufficient to account for the observed differences in biomass.

There are differences between the depths of water over the areas of highest biomass in both lakes. These areas, the original lake basins, were all formerly only from about 1.5 to 5 metres deep. But whilst there is now a further 14 metres of water on top of this in Great Lake there is only an additional 6 - 10 metres on the Arthurs Lake sites. However, such depth differences are not great and any advantage in light penetration to Arthurs Lake from this could easily be negated by this lakes slightly lower transparency.

If depth was a major influence on the benthic fauna of the original lake basins then one would expect a wider post flooding distribution of some elements of the fauna. Many species have probably inhabited the original lakes for considerable periods of time before flooding took place but have continued to survive following the rapid change of their habitat. Of course, the long-term depth-history of the lakes is not known and it is also not known if any species have been exterminated by the change in water levels.

Arthurs Lake does have higher TDS, TFS and dissolved ion content than Great Lake (Table 2.3) which may account indirectly, for part of the differences in standing crop between the two lakes.

The differences in biomass between the shallow sites could probably be explained by differences in organic content of the sediments with substrate type also having some effect. The deep sites appear similar between the two lakes but conditions which favour the oligochaete H. ornamentus, whatever they may be, would appear to hold the key to biomass differences between sites and between lakes.

There do not appear to be any major conclusions to be drawn from the limited growth rate or productivity data presented. The first cohort phreatoicids in Arthurs Lake (Colubotelson sp.) had faster growth rates than the same cohort in Great Lake (Onchotelson brevicaudatus).

It should be remembered that the Arthurs Lake and Great Lake samples were taken in different years and therefore not subject to exactly the same conditions. Nevertheless they may be used in a broad sense for comparative purposes in the absence of detailed production estimates.

CHAPTER 5

GENERAL DISCUSSION

In the preceeding chapters, discussion has largely concentrated on the faunal variation shown both within, and between, Great Lake and Arthurs Lake. The discussion of faunal composition was the exception in that the fauna of these lakes was considered in relation to other Australian systems.

The benthic fauna of lakes has not been extensively studied in Australia (see Timms 1980a), but considerable work has been carried out overseas. There is little to be gained by comparing the individual faunal elements of Tasmanian lakes with overseas systems. It is of interest, however, to compare their faunas as a whole, i.e. in terms of total number of species or total standing crop. In this chapter such comparisons are attempted and the problem of classification of lakes is also examined.

5.1 SPECIES DIVERSITY

The numbers of species recorded from Great Lake (54) and Arthurs Lake (56) are the highest yet recorded from any Australian Lake (Timms 1980a). The nearest to these are Lake Purrumbete in Victoria (Timms 1973a) and Lake St. Clair in Tasmania (Timms 1978), both with 38 species. Of all the lakes listed by Timms (1980a, Table 1) only Lake Purrumbete and Great Lake were studied at all thoroughly. Timms (1978) has clearly indicated that his

study of Tasmanian lakes was of a cursory nature only. It is likely that the number of species in some of these and other lakes, particularly the larger ones, would be considerably greater if more detailed studies were attempted. A recent study of Lake Sorell (Fulton unpublished) has recorded at least 53 benthic species from 120 Ekman grab samples at 8 sites, cf. 24 species from 28 Ekman samples at 7 sites (Timms 1978).

Table 4.6 shows that the number of species recorded at one site or at one time from Great Lake or Arthurs Lake was much lower than the total species complement for each lake. An increase in the number of sample sites used, particularly in Great Lake, could still further increase the length of the species list. Nevertheless, the numbers of species given by Timms (1980a) and this survey suggest that Tasmanian lakes generally have a higher species diversity than their mainland counterparts.

Some of the mainland lakes discussed by Timms are saline lakes or coastal dune lakes. The harsh physico-chemical environment of these would not be expected to support large numbers of species, nor would it favour the evolution of a diverse fauna.

It is possible that the general lack of large permanent freshwater lakes on mainland Australia has limited the opportunities for evolution of the benthic fauna in that region. Tasmania has an abundance of lakes of various types and sizes compared to mainland Australia and these may have provided more scope for species evolution. It also appears that there is a higher degree of endemism in the Tasmanian benthic fauna than is present on the mainland (Neboiss 1977a; Hynes & Hynes 1980; this study).

The chemical composition of Tasmanian lakes given by Williams (1964) and Buckney & Tyler (1973) suggests that many of the Central Plateau lakes should be termed oligotrophic. Margalef (1964) has frequently been cited as claiming an association between oligotrophy and high species diversity. This may further explain the observed differences in species numbers between Tasmanian and other Australian lakes although the classification of lakes needs to be treated carefully.

Timms (1980a) concluded that species diversity in Australian lakes is low when compared to that in the northern hemisphere. Whilst this would appear to be correct for mainland Australia, the Tasmanian situation requires further study. Of the northern hemisphere lakes cited by Timms (1980a), Llyn Tegid in Wales (Hunt & Jones 1972b) has 50 + species in the profundal zone. This is comparable to the numbers in Great Lake as only the profundal region of that lake was sampled. It is also comparable to Great Lake in area.

The other lakes cited by Timms, Great Slave Lake (Rawson 1953b) and Saginaw Bay, Lake Huron (Schneider, Hooper & Beeton 1969) have 95 and about 90 species respectively. This greater species diversity is not surprising when the surface areas of those lakes are considered. Great Slave Lake covers an area of about 26,900 sq km whilst Saginaw Bay is about 3,200 sq km in area. Samples were collected from all over these systems. Great Lake is large by Australian standards but covers an area of only 156 sq km.

It is therefore difficult to support the conclusion of Timms without further examination of lakes of comparable

size and also considering the degree of detail in the study concerned. Table 5.1 summarises the results of several other studies on lakes of varying size (above c. 10 sq km) and trophic status in other parts of the world. These studies do not appear to indicate any significant differences between the number of species found in this study of Tasmanian lakes and lakes overseas. Studies of lakes smaller than about 10 sq km are generally show species diversities similar to those found on mainland Australia (e.g. Miyadi 1932a, b; Cole & Underhill 1965; Lindegaard et al. 1978).

Many of the mainland lakes studied (Bensink & Burton 1975; Paterson & Walker 1974; Timms 1969, 1972, 1973a, b, 1976) have high salinities or other harsh physico-chemical characteristics from their coastal situations. Faunal diversity is low in these lakes throughout the world, not only in Australia. The small size of most of these lakes in Australia would also greatly limit the scope for diversification.

Most of the known benthic groups are present in Australia (Timms 1980a). Therefore, as Timms suggests, it is unlikely that zoogeographic isolation has limited the evolution of the benthic fauna. Similarly time does not appear to be of importance, but perhaps continuity or permanance may have been important on mainland Australia.

Timms (1980a) also suggests that the lack of extremes in climatic conditions in Australia compared to the northern hemisphere creates a 'need' for species to be generalists rather than specialists, thus limiting the available ecological niches. There may be a 'tendency' for this to occur but surely the 'need' to be a generalist is less

Table 5.1: Number of species present in lakes of comparable size to Tasmanian systems from the published literature. Lakes are of varying trophic status.

Lake	Country	No. of Species	Approx. area sq. km	Reference
Western Lake Erie	USA	48	1152	Carr & Hiltunen, 1960
Washington	USA	24	88	Thut, 1969
Neusiedlersee	Austria	59	180	Schiemer, 1979
Konnevesi	Finland	$\bar{c}$ 50	201	Sarkka, 1972
Esrom	Denmark	13	18	Jonasson, 1972
Loch Lomond	Scotland	$\bar{c}$ 60	100	Slack, 1965
Sibayi	South Africa	< 25	40	Boltt, 1969
Several lakes	Japan	< 25	< 100	Miyadi, 1932a, b
(c.f.	Great Lake	54	156	)
	Arthurs Lake	56	65	

important in less severe conditions. It could be argued that extremes in climatic conditions are a further physico-chemical hardship which could tend to limit species numbers such as occurs in saline lake systems.

Further thorough study, particularly of Tasmanian lakes is required, but from the present data these lakes appear to have a comparable faunal diversity with similar overseas systems. Variations within particular groups are inevitable. Other Australian lakes certainly appear to lack the same diversity as the Tasmanian systems but this does not appear to be an inherent factor, rather a result of conditions briefly outlined above.

5.2 BIOMASS COMPARISONS

In terms of biomass, Arthurs Lake (35.9 g/m^2) has the highest standing crop so far recorded for a Tasmanian lake (cf. Timms 1978). Great Lake (13.9 g/m^2) has the next highest recorded value. All Biomass values in this section are in terms of wet weight unless stated otherwise. Timms (1978) recorded a range of 1.7 - 6.9 g/m^2 for the seven Tasmanian lakes he studied. Whilst the total number of species present in the lakes Timms studied may well increase with further sampling, the biomass values should not. In fact, they may decrease slightly with consideration of other seasonal values in the chironomid dominated lakes.

For mainland Australia, Timms has recorded biomass levels higher than Great Lake only. These were 16.8 and 23.3 g/m^2 in the South Australian volcanic lakes, Valley Lake and Lake Leake respectively (Timms 1974b) and 14.9 g/m^2 in Lake Albina, a glacial lake near Mt. Kosciusko (Timms 1980b).

Paterson and Walker (1974) determined the monthly average standing crop of Tanytarsus barbitarsis, the only abundant benthic species present in Lake Werowrap, a shallow saline lake in western Victoria. The very high level of 53.75 g/m^2 was recorded. High year round temperatures in this lake apparently result in what the authors claim to be "perhaps the highest estimate (of production) recorded for an inland aquatic macrobenthos community".

It is difficult to compare standing crop estimates for Tasmanian lakes with overseas works because of differences in study techniques and methods of presentation. This was also noted by Paterson and Walker (1974) for Lake Werowrap and is a frequently encountered problem elsewhere. Many studies, particularly those from colder regions, give only summer values which may show a different standing crop level compared to a yearly mean value. Similarly some estimates combine littoral, sublittoral and profundal regions. The definition of these regions may also differ from one study to another.

Cole and Underhill (1965) have listed the standing crop values for the richest known lakes in the United States. They have also included two Canadian and one European lake. That table is reproduced (Table 5.2) with values converted to wet weight and some comparable Australian data added.

From this table it appears that Arthurs Lake has a standing crop among the highest recorded anywhere in the world. It should be stated that some of the values for European lakes (e.g. Lundbeck 1926; Berg 1938) exclude molluscs or include shell weight in the molluscan totals.

Table 5.2: Benthic standing crop in g/m^2 of various lakes. (In part from Cole & Underhill 1965).

Lake	Location	Biomass g/m^2	Period	Authority
Last Mountain	Saskatchewan	57.6	summer	Rawson & Moore 1944
Arthurs (profundal)	Tasmania	54.8	yearly mean	This study
Lake Werowrap	Victoria	54.3	yearly mean	Paterson & Walker 1974
Mendota	Wisconsin	51.6	?	Juday 1921
Esrom	Denmark	46.2	yearly mean ?	Berg 1938
Itasca (sublittoral)	Minnesota	42.2	summer	Cole & Underhill 1965
Echo	Saskatchewan	38.9	summer	Rawson & Moore 1944
Arthurs (overall)	Tasmania	35.9	yearly mean	This study
Linsley	Connecticut	34.8	yearly mean	Deevey 1941
Itasca (overall)	Minnesota	30.2	summer	Cole & Underhill 1965
Soap	Washington	29.5	?	Lauer 1959
Lenore	Washington	28.8	?	Lauer 1959
Itasca (profundal)	Minnesota	26.1	summer	Cole & Underhill 1965

Therefore, biomass values for these lakes should be examined carefully. Some lakes in that region have very large molluscan faunas and standing crops well in excess of the values in Table 5.2 are probable.

Standing crop levels are generally much lower than values in Table 5.2, as can be seen from the work of Deevey (1941, Fig. 41). The terminology in that paper is a little confusing in that he apparently uses the term 'productivity' for standing crop estimates. Deevey has compared the standing crop values of 229 European and Russian lakes (see Deevey 1941 p. 440 for various authors) with 36 Connecticut lakes he studied. From his histogram it is shown that the standing crop of the majority of these lakes is less than 10 g/m^2. Most of the Australian lakes so far studied also broadly fall into this category (Timms 1980a). There are many variables within these studies which suggest that comparisons should not be taken too seriously (Deevey 1941). Nevertheless, from the data available, it would appear that Australian lakes in general have similar benthic biomass levels to lakes in other parts of the world. Arthurs Lake in Tasmania has a comparatively high level whilst Great Lake is perhaps slightly above the average level.

The reasons for these high biomass levels in what one would intuitavely regard as two oligotrophic lakes by physico-chemical and phytoplankton characteristics, (P. A. Tyler pers. comm.) are not at all straightforward.

There have been some attempts to relate benthic standing crop to certain variables of an edaphic and/or morphometric nature. Rawson (1930) considered that the

quantity of bottom fauna was related to the volume of the lake. However, Deevey (1941) found little correlation between these factors, nor could he find a valid correlation between benthic standing crop and mean depth of lakes. Examination of correlations with other factors such as chorophyll levels (highest correlation coefficient) and chemical composition of substrates (Deevey 1941) showed that, if a relationship exists, it is quite complex.

In further studies, Rawson (1942, 1952, 1953a, b, 1957, 1959, 1960) affirmed that there was definitely a relationship between edaphic, morphometric and climatic factors and standing stocks. The quantity of bottom fauna was related to plankton stocks which were in turn related to the quantity of dissolved salts. The expression of favourable edaphic conditions in benthic standing stocks was sometimes masked by extremes in climate and morphometry. The latter point may well apply to Lake Crescent as suggested by Timms (1978). Northcote and Larkin (1956) also positively correlated dissolved solid concentrations and plankton levels in a large number of lakes in British Columbia.

From work on the Experimental Lakes Area of northwestern Ontario, Schindler (1971) proposed a relationship between lake nutrient levels and biological differences between the lakes. He related nutrient levels to the morphometry of each lake. (Catchment area plus lake area : volume of lake).

Whereas the above studies have shown correlations between various factors and benthic standing crops, there have also been studies which have not positively supported these correlations (e.g. Reimers et al. 1955; Hayes 1957 in part; Sparrow 1966).

Brinkhurst (1974) analysed the findings of 36 separate papers on 116 North American lakes by various authors (see Brinkhurst 1974, p. 62). Using stepwise regression analysis he examined relationships between the three variables: mean depth, area, and total dissolved solids, with standing stocks, the production index (standing stock x turnover ratio - predetermined from temperature data) and the morphoedaphic index of Ryder (1965) (TDS/mean depth). This analysis was not absolutely conclusive as some data sets did not conform to the general pattern. However, the work appeared to confirm that there is at least a conceptual relationship of benthic standing stock and production to environmental factors, particularly depth and dissolved solids.

Brylinsky and Mann (1973) have also examined factors governing production in lakes and reservoirs. They found that "variables related to solar energy input have a greater influence on production than variables related to nutrient concentration; in lakes within a narrow range of latitude, nutrient related variables assume greater importance. Morphological factors have little influence on productivity per unit area in either case". Whilst their work is strictly related to production and is not directly applicable to standing crop estimates, their findings in relation to morphological factors are possibly in conflict with the results discussed earlier.

Arthurs Lake and Great Lake have similar faunas qualitatively and are within a narrow range of latitude. Nutrient levels may partly explain the observed standing crop differences. However, they do not explain the reason

for such high values compared to other Tasmanian lakes. These differences may simply be a function of the species present in each system. Benthos production is not known for either lake.

5.3 LAKE TYPOLOGY

It appears to be human instinct to endeavour to provide a model or classification system into which all things, living or otherwise, can be placed, or forced. Nature does its best to resist such artificial ordering by providing a sufficient range of variation and 'exceptions to the rule' so that classification categories require continual bending with each new study. Ecological data is rarely conducive to classification. As stated by Brinkhurst (1974) "classifications of ecological entities have usually been beset by such a hugh diversity of material that few logical schemata have emerged". Nevertheless, a considerable part of the literature on lacustrine systems has been devoted to the classification of lakes. There are undoubtedly important uses for a working classification of lakes based on the quantity of benthic fauna.

A review of the development of lake classification based on benthic fauna is given by Brinkhurst (1974). As with most systems of ordering, the degree of complication has increased considerably with time and I will not attempt to follow the developments fully. Following Brinkhursts (1974) review it appears that, basically, the systems commenced with single dimensional divisions into trophic levels (e.g. Thienemann 1920, 1925) with a gradual

introduction of faunal elements (e.g. Alm 1922; Berg 1938). Two dimensions were soon introduced with divisions of each trophic level in terms of edaphic factors and/or faunal elements (Lenz 1925; Lundbeck 1926, 1936; Valle 1927; Decksback 1929; Naumann 1931; Miyadi 1933; Deevey 1941; Brundin 1949, 1956, 1958; et al.).

The chironomid group was usually chosen for characterisation of species associations, although there were inadequacies in the systematics of this group at the time (Brinkhurst 1974). A more sedentary group, less subject to violent seasonal population fluctuations may have been a more satifactory choice.

It is quite probable that researchers may now be trying to use or reject a classification system that was never intended by its author to have any wider application than to the region on which it was originally imposed. Brinkhurst (1974), in discussing the differences of opinion between various factions, stated that: "It commonly happens that disciples codify and adhere rigidly to a formalised version of what had been only a working hypotheses of its creator - and one he would probably have modified in the light of later experience".

The northern hemisphere classification systems became quite involved and many authors have tended to use only part of a system. For instance trophic status has been related to substrate factors; to broad taxonomic groups; to chironomids; to biomass depth profiles etc. The chironomid system was generally the most widely used.

Following an expedition to South America during which benthic collections revealed Tanytarsus communities in the South Andean lakes, Brundin (1958) proclaimed world wide

applicability of the chironomid based lake typology systems. Although Australian lakes have not been sufficiently studied to be properly classified the subject has already been more or less opened in this country.

Timms (1980a) has briefly examined the various typological systems in relation to his and other Australian works. He arranged the Australian lakes in ascending order of benthic biomass levels and examined this arrangement in terms of substrate organic content. No straightforward correlation was observed, although some elements of agreement with the levels for lakes of similar trophic status in Europe, as given by Rybak (1969), are indicated.

Timms (1980a) did not find any significant agreement with northern hemisphere findings in relation to trophic status and taxonomic groups (i.e. amphipods - oligotrophic, chironomids - mesotrophic - eutrophic, oligochaetes - eutrophic) as suggested by Carr and Hiltunen (1960) and Ahren and Grimas (1965). However, these two works were primarily concerned with the development of eutrophy as a result of pollution. Such faunal-trophic status relationships, at least the latter two categories, are probably applicable to some small Tasmanian systems and may warrant further examination.

The main chironomid genera, (Chironomus and Tanytarsus) used in the northern hemisphere typologies are certainly present and widespread in Australia. Species of these genera do dominate the faunas of some lakes e.g. C. duplex in Lake Coragulac (Timms 1980a), T. barbitarsis in Lake Werowrap (Paterson & Walker 1974), C. nepeanensis in Lake Barrine (Timms 1979). However, the first two systems are saline

to varying degrees, and could be classified as eutrophic. Tanytarsus is supposedly characteristic of oligotrophic systems, whilst Chironomus species indicate eutrophy (Brundin 1958). The latter association is in agreement in Lake Coragulac but Lake Barrine is oligotrophic (Timms 1979). Chironomus species, particularly C. oppositus, are very common in the colder south eastern Australian lakes (Timms 1974, 1978, 1980a, b; Fulton this study). These lakes are generally regarded as oligotrophic.

Therefore, it appears that the northern hemisphere chironomid typologies are not directly applicable to Australia. However, as concluded by Timms (1980a), there do appear to be some broad relationships between various lake types in Australia and some chironomid species. These data may be worth further investigation but at present they are confused by the occurrence of several other ubiquitous species.

Timms (1980a) also examined the relationship between trophic status and biomass:depth profiles of Australian lakes as was done by Lundbeck (1936) and Deevey (1941) in the northern hemisphere. Timms concluded that most deep Australian lakes show little variation in biomass: depth profiles irrespective of trophic status. They show a large littoral peak and low profundal levels. Timms (1980a) could not find agreement with the systems of Lundbeck and Deevey. Non-conformity in this area may be associated with the various effects of stratification which appears to be the general situation in the northern hemisphere. Most of the natural lakes, in Tasmania at least, are polymictic.

Due to this non-agreement, Timms proposed a classification system of his own based on biomass levels and distribution with depth (Timms 1980a p. 36). Although he indicates that caution is required in the use of this scheme, neither Great Lake nor Arthurs Lake could be squeezed into any of his categories by consideration of any of the possible variables. These lakes would be somewhere in the 'ultra' eutrophic area in Timms' system. His system is also in disagreement with trophic status designations based on primary production and nutrient levels for Tasmanian lakes.

Nearby Lakes Sorell and Crescent have comparatively low benthic standing crops (Timms 1978) but have high nutrient levels. Lake Crescent has been classified as eutrophic on the basis of its primary production (Cheng & Tyler 1976a, b), whilst Lake Sorell was considered to be mesotrophic by the same authors. However, Timms (1978), on the basis of benthic standing crop levels, classified Lake Crescent as oligotrophic and Lake Sorell as oligotrophic-mesotrophic. Timms suggested that the scouring effect of the wind in the shallow Lake Crescent may restrict the development of its benthic fauna. Such wind effect should enhance the 'real' trophic status of a lake.

Physico-chemical limnology as well as primary production estimates for Lake Leake and Tooms Lake suggest oligotrophy (Croome & Tyler 1972, 1973, 1975). However benthic standing crop estimates by Timms (1978) suggested eutrophic and mesotrophic-eutrophic conditions respectively to that author.

Timms is either assuming that standing crop is a

measure of production or that standing crop is directly related to trophic status. The former relationship cannot be assumed whilst the latter is not supported by the literature. The system of lake typology for Australian lakes proposed by Timms (1980a) must therefore be rejected. Tasmanian lakes may be classified according to his criteria but the classification bears little or no resemblance to the trophic status of each lake in terms of nutrient levels or primary production.

As shown in Table 5.2 Lake Werowrap and Arthurs Lake (in part) have similar standing crops and would therefore be similarly classified under the Timms system as eutrophic. The benthic production of these two systems, however, would probably differ by an order of magnitude. About seven chironomid generations per year were recorded in the former lake (Paterson & Walker 1974) compared to one in Arthurs Lake. The benthic standing crop is high in Arthurs Lake, and to a lesser extent Great Lake, largely due to the presence of large oligochaetes. These probably have a slow turnover rate and consequently a low level of production more consistent with the trophic status suggested by their nutrient levels.

It appears that the presently used systems of faunistic lake typology are inadequate for Australian lakes. This probably applies to New Zealand lakes as well (Forsyth 1976).

Other methods of classifying lakes are available but they are generally objective and have little predictive value. Lakes are often classified geographically or geomorphologically. Williams (1964) classified Victorian lakes in relation to their total dissolved matter content. Such methods have

been used overseas (e.g. Northcote & Larkin 1956; Larkin and Northcote 1958; Pennak 1958), but their predictive value in terms of benthic production is limited.

The search for a working system of lake typology is not merely an academic exercise. However, a system based on the productive ability of the lakes is required. It would be of enormous value to water management authorities, particularly in relation to fish yield, if easily determined characteristics of a lake, either edaphic, morphometric or faunistic, could enable a meaningful prediction of the fish production of that lake to be made. Benthic standing crop or biomass on its own is in no way a measure of production, and benthic production of an Australian lake has only been determined on one occasion (Paterson & Walker 1974).

Valid estimates of benthic production require considerable time and effort and for that reason alone have probably not been used in lake typology. Standing crop of benthic fauna is undoubtedly related to benthic production, but in a complex manner. Brinkhurst (1974) concluded that although there was a fundamental relationship between macroinvertebrate production and lake depth, area and dissolved solids there was little predictive value in the overall model. Therefore, it may be more rewarding to follow other avenues such as chlorophyll content (as discussed in section 5.2) or direct relationships of morphometric factors and fish yield, which has been studied by Rounsefell (1946) Rawson (1952, 1955) Hayes (1957) and Ryder (1965) in order to arrive at a more meaningful and perhaps more useful classification of lacustrine systems.

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Appendix 1: Sampling dates for each site in Great Lake and Arthurs Lake.

SGL1	SGL2	SGL3	DGL1	DGL2	DGL3
16.1.75	16.1.75	16.1.75	27.1.75	27.1.75	27.1.75
26.3.75	26.3.75	26.3.75	31.3.75	31.3.75	31.3.75
24.5.75	24.5.75	24.5.75	2.6.75	2.6.75	2.6.75
4.8.75	4.8.75	4.8.75	29.7.75	29.7.75	29.7.75
26.9.75	26.9.75	26.9.75	3.10.75	3.10.75	3.10.75
30.11.75	30.11.75	30.11.75	4.12.75	4.12.75	4.12.75

SAL1	SAL2	DAL1	DAL2	DAL3	DAL4
24.1.77	31.1.77	24.1.77	31.1.77	31.1.77	24.1.77
29.3.77	4.4.77	29.3.77	4.4.77	29.3.77	4.4.77
22.5.77	27.5.77	22.5.77	27.5.77	27.5.77	22.5.77
23.7.77	28.7.77	23.7.77	28.7.77	28.7.77	23.7.77
25.9.77	10.10.77	25.9.77	10.10.77	10.10.77	25.9.77
28.11.77	6.12.77	6.12.77	6.12.77	28.11.77	28.11.77
1.2.78	6.2.78	6.2.78	6.2.78	1.2.78	6.2.78

Appendix 2: Species lists and abundance data for faunal surveys of Great Lake and Arthurs Lake.

(Numbers may be multiplied by 2.15 to convert to individuals/m^2).

Part 1: Summary of contents of each 20 sample series taken from Great Lake during 1975

GREAT LAKE 1975

	SWAN BAY Level 1						BRANDUM BAY Level 1						CRAMPS BAY Level 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
CRUSTACEA																		
Isopoda																		
Mesacanthotelson setosus																		
Onchotelson brevicaudatus	39	74	50	44	75	109		1	1	1	3	9	52	36	69	83	32	64
Uramphisopus pearsoni							2	5	2	1	42	2						
Heterias sp.																		
Syncarida																		
Paranaspides lacustris																		
Amphipoda																		
Neoniphargus ? tasmanicus										42	5	1						
Neoniphargus sp.								2					4	2	3	2	6	2
INSECTA																		
Diptera																		
Chironomus oppositus									2									
Cryptochironomus ? griseidorsum						1	2	1	2	3	2	7		1		2		
? Tanytarsus sp.		226					1	29	1					7	2			
Polypedilum nr. tonnoiri						1												
? Harnischia sp.						2	1											
Riethia sp.	4	91		33	56	11		20	102	6	14	29	52	27	49	33	1	85
Coelopynia ? pruinosa	59	7	30	101	35	29	2					1	45	32	11	1	10	12
Paramerina sp.	2		4	1	3	2							1	2				8
Procladius ? villosimanus		1							8	2								
Ablabesmyia notabilis														1	1			2
Orthocladiinae (nr. Smittia or Cricotopus) Sp1.						1												
Orthocladiinae Sp2.																1		
(? Cricotopus sp.) Sp3.								1										
(nr. Eurycnemus) Sp4.																		

GREAT LAKE 1975

	SWAN BAY Level 1						BRANDUM BAY Level 1						CRAMPS BAY Level 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
Trichoptera																		
Atriplectides dubius	6	10	6	1	6	5		1					23	7	12	6		1
Ecnomus tillyardi																		
Notalina parkeri																		
ACARINA																		
A. longipalpus																		
Oxus meridianus	1																	
Piona uncatiformis																		
Arrenurus sp.																		
OLIGOCHAETA																		
Haplotaxis sp.	41	59	141	105	49	54	32	30	15	25	3	26	70	10	32	29	88	75
H. heterogyne							4		1	7	2		1					
Phreodrilus magnaseta		1	5	1	4	1						1	1		2	1		
P. plumaseta										6			4					
P. palustris		8	1	2	3	9	39	74	2	36	30	157	62	52	65	52	35	16
P. breviatria							1	5	9	23	11	5			7	3	3	
P. branchiatus																		
P. proboscidea																		
Antipodrilus plectilus	16	24	3	14	9	4	217	272	525	318	412	108	7		3	8	10	
A. multiseta							93	97	91	87	141	74	8	56	1	10	12	7
Telmatodrilus papillatus									1		2	1						
T. bifidus	48	175	43	34	149	117	74	70	7	49	46	35	23	37	23	27	35	25
Limnodrilus hoffmeisteri							4	18	4	4	3	4						
BIVALVIA																		
Sphaerium lacusedes				12									1				4	
Sphaerium tasmanicum																		
Pisidium spp.			11	66						1	1		1			7	8	4

GREAT LAKE 1975

	SWAN BAY Level 1						BRANDUM BAY Level 1						CRAMPS BAY Level 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
GASTROPODA																		1
Beddomeia sp.											2							
Glacidorbis pawpela															1	1	13	
TURBELLARIA																		
Romankenkius bilineatus							1	3		2	1	7	2		2	1	6	7
prorynchid																		
NEMERTEA																		
Potamonemertes sp.			2					2			1	2			1	1	1	
PORIFERA																		
unidentified sponge			2															
Totals	216	676	298	414	389	346	473	631	773	613	721	469	357	270	284	268	264	309
Mean			370						613						292			

GREAT LAKE 1975

	SWAN BAY Level 2						BRANDUM BAY Level 2						CRAMPS BAY Level 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
CRUSTACEA																		
Isopoda																		
Mesacanthotelson setosus	2	12	13			8	25	9	10		13							
Onchotelson brevicaudatus	1	54	8		3	9												
Uramphisopus pearsoni																		
Heterias sp.		5	24		1		2	5	2		1	1						
Syncarida																		
Paranaspides lacustris		2	1				1	1	1			1						
Amphipoda																		
Neoniphargus ? tasmanicus																		
Neoniphargus sp.																		
INSECTA																		
Diptera																		
Chironomus oppositus		4	6					1	42		4	4	46	159	176	261	145	42
Cryptochironomus ? griseidorsum	16	5	10	56	36	24	1	12	7	5	11	3		1			1	
? Tanytarsus sp.		24		1			7	93	32	33	1		89	121	18	24		
Polypedilum nr. tonnoiri	30	12	44	22	27	81			7	1		1	313	41	120	112	150	287
? Harnischia sp.																		
Riethia sp.	233	125	111	624	719	470	56	40	289	206	306	329	13	320	605	398	710	331
Coelopynia ? pruinosa	7	22	9	1	5	2	9	5	6	4	4	1	8	1	3	4	3	5
Paramerina sp.		2	1	4	3	3	8		2	2	4	1	1		1	1		1
Procladius ? villosimanus	66	47	33	68	101	86		3	8		4	7	177	204	218	207	295	252
Ablabesmyia notabilis		1	1		1	1	1		1	2	1			1		1	1	
Orthocladiinae (nr. Smittia or Cricotopus) Sp1.				1	9													
Orthocladiinae Sp2.				4	3					2								
(? Cricotopus sp.) Sp3.				2						2								
(nr. Eurycnemus) Sp4.											1							

GREAT LAKE 1975

	SWAN BAY Level 2						BRANDUM BAY Level 2						CRAMPS BAY Level 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
Trichoptera																		
Atriplectides dubius	76	86	68	88	106	74	14	10	12	6	15	14	9	11	23	11	19	16
Ecnomus tillyardi	1				1	1						1	1					4
Notalina parkeri		6	14			1			1			1						
ACARINA																		
A. longipalpus							1											
Oxus meridianus				1	1			3			2							
Piona uncatiformis		2	1															
Arrenurus sp.			1															
OLIGOCHAETA																		
Haplotaxis sp.			1	2														
H. heterogyne																		
Phreodrilus magnaseta																		
P. plumaseta																		
P. palustris																		
P. breviatria																		
P. branchiatus							25	30	16	29	4	8						
P. proboscidea	1	5	1	3	9		42	42	27	31	11	12	140	188	127	83	129	55
Antipodrilus plectilus																		
A. multiseta																		
Telmatodrilus papillatus									2			1						
T. bifidus																		
Limnodrilus hoffmeisteri		4	1		1	3	4	5	7	18	29	4	94	29	42	63	111	106
BIVALVIA																		
Sphaerium lacusedes					1													
Sphaerium tasmanicum																		
Pisidium spp.										1	1					2	2	

GREAT LAKE 1975

	SWAN BAY Level 2						BRANDUM BAY Level 2						CRAMPS BAY Level 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
GASTROPODA																		
Beddomeia sp.																		
Glacidorbis pawpela																		
TURBELLARIA																		
Romankenkius bilineatus																		
prorynchid																		
NEMERTEA																		
Potamonemertes sp.							5	3	4	8	2	1						1
PORIFERA																		
unidentified sponge				2														
Totals	433	418	348	879	1027	763	201	262	476	350	414	390	891	1076	1333	1167	1566	1100
Mean			646						349						1189			

Part 2: Summary of contents of additional samples taken from various sites in Great Lake on 7 November, 1975. Numbers are corrected to individuals/m^2.

SITE	E1.1	E2.1	E2.2	P1.1	P2.1	C1.1	C2.1	C2.2	L1.1	L2.1	L2.2
number of samples	3	3	3	3	3	1	3	3	2	3	3
CRUSTACEA											
Isopoda											
Onchotelson spatulatus	272		14								
Amphipoda											
Austrochiltonia australis							14				
INSECTA											
Diptera											
Chironomus oppositus		29	29		14		14			244	
Cryptochironomus ? griseidorsum									43		
Polypedilum nr. tonnoiri		129	29		14		932	201		72	14
Riethia sp.		1304	1691		1677	602	645	344	344	1218	358
Coelopynia ? pruinosa	158				29						
Paramerina sp.		14									
Procladius ? villosimanus		272	1189		72		1405	401		803	301
Ablabesmyia notabilis		14			14		57				14
Orthocladiinae Sp. 1.		14									
Plecoptera											
Leptoperla beroe							14		22		
Trichoptera											
Atriplectides dubius		158	258		72		172	129	65	172	
Ecnomus tillyardi		29								43	
Notalina parkeri		115					57	72			
OLIGOCHAETA											
Haplotaxis ornamentus	115			14					22		
Phreodrilus palustris				14							
P. branchiatus				14					194	29	29
P. proboscidea		59			14		115	14	86	129	29
Antipodrilus plectilus	330			731							
A. multiseta				1061							
Telmatodrilus bifidus	129			186		43					
Limnodrilus hoffmeisteri		14	43	43	14		43	14		86	

SITE	E1.1	E2.1	E2.2	P1.1	P2.1	C1.1	C2.1	C2.2	L1.1	L2.1	L2.2
number of samples	3	3	3	3	3	1	3	3	2	3	3
BIVALVIA											
Sphaerium lacusedes	29			14							
Pisidium sp.	115										
GASTROPODA											
Glacidorbis pawpela	57										
TURBELLARIA											
prorhynchid						43					
NEMERTEA											
Potamonemertes sp.									22		
nos/m^2	1205	2151	3253	2077	1892	688	3468	1175	798	2796	745

Key to sites (on Fig. 2.3)

1	E1.1	Elizabeth Bay level 1
2	E2.1	Elizabeth Bay level 2, site 1
3	E2.2	Elizabeth Bay level 2, site 2
4	P1.1	Poatina level 1
5	P2.1	Poatina level 2
6	C1.1	Canal Bay level 1
7	C2.1	Canal Bay level 2, site 1
8	C2.2	Canal Bay level 2, site 2
9	L1.1	Little Lake Bay level 1
10	L2.1	Little Lake Bay level 2, site 1
11	L2.2	Little Lake Bay level 2, site 2

Part 3: Summary of contents of each 20 sample series taken from Arthurs Lake during 1977-78.

ARTHURS LAKE 1977-78

	COWPADDOCK BAY							MORASS BAY						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
CRUSTACEA														
Isopoda														
Colubotelson sp.				14	3	6	1	432	549	538	351	354	414	452
Heterias sp.	55	28	23	1	4	7					2		4	
Syncarida														
Paranaspides lacustris														
Amphipoda														
Neoniphargus ? tasmanicus								247	37	17	88	86	46	38
Neoniphargus sp.														
Austrochiltonia australis	38	331	259	41	131	7	26							
INSECTA														
Diptera														
Chironomus oppositus	127	229	160	15	251	3	601				1			
Cryptochironomus ? griseidorsum						1		1		1				
? Tanytarsus sp.	51	40	2		5	5	128			1				
Polypedilum nr. tonnoiri	9	1	2	4	3	10	11							
? nr. Harnischia														
Dicrotendipes sp.	14	77	101	18	12	19	3							
Cladopelma curtivalva	162	17	12	46	22	285	211							
? Parachironomus sp.														
Parachironomus ? delinificus			1											
Riethia sp.	13	60	271	1981	309	255	4	16	58	229	57	25	17	41
Coelopynia ? pruinosa							1	171	107	82	69	52	89	63
Paramerina sp.								4	2	2	4	2		7
Procladius ? villosimanus	402	478	449	757	457	591	287	1	2	4	1	2	6	2
Ablabesmyia notabilis	1	3	4	4	1		3		3	1			9	3
Orthocladiinae Sp2.														1

ARTHURS LAKE 1977-78

	COWPADDOCK BAY								MORASS BAY					
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
Ephemeroptera														
Atalophlebia superba	10	20	19	5	9	5	10							
Plecoptera														
Leptoperla beroe		1	1	4	1									
Trichoptera														
Atriplectides dubius	8	24	15	47	6	18	7	19	3	10	5	2		9
Ecnomus tillyardi		1	1											
Notalina parkeri	8	5	3	2	2	2	10	1						
Oecetis sp.												1	2	
ACARINA														
Australiobates linderi											1			
Oxus meridianus		1												
Piona uncatiformis	1	9	18	4	22	6	1			1				
Unionicola longiseta	2	3	2											3
OLIGOCHAETA														
Haplotaxis sp.														
H. heterogyne														
Phreodrilus magnaseta														
P. plumaseta														
P. palustris														
P. breviatria														
P. branchiatus														
P. proboscidea	43	27	27	43	46	8	13							
Antipodrilus plectilus														
A. multiseta														
Telmatodrilus papillatus									1		3		12	
T. bifidus														
Limnodrilus hoffmeisteri	3	9	13	5	4	8	23	22	6	14	1		8	9

ARTHURS LAKE 1977-78

	COWPADDOCK BAY							MORASS BAY						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
BIVALVIA														
Sphaerium lacusedes														
Sphaerium tasmanicum					15									
Pisidium spp.				22				1						1
GASTROPODA														
Physastra cf. gibbosa							4							
TURBELLARIA														
Romankenkius bilineatus								1		4	2	1	4	
Spathula ochyra	3	4	5		6	2	23							
prorynchid													3	
NEMERTEA														
Potamonemertes sp.										1				
PORIFERA														
Sponge	2		20					2	2	3	5	5	5	2
HYDROZOA														
Hydra			1											
Totals	952	1368	1409	3013	1309	1238	1367	918	770	908	590	530	619	631
Mean			1548								722			

ARTHURS LAKE 1977-78

	EAST LAKE NORTH						EAST LAKE SOUTH								TI TREE BAY							WEST LAKE NORTH						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78
CRUSTACEA																												
Isopoda																												
Colubotelson sp.	145	424	425	375	368	159	163	224	150	193	140	101	733	328	2	3	10	1	9	4	11	60	3	104	110	104	221	61
Heterias sp.	1							1						2			1	4						4	23	3	22	
Syncarida																												
Paranaspides lacustris										1																		
Amphipoda																												
Neonipharqus ? tasmanicus																	10	71				158	12	116	111	95	141	38
Neonipharqus sp.	225	73	131	170	117	33	63	349	465	536	395	320	414	409	1	2	199	312	35	31	5	144	1	9	79	154	281	34
Austrochiltonia australis												1																
INSECTA																												
Diptera																												
Chironomus oppositus																					1							
Cryptochironomus ? griseidorsum													1		1	1								2				
? Tanytarsus sp.								1													1		8					
Polypedilum nr. tonnoiri			2																1			2						
? nr. Harnischia																					1							
Dicrothendipes sp.														1														
Cladopelma curtivalva																												
? Parachironomus sp.																									1			
Parachironomus ? delinificus																												
Riethia sp.	2	34	13	5	10		2	1	18	33	81	4	5	86	4	81	5	2			3	7	20	11			1	7
Coelopynia ? pruinosa	110	147	166	135	143	116	83	69	122	75	75	128	62	132	52	79	61	68	54	48	76	20	28	20	22	22	22	46
Paramerina sp.		11	1	1	3									1	1	5			1	3	10		1	1			1	1
Procladius ? villosimanus	1							1					2	1		21		1										
Ablabesmyia notabilis	4	27	9	9	4	1	1				1		1	3			1			3	5		5	1			1	5
Orthocladiinae Sp2.	19		3	1	4		1	7					3	2					1	1		4						

ARTHURS LAKE 1977-78

	EAST LAKE NORTH							EAST LAKE SOUTH							TI TREE BAY							WEST LAKE NORTH						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78
Ephemeroptera																												
Atalophlebia superba								1																				
Plecoptera																												
Leptoperla beroe								1						1														
Trichoptera																												
Atriplectides dubius	3	10	5	6	4	8	6	7	5	8	27	9	3	5	1	13		2	3	2	2	14	5	2	3	1	2	1
Ecnomus tillyardi																												
Notalina parkeri									1		1	2		2											1			
Oecetis sp.																												
ACARINA																												
Australiobates linderi																												
Oxus meridianus																												
Piona uncatiformis		1														1						1						
Unionicola longiseta																						2						
OLIGOCHAETA																												
Haplotaxis sp.	230	235	246	184	210	151	181	98	110	170	190	101	124	143	258	400	259	374	321	328	296	69	189	188	139	278	249	158
H. heterogyne	1																	1		1				1	2	1	2	6
Phreodrilus magnaseta									3																			
P. plumaseta												1		1														
P. palustris	6							34	43	19	11	30	25	44	2	18	78	94	43	57	19	10	6	47	44	28	45	13
P. breviatria												1	20						1									
P. branchiatus																						75	6			2		
P. proboscidea																												
Antipodrilus plectilus	71	15	22	56	41	45	62	10	9	79	115	52	35	23	43	24	42	89	32	31	15		3			11		3
A. multiseta								1					1									3	9	2	1	5		1
Telmatodrilus papillatus																						1	49					
T. bifidus	77	71	28	20	21	17	4	17	41	49	97	36	14	25	28	22	41	87	55	68	27	15	62	29	61	36	38	51
Limnodrilus hoffmeisteri																												

ARTHURS LAKE 1977-78

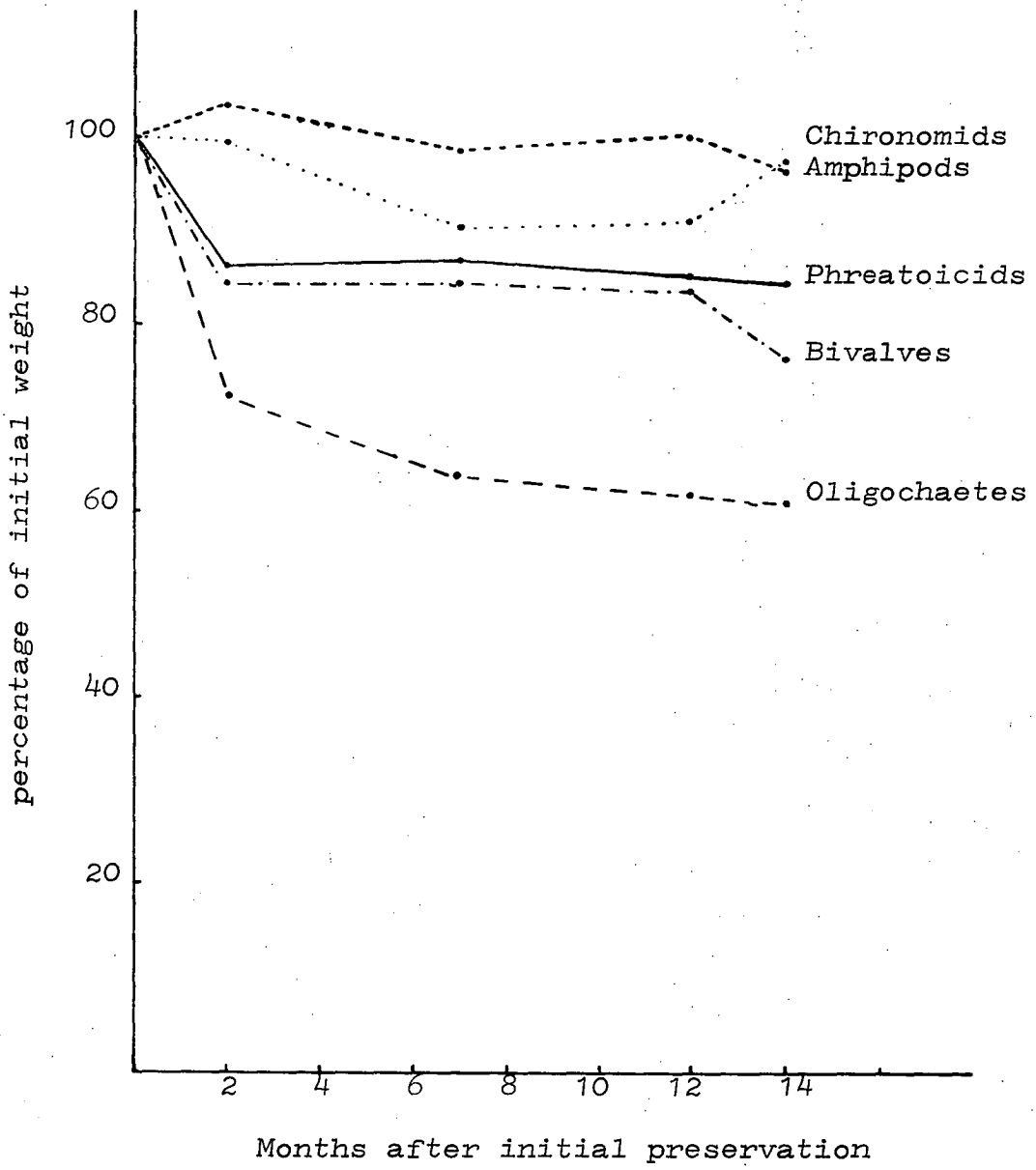
	EAST LAKE NORTH							EAST LAKE SOUTH							TI TREE BAY							WEST LAKE NORTH								
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78		
BIVALVIA																														
Sphaerium lacusedes			4	5	20	21	62	1	5	19	20	13	22	12																
Sphaerium tasmanicum																														
Pisidium spp.		9		5	32	1	271		4	8	3	2	13	10											2	2				
GASTROPODA																														
Physastra cf. gibbosa																														
TURBELLARIA																														
Romankenkius bilineatus			5					20	18	8	12	5	63	78		2	16	1	1	12						2				
Spathula ochyra																														
prorynchid	1	8										1	6	16											1	1				
NEMERTEA																														
Potamonemertes sp.								2	4	1		1	3	2			4		1	1		1	1	2	4	2	4			
PORIFERA																														
Sponge															1			3	2					2	4	2	15	1		
HYDROZOA																														
Hydra												21	1							6										
Totals	896	1065	1060	972	977	552	899	845	998	1199	1168	829	1551	1327	394	672	727	1110	560	596	472	586	408	541	608	746	1048	426		
Mean			920								1098							676							655					

Appendix 3: Graph of percentage weight loss with time in 70% ethanol preservative.

Three groups show an initial significant weight loss and then a fairly stable weight. Two groups do not show any appreciable weight loss.

From these findings the following correction factors were applied to the net weight biomass estimates for the various groups:

Oligochaetes	30%
Bivalves	15%
Phreatoicids	14%
Chironomids	nil
Amphipods	nil


100
80
60
40
20
percentage of initial weight
Chironomids
Amphipods
Phreatoicids
Bivalves
Oligochaetes
2
4
6
8
10
12
14
Months after initial preservation

Appendix 4: Tests for significant differences between Shannon-Weiner diversity indices for each sample series within each site in Great Lake and Arthurs Lake. (Site DAL1 is given in Table 4.2). Critical 't' value 3.291 for probability < 0.001 .

SGL1

Month	N	S	H	J	E(H)	var (H)
1	433	10	1.3660	0.5932	1.3556	0.0023
3	418	18	2.1191	0.7332	2.0988	0.0026
5	348	19	2.0926	0.7107	2.0668	0.0031
7	879	15	1.0802	0.3989	1.0722	0.0018
9	1027	17	1.1258	0.3974	1.1180	0.0017
11	763	13	1.3031	0.5080	1.2952	0.0018

Table of 't' values:

1	3	5	7	9	11	Month
	10.817	9.944	4.457	3.815	0.984	1
		0.352	15.618	15.187	12.304	3
			14.437	13.998	11.289	5
				0.767	3.683	7
					2.990	9
						11

Table of degrees of freedom:

1519	1491	1510	1495	1507
	1514	1484	1463	1481
		1436	1408	1431
			1523	1525
				1524

SGL2

Month	N	S	H	J	E(H)	var (H)
1	201	15	2.0928	0.7728	2.0580	0.0042
3	262	15	2.0006	0.7388	1.9739	0.0041
5	476	19	1.6074	0.5459	1.5885	0.0047
7	350	15	1.5277	0.5641	1.5077	0.0050
9	414	18	1.1798	0.4082	1.1592	0.0058
11	390	17	0.7910	0.2792	0.7705	0.0057

Table of 't' values:

1	3	5	7	9	11	Month
	1.011	5.145	5.866	9.095	13.060	1
		4.201	4.946	8.234	12.222	3
			0.808	4.171	8.017	5
				3.334	7.106	7
					3.618	9
						11

Table of degrees of freedom:

779	778	774	760	763
	776	771	756	759
		778	770	772
			775	777
				779

SGL3

Month	N	S	H	J	E(H)	var (H)
1	891	11	1.7654	0.7362	1.7598	0.0007
3	1076	11	1.7972	0.7495	1.7926	0.0004
5	1333	10	1.6190	0.7031	1.6156	0.0006
7	1167	12	1.7454	0.7024	1.7407	0.0006
9	1566	11	1.5948	0.6651	1.5916	0.0005
11	1099	10	1.6629	0.7222	1.6588	0.0005

Table of 't' values:

1	3	5	7	9	11	Month
	0.949	4.031	0.563	4.945	2.928	1
		5.524	1.655	6.704	4.365	3
			3.688	0.726	1.299	5
				4.657	2.510	7
					2.139	9
						11

Table of degrees of freedom:

2070	2189	2169	2130	2153
	2122	2157	2186	2172
		2191	2168	2183
			2188	2196
				2195

DGL1

Month	N	S	H	J	E (H)	var (H)
1	216	9	1.7476	0.7954	1.7291	0.0022
3	676	11	1.7410	0.7261	1.7337	0.0010
5	298	12	1.6235	0.6533	1.6050	0.0039
7	414	12	1.9166	0.7713	1.9033	0.0013
9	389	10	1.7152	0.7449	1.7036	0.0019
11	346	14	1.6727	0.6338	1.6539	0.0029

Table of 't' values:

1	3	5	7	9	11	Month
	0.177	1.598	2.854	0.510	1.050	1
		1.685	3.635	0.482	1.091	3
			4.069	1.212	0.598	5
				3.565	3.744	7
					0.615	9
						11

Table of degrees of freedom:

609	642	653	687	677
	514	679	635	559
		558	617	678
			672	606
				660

DGL2

Month	N	S	H	J	E(H)	var (H)
1	473	14	1.5576	0.5902	1.5439	0.0021
3	631	17	1.8226	0.6433	0.8099	0.0019
5	773	16	1.1234	0.4052	1.1137	0.0021
7	613	17	1.6926	0.5974	1.6796	0.0026
9	721	18	1.4484	0.5011	1.4366	0.0023
11	469	17	1.9114	0.6746	1.8943	0.0023

Table of 't' values:

1	3	5	7	9	11	Month
	4.161	6.671	1.966	1.636	5.328	1
		11.048	1.941	5.757	1.375	3
			8.335	4.895	11.936	5
				3.495	3.146	7
					6.843	9
						11

Table of degrees of freedom:

934	937	930	936	937
	936	918	929	931
		928	935	936
			935	934
				937

DGL3

Month	N	S	H	J	E(H)	var (H)
1	357	17	2.1733	0.7671	2.1509	0.0018
3	270	13	2.0931	0.8161	2.0709	0.0019
5	284	17	2.0653	0.7289	2.0371	0.0032
7	268	18	2.0673	0.7152	2.0356	0.0039
9	264	15	2.1291	0.7862	2.1026	0.0036
11	309	14	1.9325	0.7323	1.9115	0.0029

Table of 't' values:

1	3	5	7	9	11	Month
	1.313	1.525	1.404	0.598	3.493	1
		0.391	0.341	0.483	2.315	3
			0.024	0.772	1.699	5
				0.713	1.636	7
					2.427	9
						11

Table of degrees of freedom:

617	576	548	557	587
	580	553	561	591
		612	615	616
			617	606
				610

SAL1

Month	N	S	H	J	E (H)	var (H)
1	952	19	1.8937	0.6431	1.8842	0.0014
3	1368	21	1.9083	0.6268	1.9010	0.0009
5	1409	23	1.9764	0.6303	1.9686	0.0008
7	3013	18	1.0524	0.3641	1.0496	0.0005
9	1309	20	1.7935	0.5987	1.7862	0.0009
11	1238	18	1.4421	0.4989	1.4352	0.0011
1	1367	19	1.6709	0.5675	1.6643	0.0010

Table of 't' values:

1	3	5	7	9	11	1	Month
	0.298	1.734	18.966	2.068	8.996	4.540	1
		1.615	22.323	2.669	10.366	5.430	3
			25.141	4.396	12.247	7.217	5
				19.646	9.758	16.060	7
					7.906	2.839	9
						5.071	11
							1

Table of degrees of freedom:

2620	2547	2238	2594	2675	2627
	2721	2520	2732	2723	2733
		2598	2729	2689	2719
			2551	2440	2511
				2713	2731
					2725

SAL2

Month	N	S	H	J	E (H)	var (H)
1	918	13	1.3354	0.5206	1.3289	0.0010
3	770	11	0.9922	0.4138	0.9857	0.0018
5	908	15	1.1808	0.4360	1.1731	0.0014
7	590	14	1.2929	0.4899	1.2819	0.0022
9	530	10	1.0673	0.4635	1.0588	0.0022
11	619	13	1.2273	0.4785	1.2176	0.0029
1	631	13	1.0948	0.4268	1.0853	0.0028

Table of 't' values:

1	3	5	7	9	11	1	Month
	6.601	3.189	0.757	4.741	1.746	3.954	1
		3.361	4.784	1.189	3.455	1.530	3
			1.869	1.880	0.711	1.335	5
				3.384	0.920	2.815	7
					2.235	0.389	9
						1.766	11
							1

Table of degrees of freedom:

1160	1218	1091	1085	1007	1021
	1246	1245	1243	1191	1202
		1202	1197	1126	1140
			1261	1239	1246
				1242	1249
					1261

DAL2

Month	N	S	H	J	E (H)	var (H)
1	845	19	1.6781	0.5699	1.6675	0.0014
3	998	15	1.7163	0.6338	1.7093	0.0013
5	1199	14	1.7565	0.6656	1.7511	0.0010
7	1168	14	1.9877	0.7532	1.9821	0.0006
9	829	19	1.9324	0.6563	1.9215	0.0014
11	1551	21	1.6225	0.5329	1.6160	0.0010
1	1327	23	2.0136	0.6422	2.0053	0.0008

Table of 't' values:

1	3	5	7	9	11	1	Month
	0.735	1.597	6.769	4.800	1.120	7.015	1
		0.854	6.226	1.226	1.967	6.495	3
			5.752	3.644	3.005	6.042	5
				1.233	8.933	0.670	7
					6.346	1.728	9
						9.054	11
							1

Table of degrees of freedom:

2640	2554	2319	2651	2579	2482
	2610	2411	2649	2627	2556
		2554	2579	2651	2641
			2357	2527	2609
				2601	2514
					2629

DAL3

Month	N	S	H	J	E (H)	var (H)
1	394	12	1.1503	0.4629	1.1363	0.0034
3	672	14	1.4427	0.5467	1.4330	0.0024
5	727	13	1.7795	0.6938	1.7713	0.0013
7	1110	15	1.7655	0.6519	1.7592	0.0007
9	560	15	1.4887	0.5497	1.4762	0.0026
11	596	15	1.5743	0.5813	1.5625	0.0025
1	472	14	1.3493	0.5113	1.3356	0.0037

Table of 't' values:

1	3	5	7	9	11	1	Month
	3.847	9.216	9.640	4.381	5.522	2.367	1
		5.555	5.809	0.652	1.878	1.197	3
			0.317	4.678	3.332	6.104	5
				4.836	3.377	6.289	7
					1.198	1.760	9
						2.857	11
							1

Table of degrees of freedom:

917	784	657	927	924	942
	864	723	941	942	897
		866	847	853	764
			707	713	642
				943	915
					911

DAL4

Month	N	S	H	J	E (H)	var (H)
1	586	17	1.9998	0.7058	1.9861	0.0015
3	408	17	1.8424	0.6503	1.8228	0.0037
5	541	17	1.8275	0.6450	1.8128	0.0019
7	608	17	2.0591	0.7268	2.0460	0.0011
9	746	16	1.8032	0.6504	1.7932	0.0013
11	1048	17	1.8546	0.6546	1.8470	0.0008
1	426	15	1.9359	0.7149	1.9195	0.0022

Table of 't' values:

1	3	5	7	9	11	1	Month
	2.168	2.931	1.161	3.687	3.023	1.046	1
		0.197	3.121	0.551	0.182	1.215	3
			4.225	0.428	0.521	1.690	5
				5.230	4.743	2.152	7
					1.125	2.243	9
						1.494	11
							1

Table of degrees of freedom:

724	841	827	846	769	825
	772	653	691	595	797
		790	822	721	848
			844	829	764
				799	801
					693

Appendix 5: Tests for significant differences between Shannon-Weiner diversity indices for each site in Great Lake and Arthurs Lake for each sample series taken in the same month. (Data for month 1 is given in Table 4.4). Critical 't' value 3·291 for probability <0·001

Month 3

Site	N	S	H	J	E(H)	var (H)
DGL1	676	11	1.7410	0.7261	1.7337	0.0010
DGL2	631	17	1.8226	0.6433	1.8099	0.0019
DGL3	270	13	2.0931	0.8161	2.0709	0.0019
SGL1	418	18	2.1209	0.7338	2.1006	0.0026
SGL2	262	15	2.0006	0.7388	1.9739	0.0041
SGL3	1076	11	1.7972	0.7495	1.7926	0.0004
SAL1	1368	21	1.9083	0.6268	1.9010	0.0009
DAL1	1065	13	1.7756	0.6922	1.7699	0.0010
DAL2	998	15	1.7163	0.6338	1.7093	0.0013
SAL2	770	11	0.9922	0.4138	0.9857	0.0018
DAL3	672	14	1.4427	0.5467	1.4330	0.0024
DAL4	408	17	1.8424	0.6503	1.8228	0.0037

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	1.509	6.539	6.358	3.634	1.487	3.783	0.777	0.521	14.264	5.116	1.471	DGL1
		4.386	4.459	2.297	0.524	1.602	0.876	1.889	13.721	5.788	0.264	DGL2
			0.389	1.196	6.148	3.467	5.934	6.719	18.235	9.930	3.341	DGL3
				1.474	5.923	3.587	5.809	6.550	17.184	9.588	3.481	SGL1
					3.026	1.300	3.162	3.888	13.190	6.925	1.787	SGL2
						2.998	0.581	1.978	17.268	6.677	0.700	SGL3
							3.030	4.092	17.630	8.049	0.962	SAL1
								1.257	15.018	5.737	0.974	DAL1
									13.213	4.530	1.785	DAL2
										6.995	11.474	SAL2
											5.103	DAL3
												DAL4

Table of degrees of freedom:

729	745	671	585	685	799	799	790	745	699	612
	815	783	706	568	718	722	766	798	805	738
		797	718	581	734	739	783	814	804	736
			759	528	660	664	715	772	814	789
				481	575	579	623	689	763	814
					697	692	642	582	547	499
						799	785	735	687	602
							787	739	691	606
								778	742	653
									796	721
										778

Month 5

Site	N	S	H	J	E(H)	var (H)
DGL1	298	12	1.6235	0.6533	1.6050	0.0039
DGL2	773	16	1.1234	0.4052	1.1137	0.0021
DGL3	284	17	2.0653	0.7289	2.0371	0.0032
SGL1	348	19	2.0926	0.7107	2.0668	0.0031
SGL2	476	19	1.6074	0.5459	1.5885	0.0047
SGL3	1333	10	1.6190	0.7031	1.6156	0.0006
SAL1	1409	23	1.9764	0.6303	1.9686	0.0008
DAL1	1060	14	1.6317	0.6183	1.6255	0.0009
DAL2	1199	14	1.7565	0.6656	1.7511	0.0010
SAL2	908	15	1.1808	0.4360	1.1731	0.0014
DAL3	727	13	1.7795	0.6938	1.7713	0.0013
DAL4	541	17	1.8275	0.6450	1.8128	0.0019

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	6.481	5.263	5.634	0.175	0.068	5.153	0.118	1.914	6.105	2.177	2.684	DGL1
		12.964	13.484	5.886	9.515	15.777	9.297	11.444	0.971	11.296	11.115	DGL2
			0.346	5.167	7.236	1.403	6.788	4.792	13.064	4.275	3.327	DGL3
				5.516	7.795	1.861	7.318	5.288	13.635	4.745	3.751	SGL1
					0.159	4.977	0.326	1.987	5.477	2.233	2.713	SGL2
						9.390	0.326	3.454	9.754	3.685	4.139	SGL3
							8.300	5.187	16.853	4.285	2.838	SAL1
								2.893	9.413	3.170	3.692	DAL1
									11.836	0.486	1.322	DAL2
										11.567	11.226	SAL2
											0.848	DAL3
												DAL4

Table of degrees of freedom:

994	1072	1068	1072	710	763	779	796	887	864	972
	1037	1044	944	835	911	932	953	1040	1022	1079
		1081	1044	743	804	822	841	939	915	1019
			1037	750	813	831	850	948	925	1027
				682	727	741	755	838	817	921
					1059	1047	1032	941	964	856
						1080	1075	1015	1034	934
							1080	1032	1049	955
								1047	1061	975
									1079	1055
										1040

Month 7

Site	N	S	H	J	E(H)	var (H)
DGL1	414	12	1.9166	0.7713	1.9033	0.0013
DGL2	613	17	1.6926	0.5974	1.6796	0.0026
DGL3	268	18	2.0673	0.7152	2.0356	0.0039
SGL1	879	15	1.0802	0.3989	1.0722	0.0018
SGL2	350	15	1.5277	0.5641	1.5077	0.0050
SGL3	1167	12	1.7454	0.7024	1.7407	0.0006
SAL1	3013	18	1.0524	0.3641	1.0496	0.0005
DAL1	972	13	1.6762	0.6535	1.6701	0.0008
DAL2	1168	14	1.9877	0.7532	1.9821	0.0006
SAL2	590	14	1.2929	0.4899	1.2819	0.0022
DAL3	1110	15	1.7655	0.6519	1.7592	0.0007
DAL4	608	17	2.0591	0.7268	2.0460	0.0011

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	3.587	2.091	14.851	4.871	3.943	20.102	5.169	1.600	10.501	3.364	2.903	DGL1
		4.669	9.217	1.890	0.944	11.514	0.281	5.201	5.787	1.276	6.062	DGL2
			13.059	5.714	4.838	15.318	5.702	1.184	9.940	4.470	0.116	DGL3
				5.390	13.575	0.571	11.513	18.174	3.345	13.609	18.087	SGL1
					2.909	6.369	1.936	6.095	2.758	3.139	6.787	SGL2
						21.109	1.855	6.978	8.618	0.567	7.743	SGL3
							16.937	27.348	4.610	20.485	25.125	SAL1
								8.085	6.957	2.285	8.739	DAL1
									13.018	6.072	1.716	DAL2
										8.789	13.369	SAL2
											6.970	DAL3
												DAL4

Table of degrees of freedom:

1103	981	1184	907	1041	1021	1156	1087	1145	1106	1203
	1168	1184	1099	859	844	965	896	1208	912	1043
		1080	1195	779	768	858	806	1130	818	924
			1000	944	926	1065	988	1206	1007	1139
				740	732	803	761	1053	771	857
					1214	1169	1208	897	1202	1102
						1153	1201	880	1192	1082
							1197	1011	1205	1195
								937	1214	1143
									955	1090
										1158

Month 9

Site	N	S	H	J	E(H)	var (H)
DGL1	389	10	1.7152	0.7449	1.7036	0.0019
DGL2	721	18	1.4484	0.5011	1.4366	0.0023
DGL3	264	15	2.1291	0.7862	2.1026	0.0036
SGL1	1027	17	1.1258	0.3974	1.1180	0.0017
SGL2	414	18	1.1798	0.4082	1.1592	0.0058
SGL3	1566	11	1.5948	0.6651	1.5916	0.0005
SAL1	1309	20	1.7935	0.5987	1.7862	0.0009
DAL1	977	13	1.7730	0.6913	1.7669	0.0010
DAL2	829	19	1.9324	0.6563	1.9215	0.0014
SAL2	530	10	1.0673	0.4635	1.0588	0.0022
DAL3	560	15	1.4887	0.5497	1.4762	0.0026
DAL4	746	16	1.8032	0.6504	1.7932	0.0013

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	4.128	5.578	9.876	6.099	2.482	1.488	1.090	3.823	10.107	3.395	1.562	DGL1
		8.821	5.093	2.974	2.765	6.086	5.682	7.983	5.644	0.576	5.895	DGL2
			13.731	9.748	8.313	4.979	5.253	2.780	13.839	8.115	4.631	DGL3
				0.621	10.028	13.096	12.575	14.582	0.932	5.545	12.353	SGL1
					5.215	7.473	7.197	8.867	1.250	3.365	7.372	SGL2
						5.326	4.695	7.845	10.087	1.913	4.914	SGL3
							0.475	2.920	12.945	5.161	0.208	SAL1
								3.313	12.483	4.781	0.635	DAL1
									14.404	7.062	2.499	DAL2
										6.063	12.343	SAL2
											5.039	DAL3
												DAL4

Table of degrees of freedom:

1474	1351	1488	1178	1112	1330	1350	1456	1479	1453	1447
	1421	1457	1256	1048	1250	1270	1398	1491	1487	1385
		1317	1415	943	1094	1110	1235	1412	1450	1221
			1145	1143	1364	1382	1474	1463	1430	1467
				870	970	982	1075	1245	1298	1064
					1371	1352	1220	1056	1018	1235
						1490	1432	1262	1209	1442
							1446	1282	1229	1455
								1407	1361	1491
									1484	1395
										1347

Month 11

Site	N	S	H	J	E(H)	var (H)
DGL1	346	14	1.6727	0.6338	1.6539	0.0029
DGL2	469	17	1.9114	0.6746	1.8943	0.0023
DGL3	309	14	1.9325	0.7323	1.9115	0.0029
SGL1	763	13	1.3031	0.5080	1.2952	0.0018
SGL2	390	17	0.7910	0.2792	0.7705	0.0057
SGL3	1100	11	1.6687	0.6959	1.6641	0.0005
SAL1	1238	18	1.4421	0.4989	1.4352	0.0011
DAL1	552	10	1.7295	0.7511	1.7213	0.0011
DAL2	1551	21	1.6225	0.5329	1.6160	0.0010
SAL2	619	13	1.2273	0.4785	1.2176	0.0029
DAL3	596	15	1.5743	0.5813	1.5625	0.0025
DAL4	1048	17	1.8546	0.6546	1.8470	0.0008

Table of 't' values:

DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4	Site
	3.317	3.402	5.373	9.500	0.069	3.652	0.896	0.801	5.850	1.336	2.994	DGL1
		0.293	9.520	12.553	4.577	8.122	3.138	5.039	9.535	4.876	1.030	DGL2
			9.146	12.296	4.482	7.763	3.205	4.939	9.260	4.860	1.282	DGL3
				5.906	7.516	2.585	7.899	5.992	1.105	4.120	10.830	SGL1
					11.103	7.910	11.384	10.140	4.710	8.642	13.217	SGL2
						5.627	1.501	1.166	7.536	1.705	5.112	SGL3
							6.171	3.939	3.415	2.207	9.594	SAL1
								2.325	7.962	2.583	2.892	DAL1
									6.323	0.810	5.474	DAL2
										4.723	10.372	SAL2
											4.887	DAL3
												DAL4

Table of degrees of freedom:

2063	2095	1989	1897	1428	1727	1738	1703	2095	2084	1568
	2063	2071	1767	1526	1859	1869	1834	2066	2090	1690
		1988	1898	1427	1727	1737	1702	2095	2084	1568
			1654	1626	1965	1974	1943	1993	2043	1804
				1247	1429	1436	1412	1891	1821	1327
					1896	1886	1920	1432	1483	2035
						2095	2094	1733	1804	2042
							2093	1744	1815	2036
								1708	1779	2056
									2086	1573
										1638

Appendix 6: Similarity matrices for cluster analysis on each of three arrangements of data from all sites in Great Lake and Arthurs Lake.

Part 1: Similarity matrix using species presence/absence data only.

DGL1	1.0000											
DGL2	0.4118	1.0000										
DGL3	0.4516	0.5000	1.0000									
SGL1	0.4118	0.2558	0.2750	1.0000								
SGL2	0.3056	0.2927	0.2500	1.6061	1.0000							
SGL3	0.2593	0.2121	0.2759	0.4286	0.4444	1.0000						
SAL1	0.2564	0.1702	0.1556	0.4474	0.3846	0.3226	1.0000					
DAL1	0.4000	0.3333	0.5000	0.3333	0.2703	0.2143	0.2564	1.0000				
DAL2	0.3784	0.4250	0.5882	0.2955	0.3023	0.1622	0.3488	0.5000	1.0000			
SAL2	0.2941	0.3514	0.3056	0.3889	0.4412	0.3333	0.3784	0.3750	0.3590	1.0000		
DAL3	0.4063	0.3784	0.4545	0.3421	0.2821	0.2333	0.2683	0.6667	0.5000	0.4242	1.0000	
DAL4	0.3784	0.4250	0.5000	0.3256	0.3659	0.2286	0.2889	0.5938	0.5000	0.5143	0.6364	1.0000
	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4

Part 2: Similarity matrix from data excluding rare species.

DGL1	1.0000											
DGL2	0.3333	1.0000										
DGL3	0.5455	0.4815	1.0000									
SGL1	0.2500	0.2424	0.2647	1.0000								
SGL2	0.1852	0.2258	0.2500	0.5769	1.0000							
SGL3	0.2500	0.1481	0.2222	0.4783	0.4762	1.0000						
SAL1	0.1613	0.1053	0.1579	0.3636	0.3125	0.2963	1.0000					
DAL1	0.5263	0.2500	0.5417	0.2258	0.1667	0.2174	0.1818	1.0000				
DAL2	0.4348	0.3448	0.5185	0.2000	0.1471	0.1034	0.1944	0.6364	1.0000			
SAL2	0.1739	0.2222	0.2500	0.2414	0.3200	0.3000	0.2333	0.3636	0.2593	1.0000		
DAL3	0.3478	0.3214	0.3929	0.2500	0.2759	0.2000	0.2059	0.5455	0.5200	0.4545	1.0000	
DAL4	0.4167	0.3793	0.4000	0.2286	0.2903	0.1786	0.1982	0.4800	0.4138	0.2963	0.5600	1.0000
	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4

Part 3: Similarity matrix using all species and abundance data.

DGL1	1.0000											
DGL2	0.4696	1.0000										
DGL3	0.6388	0.5641	1.0000									
SGL1	0.3992	0.3626	0.4310	1.0000								
SGL2	0.3949	0.3684	0.4165	0.5916	1.0000							
SGL3	0.3800	0.3130	0.4012	0.4476	0.4524	1.0000						
SAL1	0.3118	0.2738	0.3305	0.3947	0.3707	0.3702	1.0000					
DAL1	0.5774	0.4179	0.5805	0.3531	0.3516	0.3239	0.2805	1.0000				
DAL2	0.5650	0.4994	0.6246	0.3807	0.3813	0.3570	0.3040	0.7014	1.0000			
SAL2	0.4655	0.3935	0.5146	0.4204	0.4242	0.4120	0.3381	0.5401	0.4915	1.0000		
DAL3	0.5772	0.5241	0.6041	0.4146	0.4297	0.3806	0.3086	0.6446	0.6719	0.5946	1.0000	
DAL4	0.4988	0.4841	0.5238	0.3806	0.4202	0.3440	0.3329	0.5609	0.5836	0.5571	0.6768	1.0000
	DGL1	DGL2	DGL3	SGL1	SGL2	SGL3	SAL1	DAL1	DAL2	SAL2	DAL3	DAL4

Appendix 7: Latent vectors and percentage variance for principal coordinates analysis on each of three arrangements of data from all sites in Great Lake and Arthurs Lake.

Part 1: Species presence/absence data only.

Latent vectors (coordinates)

	1	2	3	4	5	6	7	8
DGL1	0.0844	-0.3727	-0.2458	-0.3019	0.3208	-0.3367	0.2268	-0.1411
DGL1	0.2373	-0.4463	0.1173	0.3943	0.1571	-0.1025	-0.3983	0.0834
DGL3	0.3870	-0.3286	-0.0178	0.0056	-0.2601	0.1748	0.2044	0.0475
SGL1	-0.4622	-0.0284	-0.1080	-0.2311	0.2414	0.2231	-0.0500	0.2901
SGL2	-0.4858	-0.0296	0.1389	0.0384	0.2088	0.4041	-0.0120	-0.2335
SGL3	-0.4965	-0.2258	0.3139	-0.1874	-0.5034	-0.1638	-0.0247	-0.0415
SAL1	-0.4251	0.2878	-0.5142	0.2162	-0.1628	-0.2276	-0.1426	-0.0786
DAL1	0.3555	0.2761	0.0266	-0.3162	-0.0541	0.0243	-0.1144	0.1581
DAL2	0.3186	0.0159	-0.3312	0.2111	-0.1956	0.2825	0.1529	0.0239
SAL2	-0.1384	0.2724	0.3124	0.3589	0.1430	-0.2142	0.3519	0.2183
DAL3	0.3346	0.3045	0.1006	-0.2302	0.0241	-0.0735	-0.1944	0.0372
DAL4	0.2906	0.2748	0.2073	0.0423	0.0806	0.0094	0.0005	-0.3639

Percentage variance

1	2	3	4	5	6	7	8
22.0988	12.9776	10.5110	10.2542	9.3053	8.3279	6.8254	5.5156

Part 2: Rare species data excluded.

Latent vectors (coordinates)

	1	2	3	4	5	6	7	8
DGL1	-0.2936	-0.3501	-0.2610	-0.1889	-0.0073	-0.3267	0.2462	0.2345
DGL2	-0.1717	-0.3872	0.5264	0.3485	-0.2127	-0.0178	-0.1705	0.1111
DGL3	-0.3241	-0.3435	-0.0166	-0.0416	-0.2021	0.0941	0.1643	-0.3159
SGL1	0.5232	-0.1994	-0.0301	-0.0454	0.1864	0.3074	0.0595	0.3720
SGL2	0.5519	-0.0618	0.1973	-0.1041	0.2384	0.1753	0.2403	-0.2852
SGL3	0.5431	-0.0975	-0.0854	-0.3773	-0.1499	-0.2220	-0.4332	-0.1022
SAL1	0.4183	0.1550	-0.4491	0.6059	-0.0818	-0.1471	0.0229	-0.0614
DAL1	-0.4091	0.1460	-0.2756	-0.2146	-0.0093	0.0987	-0.0209	-0.0034
DAL2	-0.4456	0.0585	-0.2111	0.0744	-0.0071	0.3850	-0.1909	-0.0435
SAL2	0.1164	0.5575	0.2605	-0.1232	-0.4376	-0.0540	0.2303	0.0881
DAL3	-0.2549	0.4006	0.1420	-0.0145	0.2086	0.0474	-0.1384	0.0931
DAL4	-0.2539	0.1219	0.2025	0.0807	0.4745	-0.03402	-0.0097	-0.0872

Percentage variance

1	2	3	4	5	6	7	8
23.5610	12.9667	11.1842	10.0015	8.8420	7.8307	6.2998	5.6593

Part 3: All species and abundance data.

Latent vectors (coordinates)

	1	2	3	4	5	6	7	8
DGL1	-0.1911	-0.0326	-0.1766	-0.2722	-0.2433	-0.2587	0.3371	0.0992
DGL2	-0.1331	-0.1515	-0.5465	0.2093	0.3336	0.0122	-0.1368	-0.0649
DGL3	-0.1999	-0.0667	-0.2425	-0.1573	-0.0757	-0.1892	-0.0446	-0.0498
SGL1	0.4537	-0.2781	0.0290	0.1386	-0.2603	-0.0466	-0.2538	0.3610
SGL2	0.4203	-0.3672	0.1026	0.1851	-0.1293	0.0910	0.2240	-0.3683
SGL3	0.4293	-0.0289	0.0858	-0.5298	0.3543	0.1786	0.0097	0.0553
SAL1	0.4707	0.6681	-0.1660	0.1390	-0.1100	0.0047	0.0206	-0.0520
DAL1	-0.3607	0.0914	0.1792	-0.1098	-0.2249	0.1385	-0.1680	-0.1254
DAL2	-0.3372	0.0406	0.0165	-0.0625	-0.1479	0.3073	-0.1658	-0.0651
SAL2	-0.0478	0.0672	0.3896	0.0658	0.2246	-0.4402	-0.1795	-0.1314
DAL3	-0.2918	-0.0108	0.1431	0.1030	0.0785	0.0777	0.0614	0.1120
DAL4	-0.2123	0.0686	0.1857	0.2909	0.2002	0.1245	0.2957	0.2294

Percentage variance

1	2	3	4	5	6	7	8
20.9073	11.7439	11.1957	10.1593	9.4242	7.8759	7.1180	6.4878

Appendix 8: Estimates of biomass for each species at each site in Great Lake and Arthurs Lake. Values have been corrected to g/m^2. An asterisk indicates a level below 0.01 g/m^2.

Part 1: Great Lake

	SWAN BAY LEVEL 1							BRANDUM BAY LEVEL 1					CRAMPS BAY LEVEL 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
CRUSTACEA																		
Isopoda																		
Mesacanthotelson setosus																		
Onchotelson brevicaudatus	1.39	2.19	2.11	2.30	2.37			0.05	0.05	0.05	0.16	0.40	1.69	1.55	3.01	3.20	1.36	2.04
Uramphisopus pearsoni							0.09	0.27	0.21	0.03	0.03	0.08						
Heterias sp.																		
Syncarida																		
Paranaspides lacustris																		
Amphipoda																		
Neoniphargus ? tasmanicus										0.13	0.02	*						
Neoniphargus sp.								0.01					0.01	*	*	0.01	0.02	*
INSECTA																		
Diptera																		
Chironomus oppositus									0.02									
Cryptochironomus ? griseidorsum						0.01	0.02	0.01	0.01	0.01	0.01	0.06		*		0.01		
? Tanytarsus sp.		0.44					*	0.04	*					0.02	*			
Polypedilum nr. tonnoiri						*												
? Harnishia sp.						*	*											
Riethia sp.	0.02	0.12		0.18	0.18			0.03	0.55	0.02	0.06	0.21	0.66	0.05	0.13	0.28	0.01	0.91
Coelopynia pruinosa	0.68	0.09	0.14	0.46	0.29	0.36	0.04					0.03	0.31	0.08	0.06	0.02	0.06	0.05
Paramerina sp.	0.01		0.01	*	0.01	0.01							*	0.01				0.02
Procladius ? villosimanus		*							0.05	0.02								
Ablabesmyia notabilis														*	*			0.01

	SWAN BAY LEVEL 1						BRANDUM BAY LEVEL 1						CRAMPS BAY LEVEL 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
Orthocladiinae Sp. 1.						*												
Orthocladiinae Sp. 2.																*		
Orthocladiinae Sp. 3.								*										
Orthocladiinae Sp. 4.																		
Trichoptera																		
Atriplectides dubius	0.12	0.15	0.12	0.01	0.26			0.02					0.31	0.04	0.14	0.08		0.01
Ecnomus tillyardi																		
Notalina parkeri																		
ACARINA																		
Australiobates longipalpus																		
Oxus meridianus	*																	
Piona uncatiformis																		
Arrenurus sp.																		
OLIGOCHAETA																		
Haplotaxis ornamentus	11.46	27.42	52.49	46.57	19.89	16.60	8.48	9.84	4.26	6.73	0.84	7.27	19.96	3.35	9.07	5.79	12.10	20.76
H. heterogyne							0.07		0.03	0.05	0.01		0.05					
Phreodrilus magnaseta		*	*	*	*	*						*	*		*	*		
P. plumaseta										0.01			*					
P. palustris		0.13	0.01	0.03	0.07	0.13	0.34	0.97	0.03	0.23	0.38	1.76	1.51	1.80	1.45	1.09	0.44	0.22
P. breviatria							*	0.01	0.02	0.04	0.02	0.01			0.01	0.01	0.01	
P. branchiatus																		
P. proboscidea																		
Antipodrilus plectilus	0.03	0.05	*	0.03	0.03	0.01	0.42	0.53	1.03	0.71	1.38	0.27	0.01		0.01	0.02	0.03	
A. multiseta							2.94	2.09	2.16	2.26	1.50	1.16	0.25	1.21	0.02	0.26	0.13	0.11
Telmatodrilus papillatus									*		0.01	*						
T. bifidus	0.09	0.34	*	0.07	0.25	0.20	0.14	0.14	0.01	0.10	0.08	0.07	0.04	0.07	0.04	0.05	0.07	0.05
Limnodrilus hoffmeisteri							0.06	0.25	0.06	0.06	0.03	0.06						

	SWAN BAY LEVEL 1						BRANDUM BAY LEVEL 1						CRAMPS BAY LEVEL 1					
	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75	16.1.75	26.3.75	24.5.75	4.8.75	26.9.75	30.11.75
BIVALVIA													*				0.01	
Sphaerium lacusedes				0.05						*	*		*			0.03	0.35	0.02
Pisidium spp.			0.04	0.23														*
GASTROPODA																		
Beddomeia sp.											*							
Glacidorbis pawpela															*	*	0.04	
TURBELLARIA																		
Romankenkius bilineatus							*	0.01		*	*	0.02	0.01		0.01	*	0.02	0.02
prorhynchid																		
NEMERTEA																		
Potamonemertes sp.			0.01					0.01			*	0.01			*	*	*	
PORIFERA																		
unidentified sp.			0.02															
Totals	15.31	30.94	55.04	49.92	23.32	20.04	12.60	14.29	8.48	10.46	4.53	11.18	24.82	8.18	13.98	10.85	14.33	24.22

	SWAN BAY LEVEL 2						BRANDUM BAY LEVEL 2						CRAMPS BAY LEVEL 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
CRUSTACEA																		
Isopoda																		
Mesacanthotelson setosus	0.22	0.76	0.69			0.27	1.84	0.57	0.77		0.99							
Onchotelson brevicaudatus	0.17	2.44	0.43		0.16	0.37												
Uramphisopus pearsoni																		
Heterias sp.		0.01	0.03		*		*	0.01	0.01		*	*						
Syncarida																		
Paranaspides lacustris		0.19	*				0.02	0.06	0.12			0.01						
Amphipoda																		
Neoniphargus ? tasmanicus																		
Neoniphargus sp.																		
INSECTA																		
Diptera																		
Chironomus oppositus		0.02	0.03					*	0.52		0.03	0.05	0.53	0.89	2.38	4.66	2.06	0.78
Cryptochironomus ? griseidorsum	0.10	*	*	0.10	0.09	0.10	*	0.02	0.02	0.02	0.03	0.02					*	
? Tanytarsus sp.		0.05		*			0.01	0.18	0.08	0.10	*		0.21	0.34	0.04	0.09		
Polypedilum nr. tonnoiri	0.09	0.01	0.04	0.02	0.02	0.10			0.01	*		*	0.94	0.02	0.10	0.10	0.13	0.37
? Harnishia sp.																		
Riethia sp.	2.91	0.32	0.57	4.56	5.72	4.24	0.66	0.10	1.49	1.06	1.91	3.25	0.14	1.38	5.46	3.94	7.63	4.20
Coelopynia pruinosa	0.11	0.16	0.03	*	0.02	0.02	0.16	0.05	0.10	0.07	0.05	0.02	0.05	0.02	*	0.05	0.05	0.13
Paramerina sp.		0.01	*	0.01	0.01	0.01	0.02		0.01	0.01	0.01	*	*		*	*		
Procladius ? villosimanus	0.38	0.19	0.11	0.35	0.50	0.41		*	0.06		0.03	0.03	1.79	1.71	1.69	1.42	2.16	2.11
Ablabesmyia notabilis		*	*		*	*	*		*	0.01	*			*		*	*	
Orthocladiinae Sp. 1.				*	0.01													
Orthocladiinae Sp. 2.				0.01	0.01					0.01								
Orthocladiinae Sp. 3				0.01						0.01								
Orthocladiinae Sp. 4.											*							

	SWAN BAY LEVEL 2						BRANDUM BAY LEVEL 2						CRAMPS BAY LEVEL 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
Trichoptera																		
Atriplectides dubius	0.52	1.14	0.62	0.83	1.30	0.65	0.17	0.18	0.32	0.11	0.48	0.50	0.12	0.15	0.63	0.39	0.47	0.23
Ecnomus tillyardi	0.01					0.02						*	0.02					0.05
Notalina parkeri		0.01	0.01		0.02	*			*			*						
ACARINA																		
Australiobates longipalpus							0.01											
Oxus meridianus				*	*			*			*							
Piona uncatiformis		0.01	*															
Arrenurus sp.			*															
OLIGOCHAETA																		
Haplotaxis ornamentus			0.03	0.06														
H. heterogyne																		
Phreodrilus magnaseta																		
P. plumaseta																		
P. palustris																		
P. breviatria																		
P. branchiatus							0.10	0.12	0.09	0.14	0.02	0.04						
P. proboscidea	*	0.01	*	0.01	0.02		0.06	0.07	0.05	0.06	0.02	0.03	0.27	0.37	0.25	0.19	0.25	0.12
Antipodrilus plectilus																		
A. multiseta											0.01							
Telmatodrilus papillatus																		
T. bifidus																		
Limnodrilus hoffmeisteri		0.06	0.01		0.01	0.05	0.01	0.01	0.06	0.12	0.22	0.01	1.29	0.42	0.59	0.93	1.18	1.60
BIVALVIA																		
Sphaerium lacusedes					*													
Pisidium spp.										*						*	*	

	SWAN BAY LEVEL 2						BRANDUM BAY LEVEL 2						CRAMPS BAY LEVEL 2					
	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75	27.1.75	31.3.75	2.6.75	29.7.75	3.10.75	4.12.75
GASTROPODA																		
Beddomeia sp.																		
Glacidorbis pawpela																		
TURBELLARIA																		
Romankenkius bilineatus																		
prorhynchid																		
NEMERTEA																		
Potamonemertes sp.							*	0.01	0.02	0.03	0.01	0.01						*
PORIFERA																		
unidentified sp.																		
Totals	4.51	5.38	2.61	5.98	7.90	6.25	3.08	1.48	3.73	1.73	3.81	3.98	5.37	5.29	11.15	11.77	13.93	9.59

Part 2: Arthurs Lake

	COWPADDOCK BAY							MORASS BAY						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
CRUSTACEA														
Isopoda														
Colubotelson sp.				1.14	0.36	0.55	0.13	6.99	15.81	12.21	7.67	7.83	7.44	12.27
Heterias sp.	0.08	0.05	0.03	0.02	0.01	*					*		*	
Syncarida														
Paranaspides lacustris														
Amphipoda														
Neonipharqus ? tasmanicus								0.85	0.21	0.10	0.30	0.29	0.18	0.22
Neonipharqus sp.														
Austrochiltonia australis	0.20	1.49	1.50	0.19	0.76	0.03	0.15							
INSECTA														
Diptera														
Chironomus oppositus	0.35	1.32	2.87	0.22	6.02	0.01	1.58				*			
Cryptochironomus ? griseidorsum						*		*		*				
? Tanytarsus sp.	0.05	0.09	*		*	0.01	0.37			*				
Polypedilum nr. tonnoiri	0.02	*	*	*	*	0.01	0.01							
? nr. Harnischia														
Dicrotendipes sp.	0.03	0.17	0.40	0.08	0.05	0.03	*							
Cladopelma curtivalva	0.52	0.01	0.01	0.04	0.01	0.37	0.67							
? Parachironomus sp.														
Parachironomus delinificus														
Riethia sp.	0.11	0.19	2.82	18.23	3.25	2.80	0.02	0.13	0.13	1.12	0.27	0.15	0.12	0.02
Coelopynia ? pruinosa							0.03	1.26	0.64	0.47	0.19	0.17	0.22	0.22
Paramerina sp.								0.01	*		*	*		0.01
Procladius ? villosimanus	1.30	4.70	3.85	7.44	4.69	5.12	0.96	*	*	0.01	*	*	0.04	*
Ablabesmyia notabilis	0.01	0.01	0.02	0.02	*		0.01		0.01	*			0.02	*
Orthocladiinae Sp. 2.														*

	COWPADDOCK BAY							MORASS BAY						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
Ephemeroptera														
Atalophlebia superba	0.23	0.01	0.43	0.09	0.15	0.28	0.12							
Plecoptera														
Leptoperla beroe		*	0.01	0.03	0.01									
Trichoptera														
Atriplectides dubius	0.05	0.23	0.20	0.90	0.13	0.25	0.08	0.34	0.25	0.35	0.08	0.04	0.23	0.15
Ecnomus tillyardi		*	0.02											
Notalina parkeri	0.10	0.02	0.02	0.01	0.01	0.02	0.21	0.01					0.01	
Oecetis sp.												0.01	0.02	
ACARINA														
Australiobates linderi											*			
Oxus meridianus		*												
Piona uncatiformis	*	0.04	0.07	0.01	0.09	0.02	0.01			*				
Unionicola longiseta	*	*	*											*
OLIGOCHAETA														
Haplotaxis ornamentus														
H. heterogyne														
Phreodrilus magnaseta														
P. plumaseta														
P. palustris														
P. breviatria														
P. branchiatus														
P. proboscidea	0.08	0.04	0.07	0.08	0.15	0.01	0.03							
Antipodrilus plectilus														
A. multiseta														
Telmatodrilus papillatus									*		0.01		*	
T. bifidus														
Limnodrilus hoffmeisteri	0.05	0.27	0.67	0.19	0.18	0.19	0.59	0.78	0.32	0.65	0.09		0.45	0.38

	COWPADDOCK BAY							MORASS BAY						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	28.11.77	1.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
BIVALVIA														
Sphaerium lacusedes														
S. tasmanicum					0.24									
Pisidium spp.				0.10				*						*
GASTROPODA														
Physastra ct. gibbosa							0.05							
TURBELLARIA														
Romankenkius bilineatus								*		0.02	0.01	0.01	0.01	
Spathula ochyra	0.01	0.01	0.02		0.02	0.01	0.13							
prorhynchid													0.01	
NEMERTEA														
Potamonemertes sp.										*				
PORIFERA														
unidentified sp.	*		0.07					*	*	0.05	0.01	0.01	0.04	0.01
HYDROZOA														
unidentified sp.	*													
	3.19	8.94	13.09	28.77	16.13	9.74	5.17	10.38	17.14	14.98	8.62	8.50	8.82	13.29

	EAST LAKE NORTH							EAST LAKE SOUTH						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
CRUSTACEA														
Isopoda														
Colubotelson sp.	4.66	12.78	13.17	10.41	9.21	5.18	6.43	3.08	2.67	6.05	3.99	2.93	6.46	5.36
Heterias sp.	*							*						*
Syncarida														
Paranaspides lacustris										0.11				
Amphipoda														
Neoniphargus ? tasmanicus														
Neoniphargus sp.	0.63	0.24	0.54	0.62	0.43	0.09	0.16	0.60	1.00	1.50	1.10	0.76	1.07	0.97
Austrochiltonia australis												*		
INSECTA														
Diptera														
Chironomus oppositus														
Cryptochironomus ? griseidorsum													*	
? Tanytarsus sp.								*						
Polypedilum nr. tonnoiri			*											
? nr. Harnischia														
Dicrotendipes sp.														*
Cladopelma curtivalva														
? Parachironomus sp.														
Parachironomus delinificus														
Riethia sp.	*	0.07	0.05	0.02	0.07		*	*	0.04	0.16	0.34	0.02	0.04	0.04
Coelopynia ? pruinosa	0.50	0.61	0.64	0.57	0.57	0.73	0.55	0.33	0.56	0.37	0.41	0.60	0.29	0.52
Paramerina sp.		0.01	*	*	*									*
Procladius ? villosimanus	*							*					*	*
Ablabesmyia notabilis	0.03	0.08	0.05	0.05	0.02	0.01	*				*		*	0.01
Orthocladiinae Sp. 2.	*		*	*	*		*	0.01					*	*

	EAST LAKE NORTH							EAST LAKE SOUTH						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
Ephemeroptera														
Atalophlebia superba								0.02						
Plecoptera														
Leptoperla beroe								*						*
Trichoptera														
Atriplectides dubius	0.05	0.17	0.04	0.06	0.04	0.09	0.07	0.01	0.03	0.14	0.21	0.02	0.04	0.06
Ecnomus tillyardi														
Notalina parkeri									*		*	*		*
Oecetis sp.														
ACARINA														
Australiobates linderi														
Oxus meridianus														
Piona uncatiformis		*												
Unionicola longiseta														
OLIGOCHAETA														
Haplotaxis ornamentus	63.84	95.90	75.49	54.47	73.65	47.24	64.65	7.55	7.49	30.61	34.97	10.51	23.31	27.95
H. heterogyne	*													
Phreodrilus magnaseta									0.01					
P. plumaseta												*		*
P. palustris	0.20							1.24	1.51	0.89	0.42	1.17	1.10	1.45
P. breviatria												*	0.02	
P. branchiatus														
P. proboscidea														
Antipodrilus plectilus	0.16	0.03	0.03	0.12	0.06	0.04	0.08	0.03	0.03	0.22	0.45	0.15	0.15	0.06
A. multiseta								0.07				*		
Telmatodrilus papillatus														
T. bifidus	0.45	0.32	0.18	0.12	0.10	0.08	0.02	0.09	0.18	0.31	0.60	0.17	0.06	0.15
Limnodrilus hoffmeisteri														

	EAST LAKE NORTH							EAST LAKE SOUTH						
	24.1.77	29.3.77	22.5.77	23.7.77	25.9.77	6.12.77	6.2.78	31.1.77	4.4.77	27.5.77	28.7.77	10.10.77	6.12.77	6.2.78
BIVALVIA														
Sphaerium lacusedes			0.03	0.02	0.61	0.67	1.11	*	0.05	0.71	0.34	0.31	0.57	0.37
S. tasmanicum														
Pisidium spp.		0.03		0.33	0.12	*	0.39		0.02	0.03	*	0.01	0.06	*
GASTROPODA														
Physastra ct. gibbosa														
TURBELLARIA														
Romankenkius bilineatus			0.02					0.03	0.07	0.03	0.07	0.04	0.11	0.16
Spathula ochyra														
prorhynchid	*	0.02										*	0.02	0.04
NEMERTEA														
Potamonemertes sp.								0.01	0.02	0.01		*	0.01	0.01
PORIFERA														
unidentified sp.														
HYDROZOA														
unidentified sp.												0.02	*	
	70.55	110.25	90.24	66.80	84.90	54.13	73.47	13.08	13.69	41.14	42.91	16.72	33.31	37.18

	TI TREE BAY							WEST LAKE NORTH						
	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78
CRUSTACEA														
Isopoda														
Colubotelson sp.	0.54	0.57	0.41	0.09	0.57	0.44	1.73	1.84	0.21	5.43	3.04	3.00	6.00	2.03
Heterias sp.			*	0.01						*	0.02	*	0.01	
Syncarida														
Paranaspides lacustris														
Amphipoda														
Neonipharqus ? tasmanicus			0.06	0.23				0.57	0.05	0.52	0.40	0.34	0.68	0.12
Neonipharqus sp.	*	0.01	0.56	0.80	0.17	0.09	0.05	0.40	*	0.03	0.25	0.40	0.72	0.12
Austrochiltonia australis														
INSECTA														
Diptera														
Chironomus oppositus							*							
Cryptochironomus ? griseidorsum	*	*								0.01				
? Tanytarsus sp.							*		0.01					
Polypedilum nr. tonnoiri					*			*						
? nr. Harnischia							*							
Dicrotendipes sp.														
Cladopelma curtivalva														
? Parachironomus sp.											*			
Parachironomus delinificus														
Riethia sp.	0.01	0.19	0.02	*			*	0.03	0.11	0.12			*	*
Coelopynia ? pruinosa	0.24	0.34	0.41	0.55	0.29	0.23	0.46	0.08	0.18	0.10	0.20	0.09	0.13	0.33
Paramerina sp.	*	*			*	*	0.01		*	*			*	*
Procladius ? villosimanus		0.07		0.01										
Ablabesmyia notabilis			*			0.01	0.02		0.01	0.01			0.01	0.02
Orthocladiinae Sp. 2.					*	*		*						

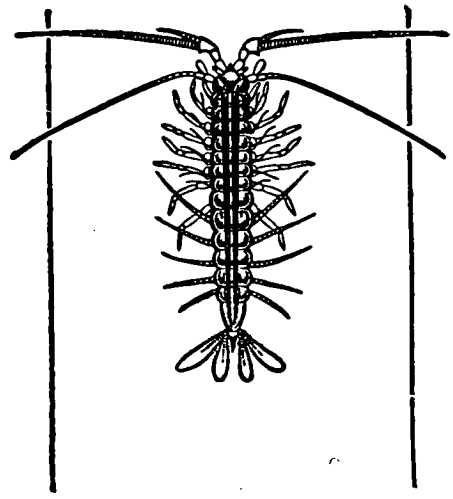
	TI TREE BAY							WEST LAKE NORTH						
	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78
Ephemeroptera														
Atalophelbia superba														
Plecoptera														
Leptoperla beroe														
Trichoptera														
Atriplectides dubius	0.02	0.12		0.05	0.01	0.01	0.01	0.39	0.04	0.04	0.04	*	*	*
Ecnomus tillyardi											*			
Notalina parkeri														
Oecetis sp.														
ACARINA														
Australiobates linderi														
Oxus meridianus														
Piona uncatiformis		*						*						
Unionicola longiseta								*						
OLIGOCHAETA														
Haplotaxis ornamentus	60.09	89.47	51.26	67.53	70.43	60.85	58.72	9.92	38.49	38.29	33.06	51.04	50.03	41.20
H. heterogyne				0.04		0.02				0.05	0.08	0.02	0.02	0.25
Phreodrilus magnaseta														
P. plumaseta														
P. palustris	0.07	0.65	2.99	3.63	1.68	2.23	0.64	0.37	0.25	1.01	1.30	1.10	1.76	0.44
P. breviatria					*									
P. branchiatus								0.23	0.01			0.01		
P. proboscidea														
Antipodrilus plectilus	0.10	0.05	0.06	0.20	0.04	0.07	0.02		*			0.03		0.01
A. multiseta								0.23	1.68	0.50	0.20	0.49		0.20
Telmatodrilus papillatus								0.02	0.23					
T. bifidus	0.16	0.12	0.26	0.53	0.26	0.30	0.16	0.08	0.28	0.19	0.38	0.17	0.17	0.30
Limnodrilus hoffmeisteri														

	TI TREE BAY							WEST LAKE NORTH						
	31.1.77	29.3.77	27.5.77	28.7.77	10.10.77	28.11.77	1.2.78	24.1.77	4.4.77	22.5.77	23.7.77	25.9.77	28.11.77	6.2.78
BIVALVIA														
Sphaerium lacusedes														
S. tasmanicum												0.01	0.01	
Pisidium spp.														
GASTROPODA														
Physastra ct. gibbosa														
TURBELLARIA														
Romankenkius bilineatus		*	0.06	0.01	*	0.03						0.01		
Spathula ochyra														
prorhynchid											*		*	
NEMERTEA														
Potamonemertes sp.			0.01		*	0.02		*	*	0.01	0.02	0.01	0.02	
PORIFERA														
unidentified sp.	0.01			0.02	*					*	0.01	0.01	0.02	*
HYDROZOA														
unidentified sp.						0.01								
	61.24	91.61	56.10	73.68	73.48	64.31	61.82	14.17	41.56	46.32	39.01	56.72	59.60	45.05

ATTACHMENT 1

No. 64

RECORDS OF THE QUEEN VICTORIA MUSEUM LAUNCESTON



Edited by
C. B. TASSELL
Director of the Museum

Correction - Page 5 -
Phreodrilus (Insulodrilus)
nudas sp. nov. - should read
Phreodrilus (Insulodrilus)
nudus sp. nov.

SOME AQUATIC OLIGOCHAETA FROM TASMANIA

by

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ABSTRACT

Ten new species of aquatic oligochaetes are described from Tasmania. The species are all in the families Tubificidae (four species), or Phreodrilidae (six species). Nine other species already described are shown to be present in the State thus bringing to nineteen the total number of oligochaete species positively identified from Tasmania.

INTRODUCTION

The aquatic oligochaete fauna of Tasmania was unknown prior to the discovery of the three tubificids *Telmatodrilus multiprostatus, T. pectinatus* and *Antipodrilus davidis* and the cosmopolitan *Lumbriculus variegatus* by Brinkhurst (1971). More recently Timms (1978) has established the presence of five other species (*Phreodrilus branchiatus, P. mauienensis, Tubifex tubifex, Limnodrilus hoffmeisteri* and *L. udekemianus*). Material now available from the South Esk River, Great Lake, and some other lakes, collected by the junior author, Mr. R. H. Norris and Dr. B. V. Timms, has confirmed the presence of two of these and uncovered ten species new to science, giving a total of nineteen known Tasmanian forms. This new material has made possible the identification of some of the forms previously recorded from Tasmania but not described for lack of adequate material (Brinkhurst, 1971, p. 110), but several species remain to be described.

The descriptions are brief but are adequate for the identification of the species concerned. In some instances, there was enough material to permit serial sections to be made as noted in the text, sometimes there was not. More detailed studies should be made but are beyond the scope of this initial report.

All specimens used in the study were collected by the junior author (unless otherwise stated in the text) from Great Lake, Tasmania, at various dates throughout 1975. Type material of the new species as well as specimens of some of the other species discussed has been deposited in the Quen Victoria Musum, Launceston (QVM). This abbreviation appears in the text with the type or deposit number for the material.

Family TUBIFICIDAE

Genus *Limnodrilus* Claparede, 1862

Limnodrilus hoffmeisteri Claparede, 1862

This cosmopolitan species was found in small numbers in Brandum Bay, Great Lake. It was first recorded, along with *L. udekemianus,* by Timms (1978) who also reported the cosmopolitan *Tubifex tubifex.*

Genus *Antipodrilus* Brinkhurst, 1971

Antipodrilus plectilus sp. nov.

Figures 1-5

Description : Small thin red worms up to 40 mm extended. Dorsal and ventral anterior bundles of setae with 7 to 8 or 9 setae, reducing in number to 3 per bundle and eventually to only 4 per segment posteriorly. Setae of II with upper tooth shorter and thinner than the lower, setae of other pre-clitellar bundles with teeth equally long, upper slightly thinner if not equal in width; posteriorly upper teeth shorter and thinner. Spermathecal setae single, thin, hollow-tipped, lying in glandular sacs. Atria elongate, distended where vasa deferentia and prostate glands are attached; ejaculatory ducts moderately long, penes simple without cuticular sheaths. Spermatozeugmata elongate, one end thin. Other characteristics as for the family.

Material : Collected from Swan Bay, Cramps Bay and Brandum Bay in Great Lake. Seven specimens examined, four mature.

Holotype, 1977/14/6 — QVM type 242.

Paratypes, 1977/14/1-5, 7 — QVM types 258-263.

Discussion : *A. plectilus* is found in clusters of up to about fifty specimens where abundant, most often in fine silts with more than 50% by weight below 4.0 ϕ units.

The distinction between this and other species in the genus will be discussed below.

Antipodrilus multiseta sp. nov.

Figures 6-8

Description : Large worms, up to 50 mm long. Red-pink in colour, covered by a sheath of small sand grains. Anterior end tapering to coiled tail. Dorsal and ventral anterior bundles of II with 12-15 setae, gradually diminishing in number to 3-4 posteriorly. Anterior setae bifid with blunt teeth of equal thickness, the upper slightly longer. Posterior setae with upper teeth shorter than the lower. Spermathecal setae single, thin, hollow-tipped, apparently in glandular sacs. Atria small, vasa deferentia moderately long, ejaculatory ducts long and thin, prostate glands small, penes simple, no cuticular sheaths. Spermathecae voluminous, spermatozeugmata elongate. Other characteristics as for the family.

Material : Collected from Cramps Bay and Brandum Bay in Great Lake. Five specimens examined.

Holotype, 1977/14/8 — QVM type 243.

Paratypes, 1977/14/9-10, 110 — QVM types 264-265, 354.

Discussion : The type species *A. davidis* (Benham) and the only other species *A. timmsi* Br., have hair-setae which are lacking in both new species. Otherwise the new species share many of the characteristics of the genus, but differ from each other in the number and form of the setae and the length of the ejaculatory ducts.

The genus is limited to Australia and New Zealand.

Genus *Telmatodrilus* Eisen, 1879

Telmatodrilus (Alexandrovia) papillatus sp. nov.

Figures 9-14

Description : Worms encrusted with foreign particles. Pharynx eversible. Body wall papillate, large papillae in rings halfway between successive seta bundles, rings of smaller papillae halfway between each seta series and the ring of larger papillae. Anterior setae bifid, 5-7 per bundle with each tooth broad, shovel-shaped, gradually becoming hair-like until post-clitellar segments with 5-9 hair setae in dorsal and ventral bundles. Penial setae 3-4 per bundle, with bifid tips. Male pore median, two short atria enter median chamber close together. At least 2 or 3 prostate glands on atria apically. Prominent tubercle on IX.

Material : Collected from Brandum Bay in Great Lake and also from Lake Sorell (B. V. Timms). Seven specimens examined, one mature.

Holotype, 1977/14/11-12 — QVM types 244-245.

Paratypes, 1977/14/94-99 — QVM types 338-343.

Discussion : The genus *Telmatodrilus* originally consisted of the two poorly described Californian species, *T. vejdovskyi* and *T. mcgregori.* Fresh specimens were obtained by the senior author in 1966 and were identified as *T. vejdovskyi,* the second species having early been regarded as a synonym of this species (Brinkhurst, 1965). Two multi-prostate species were described from Lake Pedder, Tasmania, as *T. pectinatus* and *T. multiprostatus* by Brinkhurst (1971). The former has since been recorded from Lake Tali Karng, Victoria, Australia (Timms, 1974) and the latter has been identified by the senior author from material collected in the South Esk River, Lake Sorell and Lake Crescent in Tasmania. *Telmatodrilus pectinatus* was thought to be the only tubificid having the pectinate setae limited to posterior segments rather than the anterior dorsal segments, but Holmquist (1974) recognised an oversight in the earlier descriptions of the Californian species, which also proves to have pectinate (or rather brush-tipped) posterior setae. That author, however, recognised the rediscovered Californian material as *T. mcgregori* rather than *T. vejdovskyi,* and considered the Tasmanian species to be excluded from *Telmatodrilus* but did not assign them to a taxon other than the (monogeneric) subfamily Telmatodrilinae. She also preferred to see the other multiprostate species *T. onegensis* and *T. ringulatus* remain in the genus *Alexandrovia,* proposed by Hrabe (1962) for the former, which he found in Onega Lake (located between the Gulf of Finland and the White Sea in European Russia). Holmquist expanded the description of this genotype from Alaskan material. These two species are papillate, as is the new species found in Tasmania, and hence this new form is assigned to *Alexandrovia,* but that taxon is regarded as a subgenus pending clarification of the various points of difference between it and *Telmatodrilus.* Spermatozeugmata have been recorded in both *Alexandrovia* species, but the newly described specimen seems to lack spermathecae. There are no spermatozeugmata in *T. vejdovskyi* (as *mcgregori* acc. Holmquist).

The latest member of the assemblage *T. papillatus* is instantly recognisable by its extraordinary setae, in which bifid setae with shovel-like teeth become transformed into hair-like setae in all bundles. This characteristic alone might be regarded by some as sufficient grounds for the erection of a new genus, but the senior author prefers the conservative position of retaining one generic name for all these multi-prostate species in order to signal this unique similarity, at least until they are all subject to more detailed examination.

Telmatodrilus (Telmatodrilus) multiprostatus Brinkhurst 1971

Two mature specimens from the South Esk River (R. H. Norris coll.). Also Lake Sorell and Lake Crescent (B. V. Timms).

1977/14/100-101.

Telmatodrilus? (Telmatodrilus?) bifidus sp. nov.

Figures 15-19

Small pink worms, up to 25 mm long, generally uniform in thickness but narrowing posteriorly. Setae bifid, anteriorly up to 13 per bundle with upper tooth longer than but thinner than the broad lower. Posteriorly setae progressively fewer in number, upper tooth thinner and shorter than lower from VIII or X, setae strongly sigmoid posteriorly. Some of the setae appear to be ornamented (figure 15). Spermathecal setae single straight, thin, hollow-tipped, varying in length from shorter than to three times longer than the normal ventrals. Penial setae bifid, straight, twice as long and thick as ventral setae, 6-7 per bundle. Spermathecae small, bilobed with short duct-like extension; pores lateral. Spermatozeugmata short. Atria small, spherical bodies on short, straight stems; vasa deferentia short. No cuticular penis sheaths. Prostate glands bilobed, extending around the vasa deferentia anteriorly but with a posterior lobe, precise attachment to atria not discerned. Male pores and penial setae open into large median depression.

Material : Collected from a depth of about 15 m in Swan Bay, Brandum Bay and Cramps Bay in Great Lake. Five mature specimens dissected, two sectioned, three immature sectioned.

Holotype, 1977/14/13 — QVM type 246.

Paratypes, 1977/14/14-24 — QVM types 266-276.

Discussion : This species is assigned to *Telmatodrilus* with some degree of uncertainty, which will only be clarified by examining the precise association between the prostate glands and atria. The prostates are at least bilobed, but whether they connect to the atria by one broad connection or two or more connections, cannot be discerned from dissections or sections of the first series of specimens.

The relatively large number of setae, presence of both modified spermathecal and moderately modified penial setae, presence of an eversible pseudopenis and absence of coelomocytes together with the short, rounded atrial form agree quite closely with another Tasmanian species, *Telmatodrilus pectinatus,* described from Lake Pedder (Brinkhurst, 1971). The prostates were quite clearly seen in that species, and the setae were assigned to their appropriate locations. Holmquist (1974) found the specimens to be in a poor condition, and the same is true of those still in the senior author's possession. For some reason, the mounting medium beneath the sealed-on cover glass has disappeared, forming large bubbles. The gut of those specimens was full of large coarse sand grains, so much so that the preparations are unusually thick, and sections could not be prepared without obtaining live material and starving them which was not feasible. Holmquist pointed out that the number of prostates, their position on the atria, and the form of atria in the Tasmanian species are quite different to those found in *T. vejdovskyi/mcgregori,* as is the lack of a true penis. She proposed to exclude them from both *Telmatodrilus* and *Alexandrovia* to retain them in the subfamily, but declined to erect a new genus until more adequate material is available. Her proposals are supported by the similarities between members of this assemblage including the primary character, numerous prostates, and some other minor points, such as a rather large number of setae. There *are* differences, just as there are within the monogeneric family *Phreodrilidae* (genus *Phreodrilus*) as described below, but it would seem more convenient, given our state of knowledge, to emphasise the similarity rather than the differences until more is known. The only decision to make is the level at which the similarity is recognised.

However, this latest form quite clearly has spermatozeugmata in the spermathecae, which are absent in *T. vejdovskyi,* but present in *T. (A.) onegensis* and *T. (A.) ringulatus.* Holmquist (1974) seemed certain that the sperm are in bundles in *T. multiprostatus* and *T. pectinatus* after examining the poorly preserved slides of the senior author's dissections. The senior author is less certain as to the presence or absence of spermatozeugmata in them.

Family PHREODRILIDAE

Genus *Phreodrilus* Beddard, 1891

Phreodrilus (Phreodriloides?) plumaseta sp. nov.

Figures 23-27

Description : Dimensions unknown. Ventral setae two per bundle, bifid with upper tooth shorter and thinner than lower, those of XII missing, those of XIII paired spermathecal setae, one long and one short, hollow-ended. Dorsal setae from III single brush-tipped broad setae with paired short needles. Atria elongate, tubular vasa deferentia joining basally, apparently no penes.

Material : Collected from a depth of about 15 m from Cramps Bay and Brandum Bay in Great Lake.

Holotype, 1977/14/36 — QVM type 249.

Paratypes, 1977/14/37, 107-109 — QVM types 286-293, 351-353.

Discussion : Insufficient details are available to place this species in a subgenus, though the choice is clearly between the group *Pheodriloides* (without penes, without ampullae on spermathecal pores), and *Insulodrilus (*with ampullae, with penes), both of which have ventral genital openings. However the species is quite distinct from the members of both subgenera. Only *P. magnaseta* (below) has similar dorsal setae, but it has very distinctive ventral setae. *P. nudus* (below) has similar ventral setae but lacks the plumed hair setae, and is clearly an *Insulodrilus.* The limited amount of material available has prevented further investigation of the genital pores, the presumption at present being that they are simple, lacking ampullae or penes.

Phreodrilus (Insulodrilus) nudas sp. nov.

Figures 20-22

Description : Dorsal setae from III single, broad based and narrowing abruptly, nonserrate. Ventral setae paired, bifid, lower tooth broader than the upper, both teeth short and blunt. Spermathecal setae long, paired, with hollow tips. Genital pore in line ventro-laterally, spermathecal pores with well-developed vestibulae, penis sacs with elongate penes. Spermathecal setae enclosed in glandular sacs. Spermathecal ampullae at the end of elongate ducts. Atria long, cylindrical.

Material : Collected from the South Esk River (R. H. Norris coll.), Lake Pedder, March 1966 (W. D. Williams coll.). Five specimens examined.

Holotype, 1977/14/90 — QVM type 252.

Paratypes, 1977/14/91-93 — QVM types 335-337.

Discussion : This species is very similar to the following species, but differs primarily in the absence of serrations on the hair setae. Of the other species in the subgenus, *P. lacustris* has rudimentary vestibulae, *P. campbellianus* has no spermathecal setae, *P. litoralis* has one, and all three have dissimilar ventral setae (one simple pointed, one bifid in each pair).

Phreodrilus (Insulodrilus) magnaseta sp. nov.

Figures 28-32

Description : Dimensions unknown. Ventral setae two per bundle, simple pointed, becoming progressively larger from II to VIII, smaller from VII on, simple pointed or with reduced upper tooth. No ventral setae on XII. Spermathecal setae on XIII two per bundle, one very much longer and thinner than the other, both hollow-tipped. Dorsal setae from III, hair-like with brush tips, becoming hairy in succeeding segments, but becoming shorter and blunter behind the clitellum, one per bundle with two short lateral needles. Vasa deferentia enter long cylindrical atria basally, penes in cuticularised sacs, spermathecal pores with small vestibulae and setal sacs in line with penis sacs. Other characters as for the family.

Material : Collected from a depth of about 15 m from Swan Bay and Cramps Bay in Great Lake. Seven specimens examined.

Holotype, 1977/14/31-32 — QVM type 247-8.

Paratypes, 1977/14/25-30, 33-35 — QVM types 277-285.

Discussion : The ventral setae of this species are unique in the family, being reminiscent only of those described for *Haplotaxis gastrochaetus* (Yam.) from Japan (Yamaguchi, 1953), but in the latter the setae become larger up to the twentieth segment rather than the seventh. The dorsal setae resemble those of *P. plumaseta* (q.v.).

Phreodrilus (Insulodrilus) breviatria sp. nov.

Figures 33-36

Description : Dimensions unknown. Ventral setae clearly bifid with thin, short upper teeth. No spermathecal setae. Hair setae with needles dorsally, (3) 4-5 (6) per bundle, distinct and thick from III on, bent, tapering beyond the bend, 13-16 setae medially, Vasa deferentia join atria submedially, atria short thick cylinders, penes small in large penis sacs. Spermathecal pores close to male pores, with small vestibulae.

Material : Collected from a depth of about 15 m from Cramps Bay and Brandum Bay in Great Lake. Four mature, six immature specimens examined.

Holotype, 1977/14/45 — QVM type 250.

Paratypes, 1977/14/46-49 — QVM types 294-297.

Discussion : The atria are short and thick in this species, and consequently the near-basal position of the vasa deferentia appears to be more medial than in other species in the sub-genus. The species has bifid ventral setae in each pair, no spermathecal setae, and small vestibulae on the spermathecal pores. It does not have plumed setae nor enlarged ventrals, and so is distinguishable from the other species in the sub-genus.

Phreodrilus (Phreodrilus) branchiatus Beddard, 1891

Figures 37-38

Description : Dorsal setae from III, 1-3 long thin straight hair setae, two short needles on each side of each hair basally, often a third short hair seta. Ventral setae one thin simple pointed seta and one broad bifid seta with short, thin upper tooth in each bundle. Sixteen to fifty pairs of dorso-lateral gills posteriorly.

Material : Collected from Brandum Bay in Great Lake and from the South Esk River (R. H. Norris coll.).

Five specimens examined. 1977/14/102-106.

Discussion : The original locality for this species is in Southern Chile. It was only briefly described, but the Tasmanian material fits the description apart from a larger number of gills (from 16 in the smallest to 50 in largest specimen as opposed to 13 in the type material). Timms (1978) recorded the species from Tasmania.

Phreodrilus (Phreodrilus) palustris sp. nov.

Figures 39-43

Description : Length 10-40 mm, up to 2 mm thick. Light brown worms, in two size classes in the collection. Ventral setae 2 per bundle, both more or less blunt with a rudimentary upper tooth. Dorsal setae anteriorly thin hair-setae, progressively increasing in number and size posteriorly from 1 or 2 to 5-8 and eventually up to 19 setae a bundle, with short needles between the hairs, the setae bent, narrowing abruptly beyond the bend, dorsal setae diminish in size and number at posterior end. No modified genital setae. Vasa deferentia strongly coiled, long with thin portion proximally, thicker portion distally, joining atria at or near elaborate eversible pseudopenes. Atria moderately long, thick. Spermathecae with sperm traps in ducts, reach to 7 segments behind pores, which are dorsal with muscular vestibulae. Swims quite rapidly with a spiral motion.

Material : Collected from Swan Bay, Cramps Bay and Brandum Bay in Great Lake. Six mature specimens, three sectioned, seven immature examined.

Holotype, 1977/14/54 — QVM type 251.

Paratypes, 1977/14/51-53, 55-79 — QVM types 298-325.

Discussion : This species is, at first sight, rather similar to *P. breviatria.* In all specimens examined to date the anterior end of *P. palustris* has few, thin hair-setae and each segment has about the same diameter as the next. In *P. breviatria* the hair-setae are larger, more obvious right from III, there are more setae in III, and the anterior end is tapering because the segments increase in diameter quite abruptly. The male ducts are quite clearly different also, with true penes in *P. breviatria,* the two species therefore belonging to separate sub genera. The two ventral setae of each bundle are alike in *P. palustris,* whereas in the other species in the same subgenus they ar dissimilar. Also, there are more hair-setae per bundle in this species than in others in the subgenus, especially in the median segments.

Phreodrilus proboscidea sp. nov.

Figures 44-46

Description : Prostomium with a proboscis. Dorsal setae from III, 2-4 serrate hair-setae, long, thin and straight, numerous shorter needles, usually one each side of each hair-seta. Ventral setae of III and IV simple pointed, one thicker than the other, from V on one bifid with short thin upper tooth, one thinner simple pointed.

Material : Collected from Cramps Bay in Great Lake and also from Lake Pedder, March 1966 (W. D. Williams). Ten whole mounts.

Holotype, 1977/14/80 — QVM type 253.

Paratypes, 1977/14/81-89 — QVM types 326-334.

Discussion : Some fragmentary specimens of a phreodrilid with a proboscis and serrate hair-setae were found in the Lake Pedder collection (Brinkhurst, 1971, p. 110) but no name had been given to the species. The above description is clearly provisional, but will suffice to distinguish this species from all others unless further research turns up two with this combination of characters. The species cannot be assigned to a subgenus pending description of the reproductive system. The definition of the family requires changing as a result of these descriptions.

Similar specimens with a proboscis and the bamboo-like serrate hair setae were sent to the senior author from a trickle beside Guthries Creek, Mt. Kosciusko, New South Wales, collected 9.1.74 by H. B. N. Hynes.

Family HAPLOTAXIDAE

Several specimens, apparently assignable to at least two species in this family, were found in Great Lake but could not be described for lack of mature specimens.

Family LUMBRICULIDAE

One immature form resembling *Lumbriculus variegatus* was observed in the South Esk River. This species has been recorded in Tasmania, and is the only cosmopolitan form in the holarctic family.

DISCUSSION

According to earlier records (Brinkhurst, 1971) the only aquatic oligochaete species known from Tasmania were *Lumbriculus variegatus, Antipodrilus davidis* and two new species of *Telmatodrilus* from Lake Pedder (*T. multiprostatus* and *T. pectinatus*). A preliminary inspection of a collection on loan from B. V. Timms established the presence of one of these (*T. multiprostatus*) in two Tasmanian lakes, together with the cosmopolitan *Limnodrilus hoffmeisteri* in a third. This collection was subsequently investigated in more detail by Dr. K. V. Naidu who found *Tubifex tubifex, Limnodrilus udekemianus,* both the new *Telmatodrilus* species and *Phreodrilus branchiatus* together with some unnamed species (Timms, 1978).

The present collection contains ten new species plus *P. branchiatus* and *Limnodrilus hoffmeisteri.* The absence of other known Australian species and the presence of so many new species further emphasises the unique nature of the Tasmanian aquatic oligochaete fauna. Of the known Tasmanian species *P. branchiatus* is known only from Chile, *L. hoffmeisteri, L. udekemianus* and *L. variegatus* are cosmopolitan, *T. pectinatus* is known from the Australian mainland and *A. davidis* from the Australian mainland and New Zealand, leaving eleven species which may be endemic to the island.

Likewise a difference between Tasmanian and Australian mainland faunas has been noted in the stonefly group. Hynes (1976) found that only six out of a total of sixty-six stonefly species can be found on both sides of Bass Strait according to the most conservative count. However, the genera are often shared, both in the oligochaetes and stoneflies.

The generic limits in the oligochaeta may yet be revised, especially in the monotypic "Gondwanaland" family Phreodrilidae.

ACKNOWLEDGEMENTS

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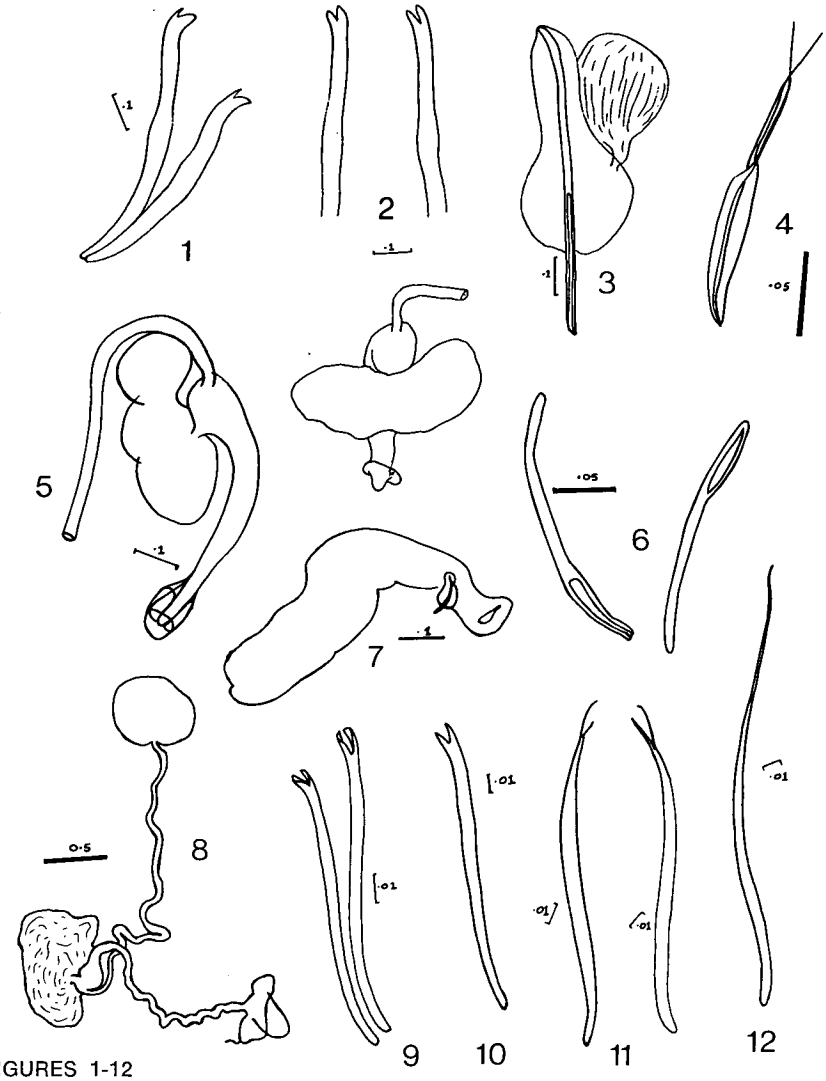


FIGURES 1-12

Figures 1-5 *Antipodrilus plectilus* sp. nov.

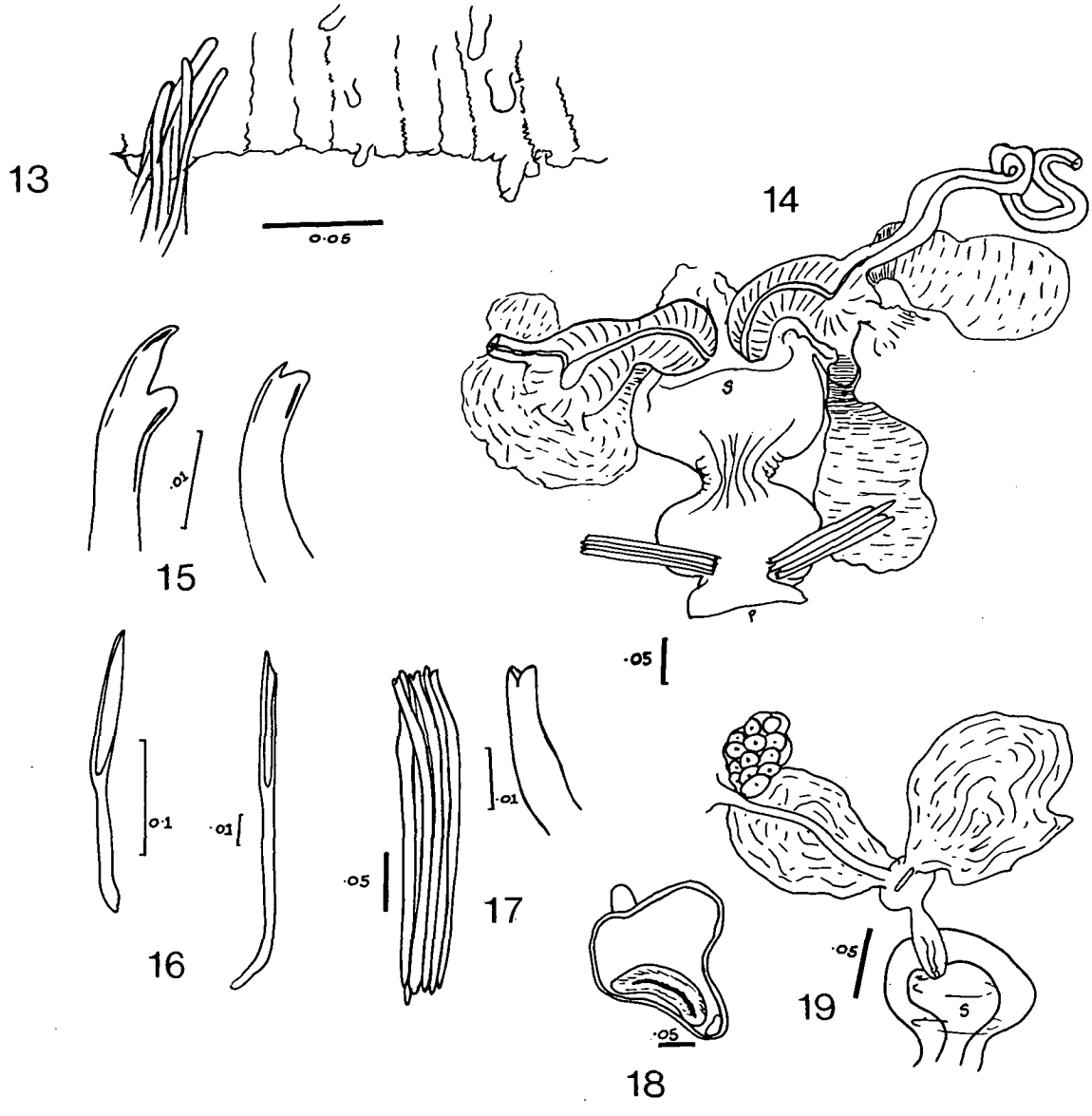
1. Setae of II.
2. Setae of VII.
3. Spermathecal seta in sac with glands.
4. Two spermatozeugmata.
5. Atria, prostates, vasa deferentia and ejaculatory ducts.

Figures 6-8 *Antipodrilus multiseta* sp. nov.

6. Spermathecal setae.
7. Spermatheca and spermathecal seta.
8. Male efferent duct — sperm funnel at top, penis on lower right.

Figures 9-12 *Telmatodrilus papillatus* sp. nov.

9. Ventral setae of IV.
10. Setae of VIII.
11. Setae of XI-XIII.
12. Posterior seta.



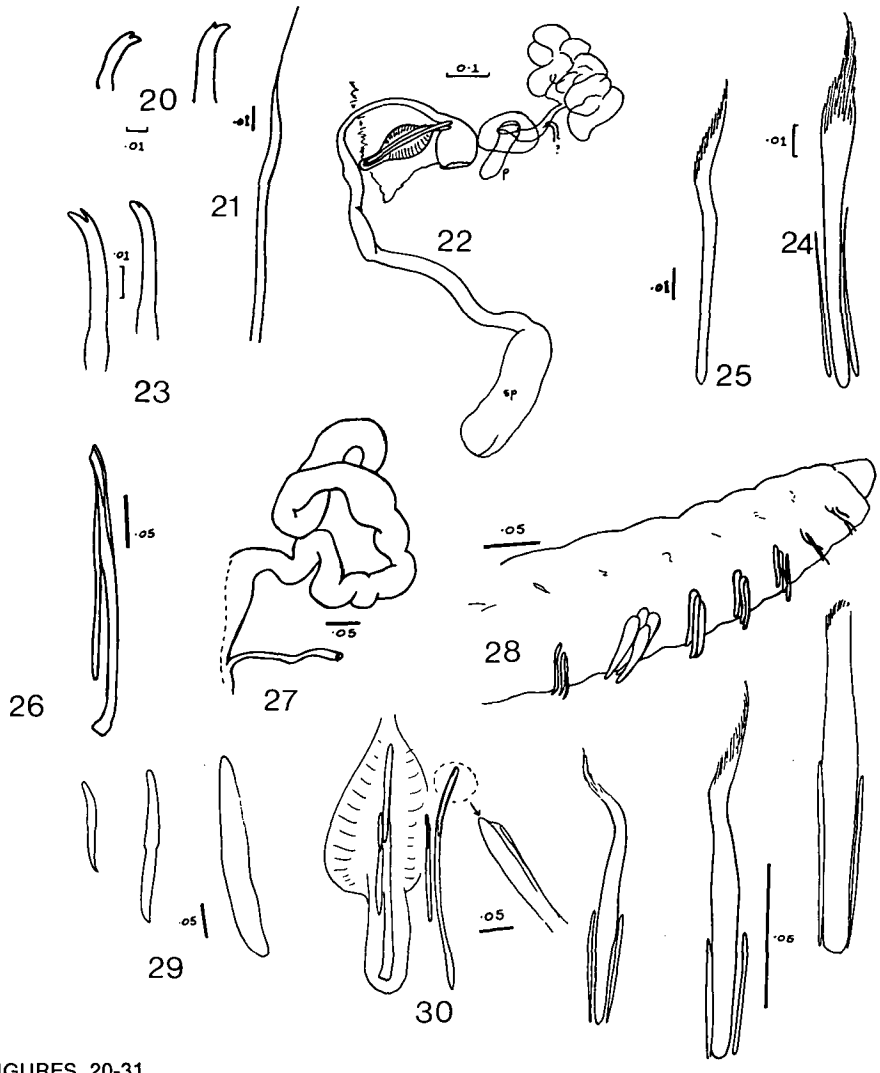
FIGURES 13-19

Figures 13-14 *Telmatodrilus papillatus* sp. nov. (cont.)

13. Body wall showing papillae.
14. Male efferent ducts — two atria with prostates (attachment not certain) entering common median sac(s) to median pore (p) with penial setae.

Figures 15-19 *Telmatodrilus bifidus* sp. nov.

15. Setae, anterior and median.
16. Spermathecal setae (note two sizes).
17. Penial setae.
18. Spermatheca with spermatozeugmata.
19. Vas deferens, ovary, prostate (attachment uncertain), atrium and median sac(s).



FIGURES 20-31

Figures 20-22 *Phreodrilus nudus* sp. nov.

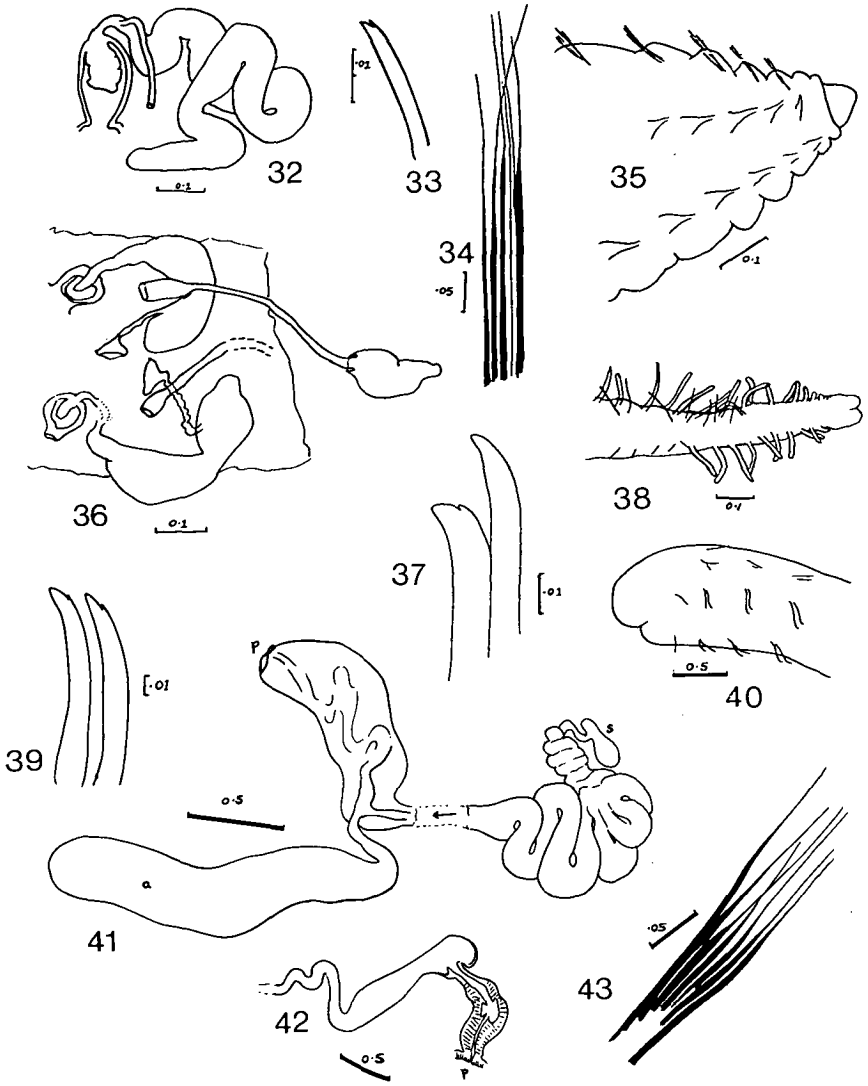
20. Ventral setae of III, VII.
21. Dorsal seta.
22. Reproductive system: spermathecal ampulla (sp) with long duct, vestibulae anterior to spermathecal seta; penis (p) and coiled atrium.

Figures 23-27 *Phreodrilus plumaseta* sp. nov.

23. Anterior ventral setae.
24. Anterior dorsal seta.
25. Median dorsal seta.
26. Spermathecal seta.
27. Male duct.

Figures 28-31 *Phreodrilus magnaseta* sp. nov.

28. Anterior end showing progressive enlargement of ventral setae.
29. Ventral setae of II, V, VI (from left to right).
30. Spermathecal setae in sac, detail of tip.
31. Dorsal seta of II, VIII, XV (from left to right).



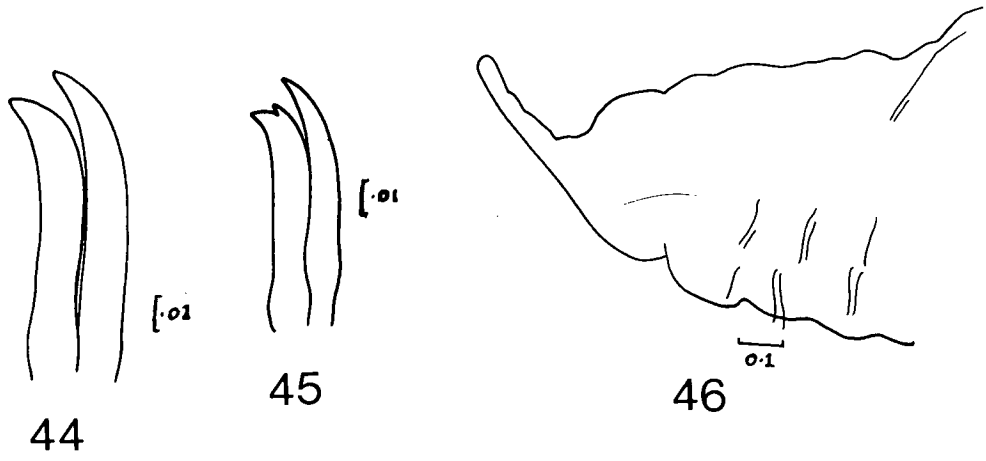
FIGURES 32-43

Figure 32 *Phreodrilus magnaseta* sp. nov. (cont.)
32. Male efferent duct.

Figures 33-36 *Phreodrilus breviatria* sp. nov.
33. Ventral seta.
34. Dorsal setae.
35. Prostomium and conical anterior end.
36. Male efferent ducts and spermathecae.

Figures 37-38 *Phreodrilus branchiatus*
37. Ventral setae.
38. Posterior end with gills.

Figures 39-43 *Phreodrilus palustris* sp. nov.
39. Ventral setae.
40. Anterior end — not tapering, conical (c.f. 35).
41. Male efferent duct: male pore (p), sperm funnel (s), and atrium (a).
42. Spermathecal pore (p), sperm trap, spermathecal duct leading to ampulla.
43. Dorsal setae.



FIGURES 44-46

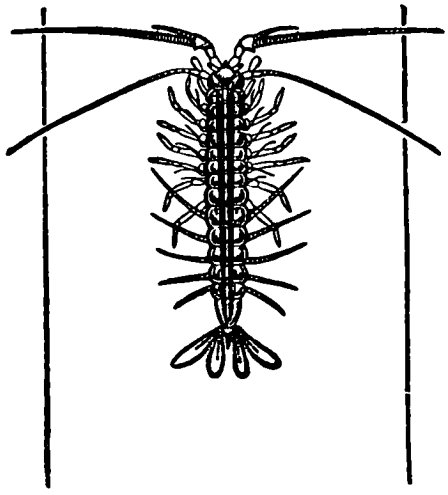
Figures 44-46 *Phreodrilus proboscidea* sp. nov.

44. Ventral setae of II.
45. Ventral setae of V.
46. Anterior end with proboscis.

ATTACHMENT 2

No. 72

RECORDS OF THE QUEEN VICTORIA MUSEUM LAUNCESTON



Edited by
C. B. TASSELL
Director of the Museum

ON **HAPLOTAXIS ORNAMENTUS** SP. NOV. (OLIGOCHAETA, HAPLOTAXIDAE) FROM TASMANIA

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ABSTRACT

Haplotaxis ornamentus sp. nov. is described from Tasmania. It is a hologynous species with ornamented setae resembling those of species known from the Cordillera Cantábrica, Spain, the Pyrénées-orientales, and Pyrénées centrales, France, and caves in Bulgaria-Roumania-Yugoslavia.

INTRODUCTION

The family Haplotaxidae is discontinuously distributed around the world, but the species have limited distributional ranges apart from the various forms of *H. gordioides*, which seem to be at least holartctic, possibly cosmopolitan although mature specimens have yet to be described from various localities.

A new species has been found in Great Lake and Arthurs Lake, Tasmania, in large numbers, by the junior author.

Both of these lakes have had their levels raised for hydro-electric purposes but the new species has only been found in the original level of either lake. The depth of this part of Arthurs Lake is from about 8 to 12 m whilst in Great Lake it varies from about 12 to 18 m. Abundance varied considerably between sites and throughout the season with a maximum mean number per Ekman grab sample (232 sq. cm version) at any sample site of 7 in Great Lake and 20 in Arthurs Lake. Biomass estimates for this species varied with season and between sites up to a maximum of 90 g/sq.m at one site in Arthurs Lake.

Sediment analysis at the sites occupied by the new species showed that there was usually in excess of 50% by weight (often more than 75%) of the sediments below 63 μ in size. Organic content of these sediments ranged from about 5 to 20% as determined by weight loss on ignition.

Family HAPLOTAXIDAE

Genus *Haplotaxis* Hoffmeister, 1843

Haplotaxis ornamentus sp. nov.

Figures 1 - 5

Description : Large irridescent worms c. 120 mm long, 2-3 mm broad (preserved) purple-red in life. Prostomium prolobous, bluntly conical. Double annulation from V to about XIV, the anterior, non-setate ring just less than half the width of the larger setate ring, setae about two-thirds back from the front edge of the larger ring, a slight annular groove at the setal line of XIV. Setae closely paired, setal formula (at V) 8 : 1 : 5 : 1 : 8. Setae of a pair of different lengths, ventral anterior setae longer than the dorsals, reaching a maximum length in IX-X. Setae ornamented, with broad semi-lunar depressions scattered irregularly along the exposed parts, most abundant just below the curved, blunt tips. Genital pores (observable on detached cuticle) present, spermathecal pores in 6/7 and 7/8 ventro-lateral, median in the line b-c. Anterior male pores beside setae b in XI, those in XII behind 11/12 lateral to line b. Female pores in 12/13 and 13/14 in setal line ab.

Vascular systems prominant anteriorly, with long commissural vessels. The commissural vessels visible externally in II arise from the division of the dorsal vessel by the brain, those of III arise from behind that segment such that the dorsal vessel has a long, unbranched anterior portion. These commissurals unite to form a median ventral vessel in about V, beyond which the vessels are less prominant.

Intestine without crop or gizzard, roof of pharynx somewhat thickened. Pharangeal glands present, ? in IV-VII. Intestine narrows from X to XV or XVI, widening to largely fill posterior segments.

Reproductive system with testes and large male funnels in X and XI, male ducts simple, more or less elongate but difficult to discern. Ovaries and female funnels in XII and XIII. Spermathecae somewhat cylindrical, ducts not much narrower than ampullae, which are filled with balls of sperm, paired in VII and VIII. Sperm sacs extensive, reaching from X to about XIII or more. Eggs sacs to XV.

Cocoons somewhat egg-shaped with elongate processes, single eggs.

Material : Collected from Great Lake, Arthurs Lake, Tasmania (W. Fulton coll.) at various dates.
Type series : fourteen mature specimens, grid reference DP 951 562 (Tasmanian Lands Dept. Tasmap series), Arthurs Lake, Tasmania, 25.9.77, cocoons Tea-tree Bay, Arthurs Lake, 28.7.77.

Holotype : QVM type 372, 1980/14/1, specimen in fluid.

Paratypes : (i) QVM : QVM types 373-386, 1980/14/2-15, 13 specimens in fluid, 1 specimen, serial sections on 77 slides.
(ii) Brinkhurst Collection : Serial sections of two other specimens totalling 79 slides, and five slides from three other specimens.

DISCUSSION

Many of the species of the family Haplotaxidae are hologynous, as is the present species. Few of them have ornamented setae, however. The oldest known species with this characteristic is *H. bureschi* (Michaelsen) from the Balkan states. In the description of this species cited by Brinkhurst (1966) and Brinkhurst and Jamieson (1971) the two-ringed segments are said to have the shorter, non-setate ring behind the larger setate ring, but this is clearly an error as the reverse situation is now suggested in recent accounts by Delay (1972, 1973) who described two species from the Pyrenees of France and Spain which are close to *H. bureschi* (and a third, *H. navarrensis,* which has setae both ornamented, like the above, and keeled like *H. leruthi* from France). Of these two species, *H. corbarensis* is smaller than *H. bureschi,* the setal ornamentation is more variable compared with what must be a new drawing from the type of that species, and there are differences in the setal formula (U = 13aa as in Delay (1972), not 3aa as quoted in Delay (1973) for *H. corbarensis).* The second species, *H. cantabronensis,* has simple ornamentation which seems to be as helically arranged on the setae as that of *H. bureschi.* It has the same setal formula as the latter. The sexual setal glands are said to be on IX - XI in the new species but to occupy six segments in the older taxon, but various literature accounts described these glands as either single or paired in from one to six segments.

The separation of all three forms is based on quite slim differences.

The new species is immediately dinstinguishable by having only two pairs of spermathecae (a character liable to some variation in other species), a very different setal formula, more segments in a similar length, and some differences in setal shape and ornamentation. Its zoogeographic separation suggests the need for this ranking in this discontinuously distributed family, but is not regarded as a taxonomic character of course.

The Haplotaxidae, and also the southern hemisphere Phreodrilidae, are regarded as monogeneric families by the senior author, partly for convenience as there are so few species, partly as an expression of a lack of knowledge of the relative importance of, and intraspecific variation in, morphological characters commonly described. These are practical rather than systematic decisions. Righi *et al.* (1978) have recently described a new haplotaxid genus (*Tiguassu)* from the Brazilian Amazon. The prostomium has a proboscis, the anterior male funnels are non-functional and there is a single pair of ovaries and female funnels in XII, the female pore being in XIII. Spermathecae open laterally (as do the other genital pores) in 8/9 and 9/10. The absence of the anterior pair of testes is unique to this and the doubtful *Pelodrilus falcifer* Omodeo (from Africa), the proboscis is unique, but the absence of posterior ovaries is not. The ovaries of *P. falcifer* are in XIII while the testes are in XI, so the union of this with the genus *Tiguassu* seems unlikely. *P. falcifer* remains a sp. dub. *Haplotaxis brinkhursti* has testes in X - XI but ovaries only in XIII (Cook 1975).

The position of the Haplotaxidae as a stem family for the Haplotaxina, as suggested by Brinkhurst and Jamieson (1971), is clearly at odds with the traditional phylogeny, as illustrated by Knox (1972) after Pickford's account in Encyclopaedia Britannica 1962. In

these traditional versions the small Aeolosomatidae are thought to be primitive annelids that gave rise to the Naididae and Tubificidae, all of these with multiple setae derived from some polychaete-like ancestral form. The radiation of families from the Tubificidae shown by Pickford may not be generally accepted, but the derivation of the more terrestial earthworms from the Haplotaxidae via some earlier aquatic forms is more soundly based, largely because earlier studies paid far more attention to the better-known larger worms.

If we accept the concepts outlined by Clark (1964) in his penetrating analysis of the origins and functions of the coelom and septa, we may envisage a very different sequence of events. The Aeolosomatidae have been shown by Brinkhurst (in Brinkhurst and Jamieson, 1971) to bear no anatomical similarities to Oligochaeta beyond their shared annelidan characteristics. Their reproductive system cannot be derived from the simple hologynous array of the Haplotaxida, and they must be regarded as a separate higher taxon containing from one to three families depending on the classification adopted. The Haplotaxidae fulfill the requirements for an ancestral form for the Oligochaeta, but most living species have already established the characteristic four setal pairs of their terrestrial descendants. Only *H. gordioides,* the one widely distributed species, has odd setae which may echo an ancestral form with few setae derived from some earlier non-segmented coelomate that may well have been ancestral to the few surviving taxa with such a structure. In *H. smithii* the male and female genital ducts are more or less the same, again a trace of a condition that would likely have been present in a primitive oligochaete. While most of the modern species may be thought to be most closely associated with the Lumbricina of Brinkhurst and Jamieson (1971) the senior author cannot agree with the most recent rearrangement of the classification by Jamieson (1978). In his most interesting study following Hennig's principals, Jamieson confirms an earlier change in position of the Moniligastrida from an Order to a Suborder of the Lumbricina, and this has been supported by the senior author elsewhere. The other change is to elevate the Tubificina from a Suborder to a full Order, shifting them outside the Haplotaxida. My objections to this are based on the fact that no representative of either the Order Lumbriculida or the Suborder Tubificina were involved in the computerised study, and Haplotaxina were represented by a single "characteristic" species, *H. violaceus.* The latter is closely allied to the terrestrial forms and other more advanced Lumbricina in that the male pores both lie on XII, anticipating the general rearward tendency in male pore position, the only species in the Suborder where this is reported. This, together with the non-representation of the aquatic groups, would inevitably skew the analysis towards the conclusion reached. The complaint, then is not with the consistency or logic of the result obtained, but its relevance to any consideration of the position of the Tubificina viz a vis the Haplotaxina. It is unfortunate that the state of so many species descriptions and the labour involved in entering all of them into the programme prohibits a complete analysis, but the clues available from a study of the fragmentary living remnants of a truly ancient family are such that they may readily be lost in computer systems no matter how carefully set up.

One significant feature of the Tubificina which causes many biologists to balk at this concept of their position is their multiple setae. It seems to be dogma that these setae are held-over from some previous polychaetine ancestor, largely because Polychaetes are marine and are therefore thought to be ancestral to terrestrial and freshwater oligochaetes Again, I rely on Clark (1964) for the basis for rejecting this.

It so happens that more and more marine oligochaetes are now being discovered, some with quite elaborate adaptions, but most with very simple bifid setae. These do not seem to be primitive tubificids, (although the variation in prostate glands is becoming interesting). Many are members of the distinct subfamily Phallodrilinae. No relict oligochaete with polychaetine setae has been found. The complex hair and pectinate setae of many Tubificidae and Naididae are restricted to dorsal bundles but are not especially like those of polychaetes, and seem to the senior author to be an analogous development, like the simple eyes of the Naididae, a development for a swimming existence, since, abandoned by the tubificids. The Enchytraeidae have an enlarged setal number (though not often very many per bundle) and seem to have had bifid setae in their aquatic phase of evolution, now largely abandoned for a terrestrial existence (note *Propappus* the aquatic genus with bifid setae, said to be primitive). The Tubificidae may be showing a strong tendency to lose their elaborate setae, which seem hard to visualise as an adaptation to burrowing. Experiments with setal number are found in perichaetine earthworms, of course, and there seems no need to believe that multiplication of the setae has arisen only once in annelid evolution. In this sense the tubificine oligochaetes can be seen as an evolutionary line penetrating acquatic habitats after developing sexual reproduction and hermaphroditism at the earliest phase of oligochaete evolution. The functional basis of the former is generally held to be the needs for reproduction in a terrestrial environment, perhaps even an osmotically threatening freshwater environment that seems to be the ancestral home of most oligochaetes.

The functional basis of hermaphroditism seems to this author to require a breakthrough in understanding as significant as that brought to bear on the functions of the coelom by Clark (1964), as much of the received truth seems inadequate to explain its significance for the often astronomically abundant tubificids and its general widespread occurrence in "lower" phyla.

ACKNOWLEDGEMENTS

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FIGURE LEGENDS

Figure 1. Disposition of male pores (M) and female pores (F) on ventral side of segments XI - XIII (diagramatic).

Figure 2. Anterior blood vascular system A — ventral view, B dorsal view.

Figure 3. Scanning electron micrograph of seta to show ornamentation (x 4800).

Figure 4. Setae (scale = 0.05 mm).

Figure 5. Spermatheca with sperm balls (scale = 0.1 mm).

Figure 1

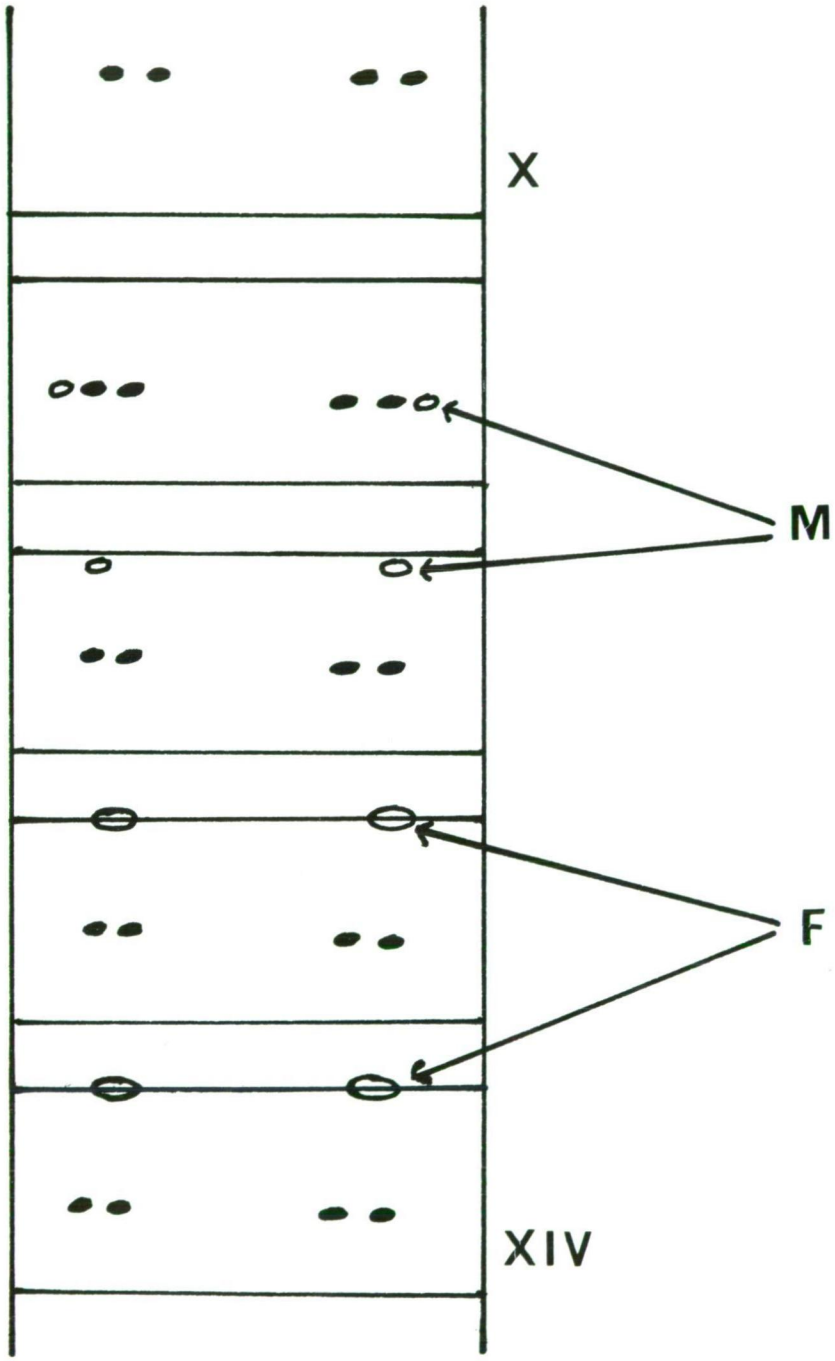


Figure 2A and 2B

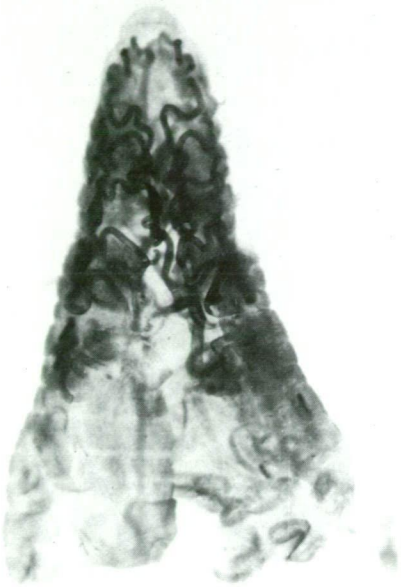


Figure 3

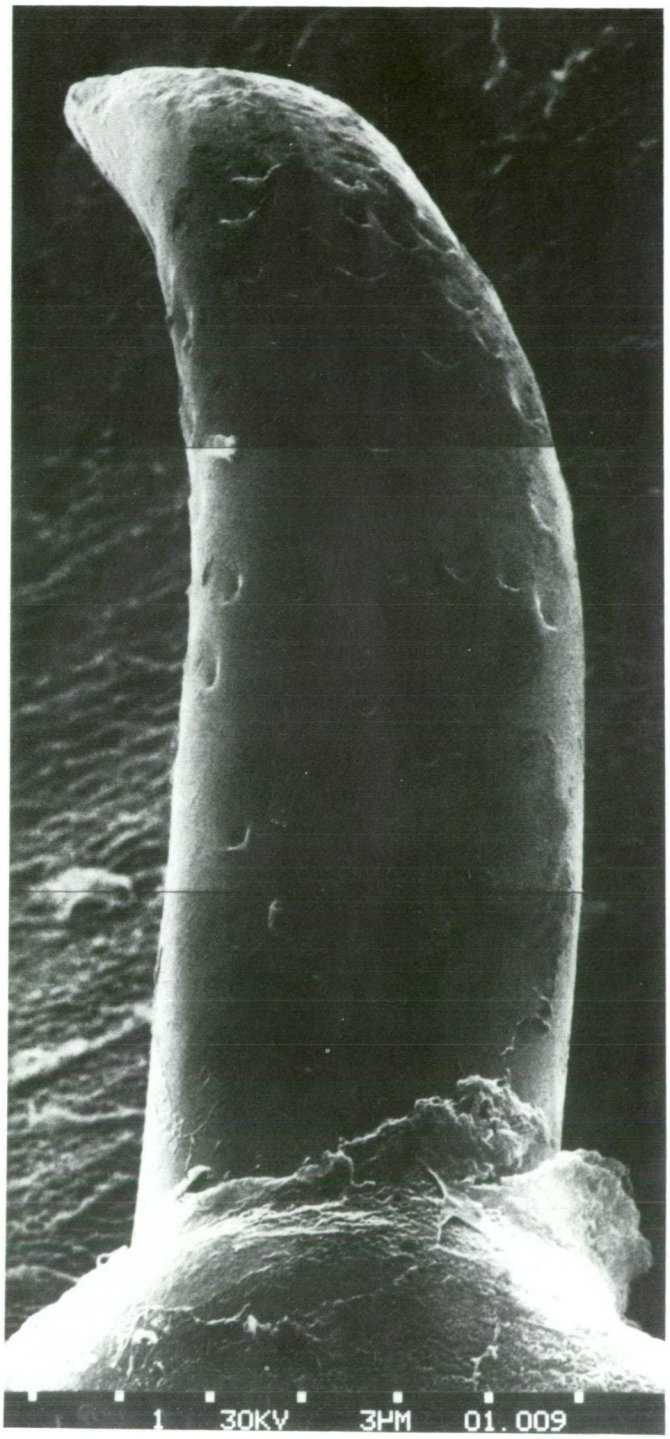


Figure 4

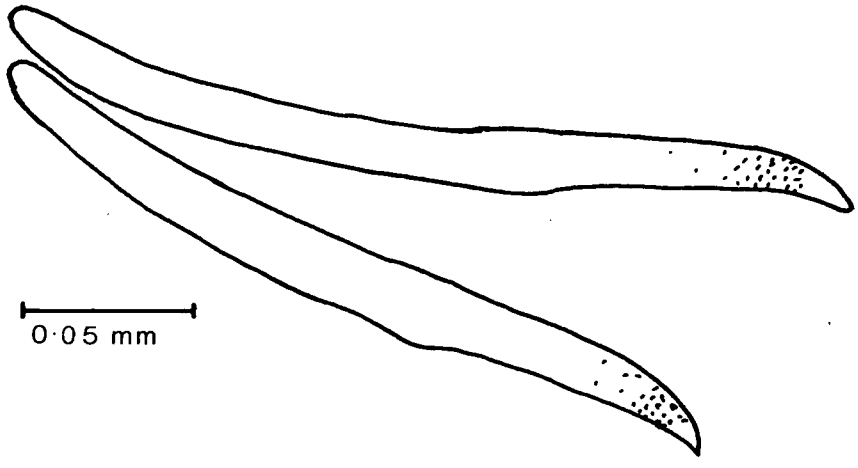
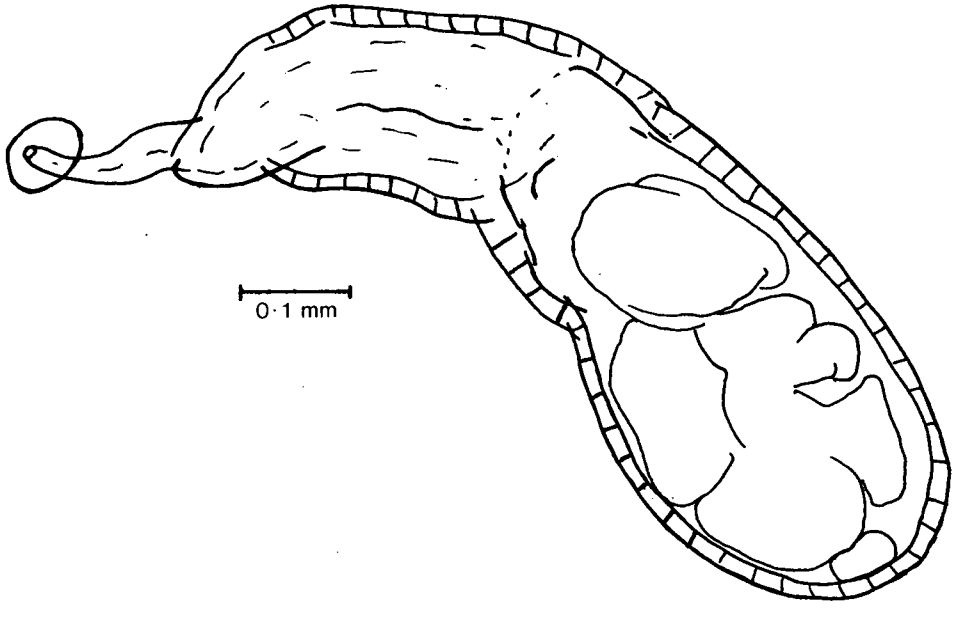


Figure 5



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