Development of a lake pollution monitoring system using periphyton in the littoral zone of Lough Gill

By

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Abstract

Periphyton is a complex mat, predominantly made up of algae, found attached to submerged surfaces in the photic zone of a waterbody. In the early 1990's this brown substance was observed to cover plants, stones and most submerged surfaces around the shoreline of Lough Gill in NW Ireland. Analysis of the water indicated a mesotrophic system, however such a substantial growth of periphyton warranted further investigation. A monitoring programme was established with six sample sites spread around the littoral zone. Three artificial substrates were used to measure periphyton; glass slides, trays of washed stone and a plastic substrate (to simulate the macrophyte *Littorella uniflora*). Substrates were submerged for periods of 1 month from February 1997 to May 1998. Phytoplankton samples were also collected.

Diatoms always dominated the biomass on slides, with peaks during spring and autumn. Green and blue/green algae became prominent in the summer and autumn. Diatom genera included *Cymbella, Gomphonema, Nitzschia* and *Synedra*. Chlorophyta included *Chaetophora, Stigeoclonium* and *Ulothrix*; and the main Cyanophyta were *Anabaena* and *Aphanocapsa*. During 1997 periphyton biomass from glass slides ranged from 25 g/m^2 (May) to <1 g/m^2 (November), in the same period AFDW ranged between 14 g/m^2 and <1 g/m^2 with algal numbers ranging between 16,200 $cells/mm^2$ and 124 $cells/mm^2$. During April 1998 periphyton biomass exceeded anything seen during 1997 with dry weight from 24 g/m^2 to 36 g/m^2, AFDW from 11 g/m^2 to 19 g/m^2 and cell numbers were greatly increased (18,850 $cells/mm^2$ to 41700 $cells/mm^2$).

A substantial proportion of cells suspended in the waters of the littoral zone were periphytic in origin. These diatoms dominated littoral phytoplankton during spring and considerably influenced phytoplankton populations throughout the rest of the year. In periods of peak periphyton growth, clots of algae became suspended through wind and wave action during stormy weather which temporarily reduced water clarity.

Considerable spatial variation was observed between the sites. This would seriously effect site selection in a monitoring program. Wind patterns and associated water movement may influence growth variability on substrates; those sites with greater exposure having greater levels of growth. Glass slides suspended in the water column were more indicative of periphyton on natural substrates, whilst trays of washed stones and artificial *Littorella* were found to trap excessive amounts of inorganic sediment. The quantity of periphyton, irrespective of spatial and temporal trends, appears to be remarkably greater than other lakes in the west of Ireland.

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Dedicated to the memory of my grandmother, Mrs. Adge Feeney

Table of Contents

Contents	Page number

Appendices

List of plates	**Page number**

List of Figures — Page number

List of Tables	**Page number**

1.0 Introduction

1.1 Background

Lough Gill, situated near the north-west coast of Ireland, is located between counties Sligo and Leitrim, 80% within the former and 20% in the latter (see Plate 1). The lake has long been recognised as one of the regions' most valuable natural assets (Brady Shipman Martin 1979, North West Tourist Board 1995). It is particularly prized for its recreational, historic and ecological value (O'Rourke c.1880, Kilgannon 1926, O'Grady 1991a and Cotton 1994). In response to the ecological importance of the lake and its environs, six sites were formally designated *Areas of Scientific Interest* by An Foras Forbartha (1972 and 1978 unpublished). The lake is listed in the *Inventory of Outstanding Landscapes* and has been recognised in its designation as a *Special Area of Conservation* under the Habitats Directive (92/43/EEC, SI 94 of 1997). Lough Gill and its immediate surroundings are now included in the list of proposed Natural Heritage Areas (Office of Public Works 1995 unpublished).

Recognising the importance of Lough Gill, Sligo County Council and Leitrim County Council with the support of the Institute of Technology, Sligo successfully obtained funding from the EU financial instrument, 'LIFE'. The aim was to develop a long-term management strategy for Lough Gill and its environs. The project ran from May 1995 to September 1998 and ended with the publication of a Management Plan (Thompson, Ryan and Cotton 1998).

The Environmental Management Project had the primary aim of protecting the natural environment of the lake and its surroundings while utilising it to its full potential in a sustainable manner. In order to achieve this, actions such as data acquisition, education, environmental monitoring, pollution prevention, planning controls and conservation management of the lake were employed (Sligo County Council 1994 unpublished). One of the primary goals of the project was the establishment of a forum, 'The Catchment Management Committee', to develop communication and understanding among the many groups with a vested interest in the lake and its environs. Within this forum a primary aim was to draw up a water quality management plan for the lake and its catchment.

Plate 1: Map of Lough Gill with the River Bonet flowing into the lake from the south-east. Lough Gill flows out through Sligo town via the Garavogue River to the north-west. The Ox Mountains are visible to the south of the lake.

During the course of the LIFE project aspects about the littoral zone of Lough Gill showed cause for concern. In spring and early summer of 1995 and 1996, while the project was undertaking a mapping program of the lakes aquatic macrophytes, a brown gelatinous material was observed covering organic and inorganic substrata and all vegetation along the shore (see Plate 2 and Plate 5). The material, which was slippery under-foot and easily re-suspended in the water column, had coated most areas of the littoral photolitic zone around the lake.

Plate 2: Brown and green gelatinous materials found in the littoral zone of Lough Gill. Plate shows submerged concrete structure with attached growth. Plate from the water pump house in Tobernalt Bay on the 2nd June 1998.

Questions were raised about the levels and effect, if any, the gelatinous material had on the lake and its ecology. The exact nature, volume and seasonal patterns of the substance were unknown. No scientific records of this occurring, or its extent on Lough Gill were available. It was unclear if its incidence was intensifying. This is with the exception of observations by Cotton (1994, unpublished) where he noted that the stones of the littoral zone were covered in slime containing recently deposited silt and organic detritus. Cotton maintained that this was bound by some filamentous algae, 'which was an on-going legacy of the Bonet drainage scheme'. There was concern that this material was an indication of the lakes first step towards enrichment and eutrophication.

It was unknown if this gelatinous mat could effect macrophyte growth by diminishing light penetration, resulting in reduce photosynthesis levels. The possibility of it reducing diversity and cover of macrophytes around the lake was also questioned. The shore weed, *Littorella uniflora* (L.) Asherson, a reasonable uncommon macrophyte in Western Europe (Perring and Walters 1993), is widely distributed in the littoral zone of Lough Gill. It was suggested that its diminishing presence elsewhere could be a result of this brown material (see Plate 3). If so, this could be the start of a change in the distribution of *L. uniflora* around Lough Gill. Also if the material clogged the lake substrate there was the possibility of damage to macro-invertebrate habitats. This could limit fish stocks by way of reducing their available food.

In Ireland the occurrence and interest in this brown mat was not confined to Lough Gill. Dr. Jim King of the Central Fisheries Board noted, at the EPA Lakes Research Workshop held in Athlone on 18th September 1996 (Bowman 1996, unpublished), that there was a need for further benthic studies of Irish lakes. This was in response to a re-survey of the Western Lakes after ten years. He observed an increased incidence of such gelatinous growth, which he considered to be algal in origin, smothering macrophytes on the beds and in the littoral zone of these shallow lakes. He went on to mention that such growths could effect water quality and disturb the spawning grounds of fish. While their very presence could indicate the deterioration or enrichment of the lake water.

Of more immediate concern to Sligo and Leitrim County Councils was the effect of this substance on water quality. Lough Gill is the main public water supply for Sligo town and surroundings. At present Sligo Country Council is building 'The Sligo and Environs Water Supply Scheme' (Jennings O'Donovan & Partners 1994 unpublished). This will sizeably augment the volume of water already being abstracted from the lake. Such measures are necessary in order to cope with increasing demand by Sligo town, close by. Leitrim County Council have also developed plans to use the lake as an abstraction point to pump water into the north of the county.

Plate 3: The macrophyte *Littorella uniflora* surrounded and coated in brown material. Plate taken in shoreline water south of the landing station at the West of Ireland Activity Centre, Corwillick on the 16th June 1997.

As part of the *Sligo and Environs Water Supply Scheme*, the consulting engineers 'Jennings O'Donovan and Partners' stated that in order to provide storage for low flow augmentation, the existing upper weir on the Garavogue River will be rehabilitated (Jennings O'Donovan & Partners *op. cit.*). From figures noted Lough Gill water levels have fluctuated between a maximum 7.60m O.D. and a minimum 5.88m O.D. The weir has a crest level ranging from 6.70m O.D. to 6.82m O.D. Repairs to the weir will allow the weir crest level to maintain a standard 6.40m O.D. year round. This will maintain water storage between 6.40m O.D. and 5.88m O.D. and maintain a low flow augmentation. This may provide a positive effect on the ecology of Lough Gills littoral zone. The less fluctuation in the water levels of a lake will benefit those shallow water species as they will not be left out of water when the lake falls and in water that is too deep when levels rise (Brinkhurst 1974).

These schemes will substantially increase the amount of water being drawn from the lake. Maintaining Lough Gills' water quality is becoming of paramount economic importance to both County Councils. From initial observations this brown mass around the lake has proved easy to re-suspend in the water column with minimum agitation. During winds and rough weather its dispersion could be detrimental to the lake overall. The re-suspension of this material and subsequent reduced water clarity and quality could thereby result in increased treatment costs after abstraction.

Locally, the fear that Lough Gill was gradually slipping towards eutrophication became very real during the late summer and autumn of 1997 and again in 1998. During 1997 the worst recorded blue-green algal bloom occurred on the lake (see Plate 4). The bloom, which was visibly dispersed in the lake water column for the weeks previous, was washed ashore along the western end following a period of calm, fine weather. Toxicity tests on water from the mouth of the Garavogue River as well as shore line scum proved positive. With notices along the lake shore warning about the danger of algal poisoning, and considerable national media attention, management of fresh water supplies within the county became a major public issue.

Plate 4: Blue-green algal scum washed ashore during the intensive blooms of September and October 1997. Plate taken north of the pier in Tobernalt Bay on the 23rd September 1997. Waters' edge can be seen on the bottom right hand side of plate. The macrophytes at the top of the picture are above the waterline.

1.2 Aims

The aim of the project was to apply a monitoring programme that would identify and quantify levels of the attached material that was deposited in the littoral zone of the lake. The minimum length of the study period was twelve months. This was to allow sufficient time to gather information about the substance over an annual cycle. The extension of the study was unconditional and could give some more depth to the data collected and provide scope for a rough comparison with results from the first year of the study.

The changes in the periphyton population, both seasonally and geographically, would be identified over time. The determination of the effect of this material on macroinvertebrates and higher plants in the littoral zone would be determined. From this work, some light may be shed on possible effects to water clarity and quality within the lake.

With seasonal trends in periphyton growth documented and observed some explanation as to its potential problems could then be identified. Problems as a result of this material, if there are any, may be recognised from an early stage and may have mitigating measures outlined before they could reach a critical point.

Spatial and temporal variations in periphytic growth and the variability in results between different substrates would go further in helping to understand the effectiveness of monitoring attached algae in the lakes of Ireland. Data acquired would provide a better picture of seasonal patterns and trends in littoral algal growth. It would help to understand the effect of weather patterns on spatial distribution of periphyton within a lake.

To validate methods used, a comparison could be drawn between the work carried out on Lough Gill with work done by other limnologists. Information gathered by the Irish Environmental Protection Agency (EPA) and University Collage Galway during 'The Western Lakes Project' was of great interest to the study (McCarthy *et al.* 1998). Such data and periphyton growth trends could provide a better understanding of lakes within a similar geographical and climatic region.

The information acquired and interpreted from the shores of Lough Gill during 1997 and 1998 may be used as a base-line set against any similar work that may be undertaken in the future. This series could be of benefit to limnologists wishing to document changes in periphytic growth over time. Such work could be of great assistance in understanding future changes in the ecology of the lake. Changes such as a shift in the nutrient budget of the catchment or spatial enrichment of the shoreline due to terrestrial activities. Periphyton work could also be utilised in the future to monitor fluctuations in the trophic nature of the Lough Gill water body.

The basic aims of the project were identification, quantification and assessment of the material occurring seasonally around the shores of Lough Gill. In order to get this overview, without getting caught specifically in one area, algal identification would only be required down to genus. Also, limited expertise was available in the field of algal taxonomy within the Institute of Technology Sligo.

1.3 Lough Gill background information

1.3.1 General morphology of Lough Gill

The Lough Gill catchment, including the lake, has a total area of 390 km^2, taking in the Bonet catchment to the north-east. The Bonet catchment is the main source of Lough Gill. Karstified limestone hills exist to the north of the lake and it has been suggested that it is part fed by groundwater from this area (Dr Richard Thorn, pers. comm.). The lake discharges into Sligo Bay by way of the Garavogue River, which passes through Sligo town.

Lough Gill lies along the junction of two distinctly different rock types. A majority of the lake basin, and its land to the north, lie almost entirely on Carboniferous limestone. A narrow band of older, hard rock, composed of schist, gneiss and quartzite adjoins the southern shore of the lake between Slish Wood and Whites' Bay. This metamorphic rock type, which runs north-east to a point beyond Manorhamilton, is an easterly extension of the Ox Mountains (Holland 1981; McDermot, Long and Harney 1996).

Hardman (1881) first investigated the shape of the Lough Gill basin. He observed a deep channel on the south side of the lake. This coincides with the direction of the Ox Mountains-Pettigoe Fault (McDermot, Long and Harney 1996). Hardman noted that the principle line of the lake is in an east-west direction. This would lie across the direction of glacial ice flow. The Central Fisheries Board completed in-lake topography of Lough Gill. From this it was evident that the lake basin mirrored the surface terrain, the steepest gradients lie on the southern metamorphic shores. This area contains under-water cliffs. A deep trough exists in the eastern end of the lake. There the lake reaches a maximum depth of 37 meters. A second deep area lies to the south-west of Church Island (King 1991).

Like Loughs Conn, Derg and Mask in the west of Ireland, Lough Gill is sited mainly over limestone butting against a non-calcareous rock. Hardman (*op. cit.*) proposed that such lakes may have originated through faults and subsidence followed by 'solution weathering' of the limestone basin, acid waters running off the adjacent metamorphic rock, attacking and dissolving the sedimentary limestone. He went on to state that ice action probably assisted in the details of carving out the lake basin. The role of such glacial erosion could be more significant (Charlesworth 1963 and Williams 1969).

1.3.2 Lough Gill littoral zone

The littoral zone of a lake is the interface between the land of the drainage basin and the open waters of the lake (see Figure 1). The size of the littoral zone in relation to the size of the pelagial region varies greatly among lakes, and depends on the geomorphology of the basin and the rates of sedimentation that have occurred since the inception of the lake. The littoral region of small, shallow lakes contributes significantly to productivity and may regulate metabolism of the entire lake ecosystem (Wetzel 1993).

King (1991) noted that there was sparse littoral development within Lough Gill. Of the lakes' surface area (1400 hectares), he found that a littoral zone less than 3 meters deep accounted for 224 hectares (16%). 182 ha (13%) of the lake bed has a depth of 3 to 6 meters with a remaining 994ha (71%) below this. If a littoral zone is associated with light penetration, and the depth and distance from shore that primary productivity occurs at, King may have overestimated the area around Lough Gill. The Lough Gill Project found that water transparency had a range of 1.0 –2.0 meters. This would suggest a smaller littoral ribbon around the lake.

As stated earlier, there is steep in-lake topography. While under-water cliffs are found close to the southern shores, the majority of the lakes littoral zone is in limestone bays to the north. These few areas that do occur are quite sheltered. This limited littoral development affects wildlife habitats.

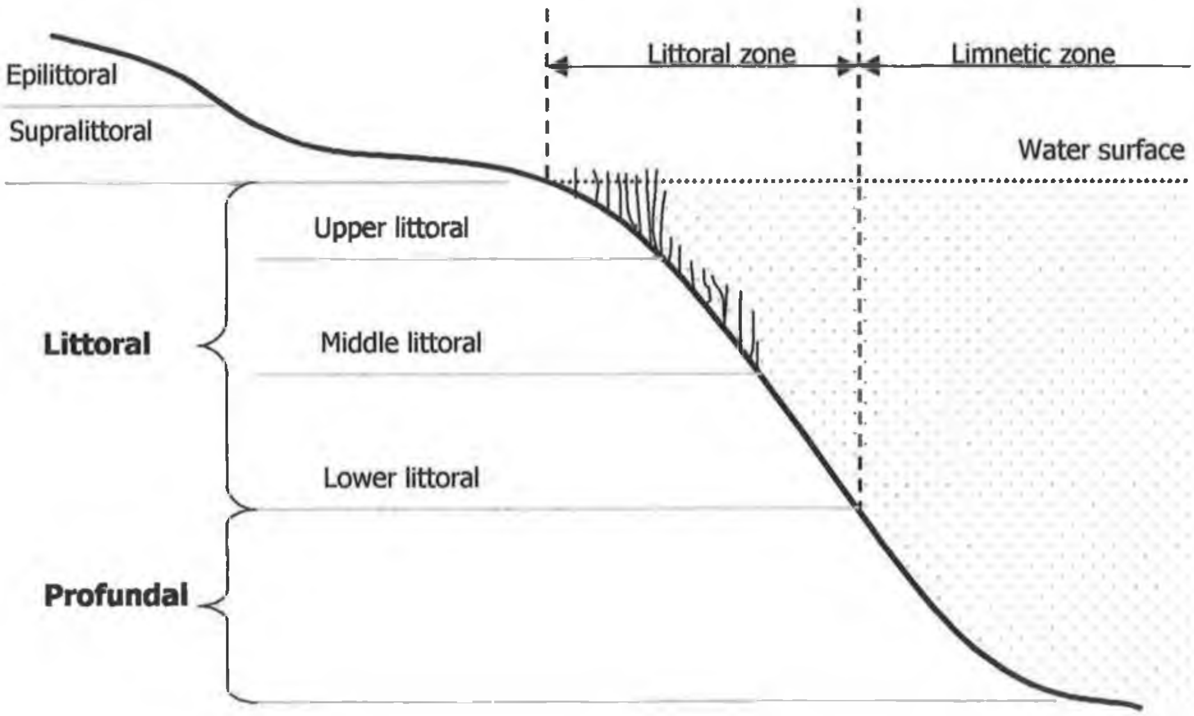


Figure 1: Cross section of a lake shoreline showing zonation. Included is the zonation of the littoral zone and limnetic zone with its associated profundal zonation of the lake bed.

1.3.3 Ecology of Lough Gill

1.3.3.1 Algal ecology

During the late summer of 1953 Round and Brook (1959) carried out an assessment of the trophic status of some Irish loughs. A single sample of littoral plankton was taken from Lough Gill. Round and Brook found the lake to be quite eutrophic. *Fragilaria crotonensis* (Kitton) was the dominant phytoplankton taxa found. Of the twenty algal species identified from the Lough Gill sample the lake was noteworthy for being the only one of 26 sampled to have no Desmids present (Brook 1958).

About the same time Round (1959) took a sediment sample from Lough Gill as part of a comparative survey of the epipelic diatoms in 26 Irish lakes. It is unclear where the sample was taken from but it is assumed it must have been from the littoral photolitic zone of the lake. As far as the author was aware no comparable data had been obtained from Lough Gill or any of the other lakes investigated prior to his own study. 47 attached diatom species were identified from the Lough Gill sample. The dominant diatom species in the calcareous classified Lough Gill was *Fragilaria* species and *Cocconeis placentula* (Ehr.).

Flanagan and Toner (1975) found from the phytoplankton population of Lough Gill that the majority of the genera recorded, with the exception of desmids present in the June sample, corresponded with those listed by Round and Brook (*op. cit.*). This would indicate little change over the intervening years. However Flanagan and Toner noted that there had been reports of algal blooms on the lake in the pervious two years but found no evidence of such during the course of their survey. It was stated that the phytoplankton community present would probably indicate a naturally eutrophic system. It was felt that a more detailed study of the lough was required to clarify the position and to determine the cause and effects of the reported algal blooms.

Work carried out by the Central Fisheries Board, to determine the effects of The Bonet River Drainage Scheme, found the algal crop for 1989 was dominated by diatoms (Bacillariophyta) and cryptophytes with small amounts of blue/green (Cyanophyta) and green (Chlorophyta) algae, which included some desmids (King 1991). King found that the algal composition of Lough Gill was similar to that observed by Flanagan and Toner (*op. cit.*). In the same report it was suggested that overall lake productivity was of a mesotrophic status. Low water clarity was a result of high colour values and not high primary productivity. King stated that no change in the trophic status of Lough Gill had occurred in recent years either as a result of the Bonet drainage scheme or through any other changes within the catchment.

Previous to the initiation of the Lough Gill Environmental Management Project, Cotton (1994 unpublished) had reviewed the ecology of the lake and its surroundings. He drew on a number of sources for information. Apart from his own field records from lake visits during previous years, he comprehensively reviewed published literature and sourced other unpublished reports and data. The Lough Gill Environmental Management Project went further in trying to obtain and collate all scientific work and information carried out on the lake and its catchment. This program provided the first long-term detailed study of the lake. Previous to this most work carried out was from brief visits by interested parties with only quick short-term observations.

The Management Project carried out detailed monitoring of the phytoplankton in the Lough Gill waterbody between May and October 1997. Results indicated a wide variation in free-floating algae both spatially and temporally. The mid-lake sites were dominated by diatoms during May 1997. Of those identified the centric algae, *Cyclotella* and *Stephanodiscus*, along with the filamentous *Melosira* and the colonial pennates *Asterionella* and *Fragilaria* dominated the waterbody during May 1997. As the summer progressed, blue-green algae assumed dominance during July. Their numbers decreased in the following two months before a further blue-green pulse occurred in early October.

Of the six stations monitored all followed a similar pattern, graduating from diatom dominance in May to a significant blue-green presence from June to early October 1997 when the diatoms became the dominant species in a reduced phytoplankton population. The Lough Gill Environmental Management Project noted an algal scum on the lake in late summer and early autumn which was largely attributed to the colonial blue-green forms *Microcystis*, *Gomphosphaeria*, *Coelosphaerium* and *Aphanocapsa* (see Plate 4). Mean chlorophyll levels in the lake during this period are indicative of mesotrophic conditions (in accordance with OECD trophic category criteria). However the large volumes of blue-green algae and the associated scum on the water surface are indicative of nutrient rich waters.

1.3.3.2 Macrophyte ecology

King (1991) in discussing primary production within Lough Gill suggested that in littoral and shoreline areas the process was dominated by macrophytes and they were indicative of a relatively unenriched system. *Littorella uniflora* was found to be the most prominent submerged plant (see Plate 3). This macrophyte grows in soft sands and on gravelled/sandy sediments and, notably, it is found to be decreasing in lowlands (Stace 1995). It typically grows in shallow waters at lake edges but often on exposed shores at depths down to 4 meters. *Littorella* can be found as emergent, exposed plants in places where surface waters fall during summer months. From the limited work by King the highest biomass levels were obtained from exposed sites. He made no mention in his work to the contribution of littoral attached algae in the net primary productivity of the Lough Gill system.

Of the work carried out by Cotton (1994) areas of interest regarding this study include algae and submerged aquatic macrophytes, Gastropoda and other macroinvertebrates. Of these, Cotton noted that there is very limited emergent macrophyte development in the littoral zone. This he attributed to the rapid increase in the depth of the lake around most margins. The most common submerged macrophyte found was *Littorella uniflora* that carpets the littoral/sub-littoral, and was noteworthy for abundance.

The algae *Cladophora aegagropila* (L.), forming rounded masses called 'moor balls', has been noted in Lough Gill (Campbell and Scannell 1989). A large quantity of decaying algal balls collected in the autumn of 1995 on the western shores of the lake around Annagh Bay following prolonged easterly winds (Feeney 1996).

1.3.3.3 Macroinvertebrate ecology

A biological monitoring programme was carried out on a bi-annual basis during the spring and summer of 1996 and 1997. This took in the lake body, the River Bonet and the lakes smaller feeder streams. Chosen sites were given a Q Index value of between 1 and 5 based on the species diversity and abundance. This is inline with the method used by the EPA. These were finally categorised into four water quality classes ranging from Unpolluted, Slightly Polluted, Moderately Polluted and Seriously Polluted. Sites along the River Bonet were classified as Unpolluted however a number of stations were bordering on Slightly Polluted. Of the eight other feeder streams surveyed the Holy Well in Tobernalt was found to be Slightly Polluted. All other streams were unpolluted.

Twelve sites were chosen around the littoral zone of Lough Gill for biological monitoring during the autumn of 1996. Crustacea, of which *Gammarus duebeni* (Liljebörg) was the most commonly recorded, numerically dominated the results. *Asellus aquaticus* (L.) occurred in small numbers at many of the sites. *Potamopyrgus jenkinsi* (Smith) and *Lymnaea peregra* (Mull.) occurred in large numbers along the western and north-western shores of the lake. *Planorbis planorbis* Linn. was also found in this area. The majority of molluscs were recorded from the western end of the lake. Here the limestone geology and sheltered bays provide the best habitat for the Mollusca. Species richness was highest in Toberconnell Bay and Aghamore Bay and lowest at Parkes' Castle during autumn 1996.

Overall, the Lough Gill Environmental Management Project found that the lake had a poor invertebrate fauna. The western half of the lake provided the best habitats. However, the small littoral zone of the lough is a major contributing factor to this poor invertebrate status. Many of the shores are steep sided and are exposed making them a very harsh environment for any invertebrate. During the 1996 survey species diversity was low and species numbers were high. From the collections made during this period the lake was classified as being mesotrophic.

1.3.4 Lough Gill water quality

The Bonet River drainage scheme was ongoing between 1982 and 1992, whereupon 84% of the original work was carried out. The majority of the work was completed by 1989 and no damage to fish stocks or habitats occurred after this date. As part of the study carried out by the Central Fisheries Board, investigating the impact of the scheme, Murray and Lynch (1990) found the lake had been continually accumulating organic matter. Siltation levels appeared to increase as a result of accelerated drainage in the Bonet catchment. Unfortunately no work was carried out in the littoral zone but the available evidence from sediment cores depicted a lake undergoing eutrophication at a moderate rate. A slight increase in the organic content of the sediments of the profundal zone was the primary evidence for this conclusion.

After the Bonet drainage scheme interest in Lough Gill and its water quality increased dramatically. Monitoring of the lake by the Regional Water Laboratory, Castlebar for Sligo County Council occurred intermittently in the proceeding years (Mrs. Eileen Gibbons, Environmental Officer, Sligo Co. Co., pers. comm.). Samples were usually taken in spring to late summer. During the exceptionally good summer of 1995 the North Western Regional Fisheries Board found the formation of a stratification within the Lough Gill waterbody (Sheil 1995). Work carried out on two deep-water sites at the end of August revealed a thermocline at a depth of 6 to 10 meters. This was quite pronounced at the site near Goats Island. This is a feature not previously noted in Lough Gill and can only be accounted for by the long period of calm, hot weather that occurred during this year. In her report Sheil observed no major algal blooms even after overturn of the lake at the end of August. A short falling in this work is the sampling of the lake on only one date during this period of remarkable calm weather.

Intensive chemical monitoring of the Lough Gill surface waters took place between 1995 and 1997 as part of the Lough Gill Environmental Management Project. This consisted of nine sampling stations on the lake water body, two of which were again the mid-lake sites. Samples were taken once a month. In conjunction with this, stations were also established on the River Bonet (the main inflow to the lake) and eight smaller feeder streams around the lake. Sampling of the feeder streams took place in the second half of the monitoring programme.

The water quality of the Bonet was found to be within the desired EU Salmonid Water Regulations (SI No. 293 of 1988). Of note were the high levels of natural watercolour and the 3-4 fold increase in median phosphate levels between sample stations along the river from source to mouth. Colour values reflect the presence of organic molecules derived from vegetable matter such as peat, leaves, branches, etc.

Eight feeder streams were monitored. The water quality in these streams after heavy rains was of great interest. McGarrigle (1993) noted a sharp decline in quality of streams around Lough Conn after periods of heavy rain. Around Lough Gill higher levels of total oxidised nitrogen were recorded during the winter months. This is the period of the year which coincides with elevated levels of rainfall. This would indicate increased run-off from agricultural land. The spring at the Holy Well in Tobernalt was found to be moderately polluted with the highest recorded phosphate and total oxidised nitrogen levels of all sampling stations. These two parameters combined indicate septic tank or agricultural contamination of the groundwater, or both.

The waters of Lough Gill were strongly coloured on all occasions examined, with lower values occurring in the summer months when rainfall levels were low. The median values of water transparency were generally in the range of 1.0 to 2.0 meters, with higher values occurring in the summer months when calm, dry weather prevailed. The suspended solids levels followed a similar pattern to the water transparency with poor values occurring in the eastern end of the lake, when sampling coincided with periods of heavy rainfall.

Phosphate measured as molybdate reactive phosphate (MRP) showed a strong seasonal trend with maximum values occurring in the period November to March. This was followed by a sharp decline in April to the minimum values, which were maintained throughout the summer months. The Lough Gill Project noted that the trend reflected the seasonal pattern of increased run-off during the winter months, followed by rapid uptake of phosphorus by plants and algae during the spring period. Maximum values of total oxidised nitrogen also occurred after periods of heavy rainfall. The mean total phosphorus for the autumn-winter period would classify Lough Gill to be in the upper end of the mesotrophic range, according to the OECD lake classification scheme. As this figure does not include the summer levels of total phosphorus, the annual mean value would be much lower.

From the intensive nutrient monitoring of the Lough Gill catchment the lake was classified, by the OECD classification scheme, as being in a mesotrophic state containing moderate nutrient concentrations. However of grave consequence were the results of sediment core analysis taken from two mid-lake sites. Murray (1998) stated in his report that "the results obtained in the two cores examined suggest that primary productivity in Lough Gill is increasing as evident by increasing sediment pigment content and an increase in sediment phosphorus. It is suggested that phosphorus may be entering the lake bound with Magnesium (Mg) or Calcium (Ca) and accumulating in sediments". Biological monitoring of Lough Gill would appear to also point towards a more eutrophic waterbody. Work such as this compounds the difficulty of relying totally on chemical data and reinforces a joint chemical and biological approach to water monitoring. The role of this brown material in the nutrient status of the lake was unknown. Its occurrence in the littoral zone was equally cause for concern as enrichment of the Lough Conn waterbody was first noted around the shoreline prior to the whole lake becoming eutrophic. The implementation of a programme to monitor the growth of this substance around the littoral zone of Lough Gill may provide a better understanding of the eutrophication process. It may also provide a means of early evaluation in the enrichment of a waterbody.

2.0 Literature Review

2.1 Attached material found in littoral zone of lakes

2.1.1 Classification of materials

A lake may be separated into the open water limnetic zone and the littoral zone. The latter term consists of the bottom of the lake basin colonised by macrovegetation that is within the photic zone of the water body (see Figure 1). This shoreline area of a waterbody will also support large communities of aquatic flora and fauna. The abundance of life within this zone is not only a result of available light but also a high degree of oxygen saturation and the elevated nutrient levels associated with a land-water interface. This area allows a very complex food web to flourish. Various terms have been applied to groups of organisms living within the littoral zone. These terms can depend on whether the organism is attached or suspended in the water column and, if attached, the substrate it is anchored to can again be used to classify the life form.

Of the communities in the littoral zone food web, investigation into microbial producers has focused largely on phytoplankton. However a large proportion of the bottom area of most lakes receives light to support photosynthesis. Investigations into attached microbial producers in this area have been largely ignored (Lowe 1996). Within the littoral zone a conglomeration of such organisms on inorganic and organic materials have been brought together under the one term; *periphyton*. Although photosynthesising algae dominate the community structure, it is far more complex containing different microbial taxa from within the food chain.

Periphyton as defined by Wetzel (1983b) is understood to be a complex community of microbiota; algae, bacteria, fungi, protozoa and organic and inorganic detritus that is attached to submerged substrata. The substrata which it is attached to can be organic or inorganic (living or dead). The term *aufwuchs*, which is German meaning "to grow upon", is often used in older literature. Periphyton is a more commonly used term that refers to all microflora on submerged substrata.

'Periphyton' is more or less synonymous with the term 'benthic algae', where benthos refers to organisms living on the bottom of a waterbody or associated with any solid or semi-solid substrate (Stevenson *et al.* 1996). The majority of work carried out on periphyton exclusively refers to this attached benthic algae. This may be due to the fact that algae dominate the periphyton mat (Welch 1992).

Most benthic algae in freshwater ecosystems are blue-green bacteria (Cyanophyta), green algae (Chlorophyta), diatoms (Bacillariophyta) or red algae (Rhodophyta). These have a great morphological diversity with unicellular, colonial and filamentous forms. The divisions of algae are distinguished by a variety of chemical and morphological differences. There are motile and non-motile species within the above phyla, with motility provided by flagella, sheaths of mucilage or a raphe (where mucilage is extruded through a narrow opening in the cell wall). Non-motile algae may be attached to the substrate or entangled in the matrix of other organisms that are attached. Attachment method varies with species and can be by means of basal cells, mucilaginous secretions or in the case of diatoms the use of special cells, stalks or tubes (see Reisser 1992).

Benthic algae found in the photic zones of lakes may by classified according to the substratum type upon which they are found (see Figure 2). *Epilithic* algae grow on hard, inert substrates such as gravel, stones, cobbles etc. *Epiphytic* algae are found on plants and larger algae, which can provide a great source of nutrients. *Epipsammic* algae grow on hard sand that is relatively inert. The substrate can sometime be smaller than all but the smallest cell. *Epipelic* species, characteristically large motile diatoms, grow on organic and/or inorganic clay sediments.

Finally, *metaphyton* are the algae of the photic zone that are not directly attached to substrata, nor are they freely suspended in the water column. These communities originate from fragmentation of attached populations (Dodds and Gudder 1992) or occasionally from dense phytoplankton. These can aggregate together becoming clumped and loosely attached in littoral areas. This can be the result of wind induced movement of populations on submerged surfaces. They can form dense microbial rafts with intense internal nutrient recycling (Stevenson and Stoermer 1982). The collective metabolism of metaphyton can increase macrophyte reed decline (Von Roland Schroder 1987 and Ostendorp 1992) and radically alter the nutrient cycling of littoral zones upon being driven into the shore wash (Wetzel 1996).

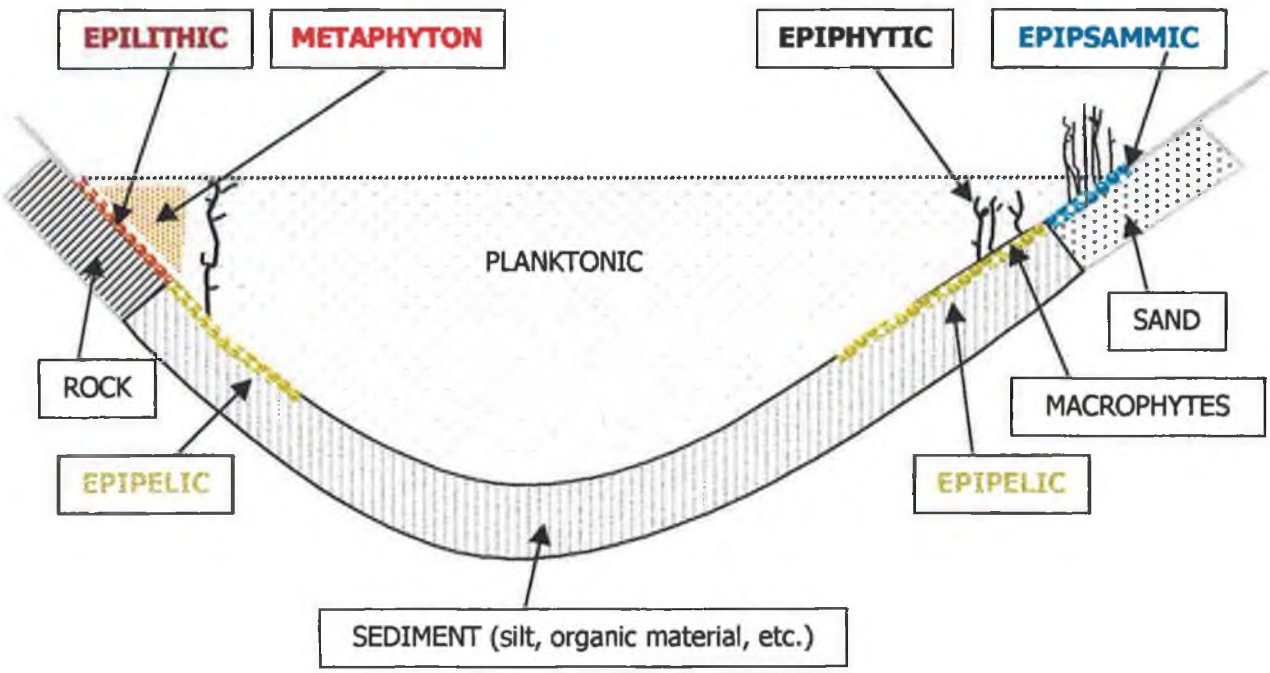


Figure 2: Cross section of a lake bed showing the water column and the various microflora communities associated with the different substrate types. The type of community found upon the substrate are colour co-ordinated with their name.

2.1.2 Physical factors influencing periphyton

The seasonal succession of attached algal species is just as pronounced as succession in planktonic species (Round 1972). Annual fluctuations in attached algae are brought about by a number of possible causes. These can include the availability of light, air and water temperature, substratum type or nutrient levels within the land-water interface. Fluctuations may also result from inhibition by planktonic algae, infection by fungi and the pressure of grazing by invertebrate animals.

Light in lentic ecosystems is attenuated with depth in the water column and also the depth of the periphyton mat. The attached nature of the mat means the extent of the photic zone and shading from canopy cover can significantly alter the patterns of a photosynthesising community. The rate of algal respiration will increase with water temperature. Commonly, light and temperature are related, the intensity of light required to saturate algal photosynthesis increases as water temperature increases (Wetzel 1983b). The abundance of nutrients in the lentic system plays a strong role, both directly and indirectly, in determining the quantity, quality and distribution (both spatial and temporal) of the periphyton community (Lowe 1996).

The concept of littoral benthic algae giving rise to phytoplankton populations has been disproved in Wetzel (*op cit.*). However interaction between the two does occur. Inoculation of the phytoplankton population from hibernating spores resting on the benthos was thought to occur. However exponential growth of algal cells present in the pelagic water accounts for the rapid spring rise in algal numbers. Disturbance of benthic populations from wind and storm driven water turbulence is well known. It is common to find strictly benthic algae or predominantly planktonic forms intermixed, especially following irregular storm turbulence (Moss and Abdel 1969 and Brown and Austin 1973). Attached algal forms are found in the interstitial waters of the littoral and limnetic zones. Of the attached periphyton population stalked diatoms appear to tolerate wave disturbance better than non-stalked forms (Cattaneo 1990 and Hoagland and Peterson 1990). Hoagland (1983) examined episodic storm action in the littoral zone and found that older communities lost a greater percentage of their biomass than younger ones. However wave action can have a positive effect on periphyton biomass where water renewal, from waves, has increased levels at exposed sites compared with those from sheltered ones (Cattaneo *op cit.*).

2.2 Periphyton and the littoral zone nutrient budget

Nutrient concentrations and their cycling rates within lakes have predominantly been examined in the context of the limnetic zone of a waterbody. Waterbodies have been treated as uniform in the context of a planktonic system with nutrient inputs, outputs and various regulators working internally within the pelagic region. Wetzels' work on the carbon budget of lakes (reviewed in Wetzel 1983b) demonstrates the overwhelming, often dominant contribution of the attached algal community to the overall productivity of many lakes. It was also noted that in lakes, which are relatively small and shallow, the wetland-littoral complex produces the major source of organic matter of most freshwater ecosystems. Areas within this habitat differ in internal nutrient microgradients but are collectively integrated in a nutrient cycle along a macrogradient from the land to the open water.

2.2.1 Macrogradient nutrient recycling

The shoreline of a freshwater basin, from the point of view of slope, is nearly always diffuse with the degree of slope dictating the rate of diffusion from shore to open water. Wetzel (1990) found that most of the particulate organic matter is decomposed within this land-water interface region. These regions are the most metabolically active and productive parts of aquatic ecosystems. Much of the nutrient loading, cycling and recycling within freshwaters is controlled by the metabolism of the wetland and littoral macrophytes and their associated microflora around the shores of a waterbody.

The region of greatest productivity is the emergent macrophyte zone. The emergent plant has a number of structural and physiological adaptations that allow it to tolerate the anaerobic sediments of such a zone. Nutrients loaded in this area tend to be assimilated by the bacterial microflora of the sediments. Dissolved organic compounds released after decomposition of the plant detrital material dominate the export of nutrients from this zone. Most of the nutrients of actively growing submersed macrophytes are also obtained from the sediments (see Figure 3). However they have a slower diffusion rate at the boundary layer resulting in a slower nutrient uptake. This results in reducing productivity. Reduced underwater light also compounds the problem.

The second most productive component of the land-water interface is the attached microflora of the littoral zone. In a lentic environment the available nutrient concentrations of planktonic communities are much lower in the extremely dilute limnetic zone. Loss of nutrients, particularly by sedimentation of producers out of the photic zone, is very high. The efficiency of utilisation, retention and recycling are subsequently much greater among closely aggregated attached communities. As a result, a primary characteristic of benthic community is the assimilation mechanism and high retention of nutrients after acquisition. This conservation and intensive recycling leads to maximal resource utilisation. The efficiency and productivity per unit area among these communities of the lentic ecosystem are extremely high (Wetzel 1996). A lot of the work done by Wetzel was based on the epiphytes attached to the macrophyte community.

Reasons for this high productivity found within the algae attached to macrophyte substrate lie in the plants physical and nutrient characteristics. Submersed aquatic macrophytes are dominated by perennials, which grow or persist for much of the year in a dormant condition. With the presence of this leaf biomass and associated surface area, epiphytic algal biomass and productivity tend to be high and relatively constant throughout the year. The algal community is exposed to nutrients from the water within and passing through the littoral zone. It also comes in contact with those released from supporting host macrophyte tissue, regardless of how small. Most nutrients, such as phosphorus, are obtained by actively growing macrophytes from the sediments and their interstitial water. Epiphytic algae and bacteria actively assimilate phosphorus from littoral water and intensively recycle it. Very little phosphorus from the water column is passed to the macrophyte (Moeller *et al.* 1988). Epiphytes rather than submersed macrophytes function as the primary scavenger of limiting nutrients from littoral waters. For this very reason attached communities are good indicators of the nutrient status within the littoral zone.

Eminson and Moss (1980) found that evidence from Hickling Broad seems to suggest that the surface of aquatic macrophytes exert little influence on the composition of the periphytic algal communities associated with them. The influence of host type in determining community composition was greatest in infertile lakes. That is, with the eutrophication of a waterbody periphyton communities rely predominantly on nutrient content of the littoral waters and not that of their host substrate.

Epilithic and epipsammic communities actively assimilate nutrients in a manner similar to those on the submerged surfaces of macrophytes. However these algae and bacteria are in more close contact with the benthos of the littoral zone. This enables them to utilise nutrient fluxes directly from attached substrates as well as the interstitial waters around them, a method of microgradient recycling (see Section 2.2.2).

As mentioned, most of the particulate organic matter in a lake system is decomposed within the wetland and littoral zone interface. Here intensive recycling and conservation of nutrients take place. Large quantities of dissolved organic matter are, however, exported from the littoral areas to the open pelagic zone. Here these carbon and energy sources supplement or dominate the pelagic bacterial metabolism and their nutrient recycling mechanism (Coveney and Wetzel 1995).

Water movements in lakes are generally very slow. Water retention times within wetland and littoral zones are often shorter than that of the adjacent lake basin. This is because of the smaller total volumes through which the total flows are occurring. This results in a reduction of physical nutrient movement and transfer across a basin. Hence, lentic ecosystems are much more closed in regard to nutrient cycling than is the case in flowing waters. Transfer of nutrients can be limited by the slow water flux over the surface of materials. The greater the water retention time through the wetlands and microbial communities of the sediments, the greater chemical complexation, immobilisation and ionic transfer.

Climatic conditions can have a sever effect on nutrient recycling within the wetland-littoral interface. When precipitation events exceed the retentive capacity of such a zone a flushing discharge can ensue. This can have a profound effect on chemical loadings to the recipient basin. In Michigan USA, Lawrence Lake received greater than 60% of its annul surface loading of phosphorus during two major precipitation events. During these periods the adsorptive and metabolic retentive capacities of the wetlands were greatly exceeded which accelerated the flow of nutrients into the lake basin (Kittelson 1988). This would justify the sampling actions at Lough Conn and Lough Gill after intensive rains.

In reviewing nutrient recycling in lentic environments, Wetzel (1996) felt that for a long time the role of epiphytic flora on submersed macrophytes had largely been treated as a curiosity and ignored. It would appear that epiphytic algae and associated micro-heterotrophs are often a major or dominant regulator of nutrient fluxes in freshwater. The littoral zone of Lawrence Lake, Michigan occupies 15% of the waterbody. However, the epiphytic algae of this relatively small area contribute between 70 and 85% of the lake primary productivity (Burkholder and Wetzel 1989). The Lough Gill littoral zone, which is less than 3 meters deep, accounts for 16% of the lake. If the Lawrence Lake situation is applied to Lough Gill then primary productivity in the littoral zone could dominate approximately 80% of the total lake production.

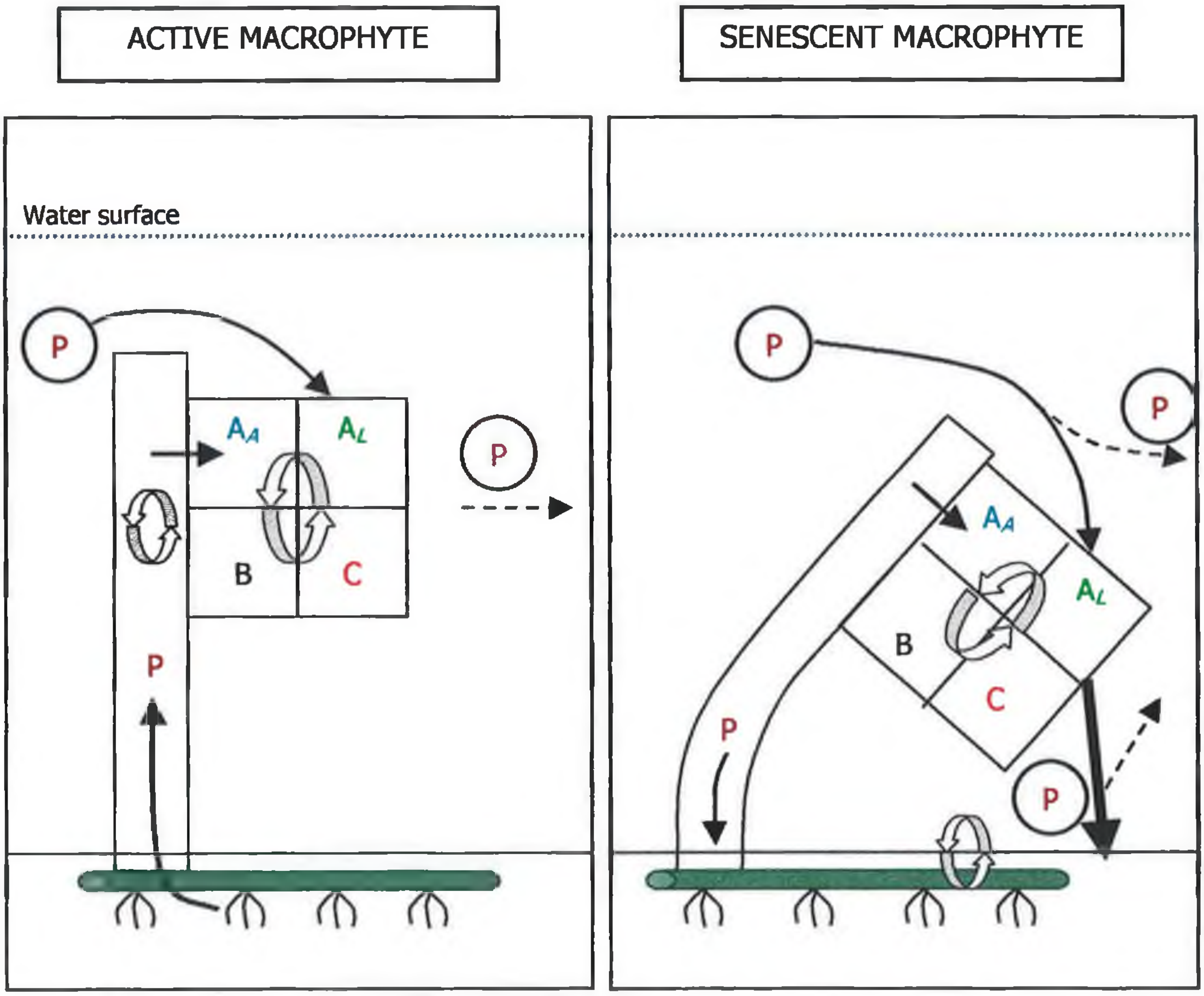


Figure 3: An actively growing macrophyte and its attached microflora population is presented on the left-hand diagram. A senescent macrophyte, at the end of the growing season, is illustrated on the right-hand diagram.
Diagram indicates the direction of fluxes of phosphorus (**P**) from the sediments to submersed littoral macrophytes and among the epiphytic microflora of the periphyton.
$\mathbf{A_A}$ = adnate algae; $\mathbf{A_L}$ = loosely attached algae; **B** = bacteria; **C** = inorganic or organic detritus (such as calcium carbonate). (Wetzel 1990)
Direction of arrows indicates the movement of phosphorus. Thickness of arrows implies the strength of phosphorus movement. Phosphorus recycling represented by twin arrows, end to end.

2.2.2 Microgradient nutrient recycling

So far nutrient recycling has been discussed at a macro-gradient scale, where nutrient movement pass through the abiotic and biotic environment of the littoral zone. This insures its recycling and reuse within lentic systems. Within the littoral environment nutrient recycling occurs through out the attached periphyton community on a microgradient scale. Nutrient recycling pathways can depend on the composition of the microbial community and the substrata that they are attached to.

Micro-gradient recycling of nutrients, occurring within the attached microflora community, is highly robust. This is because of their close proximity, even direct contact, to each other and to the living or dead substrata. Diffusion distances are very short and concentration gradients can be kept steep by constant metabolic utilisation (sinks) within the attached communities. All communities are exposed to nutrient sources from the surrounding waters as well as the substrata upon which they are on. Rates of nutrient diffusion to the attached community depend on microbial community and its metabolism, water movements (which effect boundary-layer thickness) and concentration gradients within the boundary-layer.

All attached communities are exposed to nutrient sources from the surrounding water as well as from the substrata upon which they grow (Wetzel 1996). In lentic water, four major nutrient sources from the substrata are now known. Wetzel (*op. cit.*) found that some of the quantitative data indicated the major of these sources, particularly in oligotrophic waters.

1. The micro-distribution of species and groups of epilithic algae is clearly correlated with differences in rock type and differences in solubility of specific elements from the rock (Blinn *et al.* 1980 and Smith *et al.* 1992). Mineral nutrients that leach from the rock substratum can be utilised by the attached microflora. Species and biomass levels of epipsammic algae are influenced by micro-scale differences in diffusion and micro-flows through sediments, as well as sand grain morphology (Krejci and Lowe 1986).

2. Epiphytic algae of lentic waters are clearly the most productive among phytoplankton and other attached algae, maintaining a large collective biomass throughout the year. In addition to the very large surface areas for colonisation and the retention of algae by supporting macrophytes into overlying light zones, host plants also provide

significant sources of nutrients from both living and dead tissue (Moeller *et al.* 1988 and Burkholder and Wetzel 1990). Moeller (*op. cit.*) found that certain algal species could obtain 60% of their phosphorus from the macrophyte. The algae near the outer portion of the community would obtain less phosphorus. Even when phosphorus concentrations are high in the water, some phosphorus (and presumably other nutrients) is obtained from the macrophyte. This maybe due to slow diffusion rates from the water into and within the epiphytic community.

3. Epipelic algae growing upon organic sediments often develop into dense communities. These can be both loosely attached and in dense mat-like aggregations. Regardless of how sparsely developed these communities are upon sediments, photosynthesis of the epipelic algae can markedly affect nutrient fluxes from the sediments to the overlying waters. Metabolic activities affect fluxes by modification of redox gradients (which in turn influence chemical mobility) and direct assimilation and utilisation. In addition to the indirect effects of benthic algae on nutrient fluxes from the sediments, the algae themselves are effective scavengers of interstitial nutrients migrating from the sediments.

4. Finally, attached algal mats (metaphyton) appear to show a closed system. Formation of oxygen bubbles within the mat leads to its detachment and ascent in the water column (O'Neal and Lembi 1985 and Ostendorp 1992). During flotation these algae are exposed to extreme conditions of intense radiation, dissolved oxygen, pH and localised nutrient and carbon depletion. Large diurnal fluctuations in nutrient concentrations were found in detached mats of a Danish lake (Thybo-Christesen *et al.* 1993). Recycling of nutrients was found to occur within the mat. The lower portion of the mats community showing a greater uptake of nutrients. This maybe due to the proximity of enriched sediments entrapped on and near the detached surface of the mat. The metaphyton was nearly a closed system with the majority of its nutrient requirements being supplied by internal recycling with the remaining coming from trapped sediments, littoral water advection and atmospheric precipitation.

Wetzel (1996) in concluding could not overemphasise the importance of nutrient reuse. Only by means of intensive recycling of essential nutrients (particularly phosphorus, nitrogen and inorganic carbon) can the problems of slow diffusion transport across boundary layers be sufficiently overcome within the periphyton community. This in turn will permit the extremely high levels of growth and productivity to occur in the attached communities of eutrophic, and particularly of oligotrophic waters. Algal growth and intensive nutrient recycling around the littoral zone of Lough Gill must be seriously considered when looking at the percentage primary production attributable to the periphyton of the waterbody.

2.3 Effects of nutrient enrichment on periphyton

As the water of lakes receives increasingly larger loads of nutrients, there is a strong tendency for phytoplankton to increase to the maximum capacity within existing limitations of temperature and available light. However, it is imperative that eutrophication of aquatic systems is not viewed in the restricted sense of phytoplankton productivity. Within obvious geomorphologic restrictions on littoral development, the common situation is for littoral productivity to play a major role in the early and late stages of increased fertility of the lake system as a whole (Wetzel 1983b).

2.3.1 Algae in the assessment of lake eutrophication

Some of the features of an enriched eutrophic waterbody are excessive algal and rooted plant growth, degraded water quality, extensive deoxygenation of the bottom water layers and increased fish biomass accompanied by decreased harvest quality (Rast and Thornton 1996). With excessive algal growth, studies up until recent have focused solely on the phytoplankters of a lake system. In Welch's review of the ecological effects of wastewater (Welch 1992) little mention is made about periphytic growth in lentic systems and it is not included as a qualitative characteristic of an enriched system.

There is a continued bias towards the use of phytoplankton in monitoring lake productivity. This may be a result of its historically strong tradition and the relative ease and high reproducibility by which planktonic biomass and production can be measured. However, this may be misleading in some lakes where ecosystem processes can only be described properly if phototrophs associated with bottom substrata are included (Sand-Jensen and Borum 1991). Work by Loeb, Reuter and Goldman (1983) indicate that periphyton often contribute the majority of the littoral zone production. This was especially true where substrata are predominately rock or organic sediment. Lough Gill would have just such a substrate. This would point towards high levels of periphyton productivity in the waterbody.

2.3.2 Periphyton in the lake eutrophication process

The role of periphyton is considerable in the early and late stages of long-term chronic enrichment within a waterbody. Light attenuation, temperature and nutrient availability dictate their part throughout (Stevenson, Bothwell and Lowe 1996). As nutrient levels increase so to does phytoplanktonic growth. Littoral zone productivity, within obvious geomorphological restrictions, increases with nutrient loading. Submersed macrophytes play an increasing role in total primary productivity within this area until they are severely limited by reduced light attenuation. Increased macrophyte growth provides more substrate area for attached algal biomass. As the plant surface area increases so to does the area for colonisation by epiphytic algae.

Light limitation of submerged primary producers is usually associated with intense phytoplankton and attached epiphytic productivity. As enrichment of the water column increases, elevated growth of epiphytes along with phytoplankton populations can contribute to the demise of submerged plants (Bales *et al.* 1993). On their own, dense phytoplankton populations are sufficient to attenuate light to a point where it is inadequate to support growth of periphyton (Hansson 1992) or submersed macrophytes (Mulligan *et al.* 1976).

As submersed macrophytes decline, phytoplankton, attached microflora and emerged macrophytes dominate lake productivity. The elevated levels of emergent macrophytes, which assumes a greater dominance until eventually covering large proportions of a lake basin, combine with attendant microflora to form an exceedingly productive combination. This is provided that water column depth does not exceed plant tolerances, primarily for adequate light. Attached algae develop in strong association with these emergent macrophytes (Wetzel 1983b and Rorslett *et al.* 1986). Increased levels of primary production and associated biomass within a lake body will continue long after the nutrient source desists.

2.3.3 Periphyton and littoral zone enrichment

Enrichment of waters can be through point and non-point sources. Non-point sources are a lot more difficult to locate and quantify. During the late 1980's Lough Conn, in County Mayo, exhibited traits of a water body in the early stages of enrichment. Visible indications of eutrophication included algal blooms in the littoral regions, disappearance of the arctic char

(*Salvelinus alpinus*, L.), increased average trout size (*Salmo trutta*, L.) and a large increase in the extent of submerged weed beds. However mid-lake sampling, which were relied upon to give an overall gauge of the lakes trophic status, failed to detect this elevated nutrient enrichment (McGarrigle 1993). In summarising, McGarrigle noted that the deterioration in the trophic status of the lake started from the outside, moving in. This was a result of intensive land use within the catchment. Monitoring of non-point enrichment would require more intensive work in the littoral regions of waterbodies.

The work on Lough Conn can not be over emphasised. Different forms of analysis on the lakes trophic status provided conflicting evidence about its overall condition. Over-reliance on the chemical analysis of the water body proved inaccurate and provided an imprecise picture of the lakes true status. Chemical monitoring on the Lough Gill water body indicated a mesotrophic system. Work by Murray on the sediments would point towards a more enriched status (Murray 1998). The implementation of a monitoring programme encompassing a number of elements within the system must be considered before the overall trophic nature of Lough Gill can be estimated. The role of periphyton and the nutrient status of the littoral zone must also be examined before such a picture can be obtained.

In Ireland, periphyton has been used in the assessment of a lakes trophic status. Work on the western lakes of Ireland, namely Lough Carrowmore, Lough Conn, Lough Cullin and Lough Mask, by Dr. Rick Barbiero during 1996 was the first of its kind in Ireland. It came in the wake of the work done by McGarrigle (*op cit.*), where it was felt that enrichment of the littoral zone could be observed through such monitoring methods. Dr. Rick Barbiero classified the water bodies according to the number and species of attached algae under the Trophic State Index (Whitmore 1989). The application of this index system to the lakes of Ireland is questionable. The index was originally applied in the Florida lakes and has had little use within the climate of Western Europe. Whitmores' index requires good taxonomic expertise down to species level. Assessment of a lakes nutrient status through a monitoring programme or index must be readily applicable to common situations using expertise that are within the grasp of most scientists. Whitmores' index does not provide this. It was the aim of this study to open up this work making periphyton monitoring more assessable.

Other work on littoral zone enrichment from diffuse sources concurs with the observations of McGarrigle. In the shallow littoral zone of Lake Taupo, New Zealand a localised increase in nutrient levels occurred gradually over a five year period (Hawes and Smith 1993). This was a result of partially treated waste being injected into the groundwater close to the lake. Chemical analysis clearly showed that the impacted site had significantly higher concentrations of nutrients. Such enrichment translated into significantly higher periphyton biomass in the impact area and a shift in the periphyton species composition. Work on Lake Saimaa, Finland showed a similar trend in periphyton growth (along with a species shift) when the waters were enriched by point-source waste from the pulp industry (Kettunen 1983). As a result of this point source release, Lake Saimaa showed considerable spatial variation in periphyton populations and biomass levels.

Sládečková and Sládeček (1963 in Welch 1992) described the succession of periphyton in Czechoslovakian reservoirs polluted with sugar beet waste and sewage. The combined effect of these wastes on water quality showed typical pollution zones. The periphyton structure associated with a pollution state was classified within the 'Saprobity' system. The various species identified were grouped according to their position with respect to their distance from the waste outfall. This makes such a system more suitable to point source pollution within river systems. Despite a myriad of nutrient enrichment studies, such as the one illustrated, the relationship of nutrients to benthic algae community structure is not well understood (Borchardt 1996). A few generalisations were made in the same review. Filamentous Chlorophytes, like *Cladophora* and *Stigeoclonium*, become abundant when nitrogen and phosphorus levels are relatively high and there is sufficient light. The diatom *Achnanthes minutissima* (Kutz.) appears to prefer a nitrogen and/or phosphorus enriched environment. Finally, the effects of P enrichment on species composition in benthic communities are not predictable. Sometimes this has lead to dominance by Cyanophyta and other times it has not.

One would expect that the introduction and availability of an external nutrient loading to a lentic system (as with eutrophication) would result in suppressed rates of internal nutrient recycling. The subsequent removal of the introduced nutrients in the overlying water would increase. However, because of the rapidly escalating size of the periphyton mat due to nutrient enrichment, diffusion becomes difficult and light attenuation is reduced. Physical constraints of the attached algal mat allows only a moderate shift towards a greater reliance upon external nutrient sources (Wetzel 1996). However Wetzel appears to relate this to periphyton with acute exposure to elevated nutrient levels in the water column. Chronic elevation in nutrients over an extended period, with their sedimentation and degradation in the benthic environment, resulting in nutrient recycling at a macro-gradient level is not discussed. This chronic enrichment associated with non-point source pollution is harder to identify and more difficult to quantify and prevent.

It should be noted that the control of artificial eutrophication is fraught with problems. Rast and Thornton (1996) found that although Lake Washington, in the United States, recovered very well to catchment management. Lake Shagawa, in the same country, failed to respond to treatment as predicted and remained eutrophic. The lake was subject to intense internal loadings from anoxic hypolimnetic sediments. Nutrient release from the sediments was mixing into the lake in sufficient amounts to continue to fuel nuisance levels of aquatic plants and algal growth. It was concluded that complete natural recovery of the lake could take up to a century as a result of continued leaching of phosphorus from the sediments. Numerous case studies and mitigating measures for such problems have been suggested in Cook *et al.* (1993). Subsequent to eliminating nutrient enrichment within a water body, recovery of the system may take place slowly over an extended period of years. Where large amounts of money are invested in lake rehabilitation the short term recovery often required by financiers is not always there. Work on Lough Gill to eliminate non-point source nutrient enrichment could be carried out in a short time frame. However, the knock-on effect in water quality may take a considerable length longer due to internal nutrient recycling within the water body.

2.4 Periphyton interactions within the lentic system

Freshwater aquatic ecosystems contain three different habitats for growth of phototrophic organisms, the open water, the illuminated solid surfaces and the water surface itself. Different phototrophic organisms occupy these three habitats. Their relative importance for carbon and nutrient cycling varies with the size, morphometry, water transparency and nutrient conditions of the ecosystem. The significance and often dominance of littoral zone productivity within the lentic system is widely acknowledged (Wetzel 1983b, Sand-Jensen and Borum 1991 and Lowe 1996).

Interactions among primary producers, phytoplankton, periphyton, macroalgae and macrophytes in limnological regions have been well documented under natural conditions (Moss 1981, Stevenson and Stoermer 1982, Sand-Jensen and Borum 1991 and Ostendorp 1992) and during the eutrophication process (Mulligan *et al.* 1976, Rorslett *et al.* 1986, Von Roland Schroder 1987, Hansson 1992 and Bales *et al.* 1993). It has already been observed that as nutrient availability and macrophyte cover of the littoral zone increases so to does primary productivity by epiphytic microalgae. And as nutrient availability increases further, ecosystem primary productivity can be overtaken by phytoplankton. These can restrict the distribution of rooted macrophytes and attached algae in shallow waters. Such predictions are based mainly on light and nutrient interactions among the phototrophic communities. This is perhaps too simple. Other pressures from light intensity, shading by overhanging vegetation, water and air temperature and grazing may all effect the interactions between primary producers. Of these pressures, grazers may exert a considerable control over all phototrophic communities and on microalgae in particular (Sand-Jensen and Borum 1991).

Within the lentic ecosystem the trophic structure can be broadly divided into producers and consumers. The latter category is composed herbivores, predators, detritivores and decomposers. Primary consumers (herbivores) such as insects, molluscs, crustaceans and fish are the main groups that act as grazers in aquatic communities (Lamberti 1996). Snails (*Gastropods*) are renowned benthic periphyton consumers in lentic environments (Higashi *et al.* 1981, Bronmark *et al.* 1991, Steinman and Elwood 1991 and Bronmark *et al.* 1992). Caddis flies (*Trichoptera*) and mayflies (*Ephemeroptera*) are considered to be equally conspicuous grazers (Jacoby 1987, Marks and Lowe 1989, Hart and Robinson 1990, Dudley and D'Antonio 1991, McCormick and Stevenson 1991, Dudley 1992 and Karouna and Fuller 1992). Chironomid midges (*Diptera*) may be similarly important herbivores owing to their ubiquity, high densities and short generation time (Fairchild *et al.* 1989 and Lamberti 1996). Zooplankton and benthic filter feeders, such as molluscs, are important for grazing and possible control of phytoplankton populations (Sand-Jensen and Borum 1991). Lakes with abundant zooplankton population tend to show lower phytoplankton biomass. Grazing of attached algae in microscopic food webs can play a role in the flow of energy through the benthic community (Bott 1996). Micro-consumers in such a food web include protozoa and meiofauna (organisms in the size range of 50-500 μm) such as large ciliates, rotifers, copepods, oligochaetes and insect larvae. Tadpoles have also been identified as grazers in pools and pond (Bronmark *et al.* 1991).

Steinmans (1996) review of grazer effects on freshwater benthic algae classified periphyton responses as structural and functional. Wherein structural responses can effect biomass levels, taxonomic composition, physiognomy, and species diversity of the attached community. Functional responses of algal grazing can include changes in the primary production levels, nutrient content and nutrient cycling along with successional trajectories of benthic algal assemblages. In such cases where there is a negative structural response as a result of grazing by herbivores, it follows that there is a negative functional response within the same periphyton community.

Structural responses to algal grazing can include almost always a biomass decline depending on the algae and the herbivore involved (Hart and Robinson 1990, Dudley and D'Antonio 1991, Steinman and Elwood 1991, Bronmark *et al.* 1992 and Karouna and Fuller 1992). Taxonomic changes are effected by the diet of grazing herbivores. This would suggest that their selectivity dictates the modification in community taxa. Variation in form and structure of communities, along with a decline in species richness and diversity, are also structural responses attributed to selective feeding (Hunter 1980).

In some cases algal biomass reductions do not occur in the presence of primary consumers. The removal of epiphytes by herbivores from macroalgae, such as from *Cladophora*, can have a beneficial effect on its biomass (Dudley 1992). Low grazer numbers are another likely reason why biomass may not decline. Also grazers feeding morphology may not be well matched with the dominant algal growth forms (Karouna and Fuller 1992).

Biomass changes and structural responses are not always straightforward. Bronmark *et al.* (1992) noted that the indirect effect of catfish predation upon snail biomass resulted in elevated algal growth levels with increased species diversity.

Where as enrichment of an aquatic ecosystem can have a positive effect on periphyton populations, other adjustments in the system can have a negative impact. Hickling Broad, a brackish lake in Norfolk England, under went considerable productivity changes during the mid 1970's. Eutrophication, due to enrichment by black-headed gulls and agricultural changes in the catchment, resulted in a turbid, phytoplankton dominated state (Bales *et al.* 1993). By the mid 1980's a submerged macrophyte population had recovered coinciding with a major reduction in the gulls population. However, elevated phytoplankton and nutrient levels were unchanged. An increase in the mysid, *Neomysis integer* (Leach) for unknown reasons resulted in elevated grazing upon periphyton populations. This caused the subsequent decline in attached algae and the vigorous recovery of the submerged plant community. The size of the periphyton burden, similar to that of the phytoplankton crop, is a function not only of conditions for its growth but also of loss mechanisms which remove it.

With functional responses to grazing in the attached algal community, Steinman (1996) observed that primary productivity would decline in relation to biomass where photosynthesising material is lost during herbivory. The nutrient content of periphyton can change with grazing. Nutrient cycling within the attached algal population will increase because of nutrient regeneration by using herbivore excretion. Also the physical movement of herbivores prevents the accumulation of litter within the structure. Succession of freshwater benthic algae undergoing grazing is difficult to interpret. Succession trajectories of algae depend on a local environment and grazing may mitigate final stage development or facilitate growth after a shift in species composition.

Work by the Lough Gill Environmental Management Project on the macroinvertebrate population in the littoral zone of Lough Gill indicated that the Gastropoda *Potamopyrgus jenkinsi*, *Lymnaea peregra* and *Planorbis planorbis* were numerically prevalent. Grazers such as these, along with Crustacea, have unknown effects on the periphyton community of the Lough Gill littoral zone. Their presence and associated impact (either negatively or positively) must be recognised before the effects of the periphyton community on the Lough Gill ecosystem can be understood.

2.5 Periphyton Monitoring Methods

2.5.1 Introduction

If the water of a lake receives increasingly large loads of nutrients, there is a strong tendency for phytoplankton to increase to the maximum capacity within the limitations of temperature and available light. It is important that eutrophication of Lake systems are not viewed in the restrictive sense of phyto-planktonic productivity (Wetzel 1983b). The common situation is for littoral productivity to play a major role in the early and late stages of lake eutrophication. With this realisation considerable work has been carried out on measuring the primary productivity of the shoreline. Of this, a substantial body of work has focused on methods of monitoring periphyton productivity.

Apart from periphyton as a monitoring method, other biological systems used include aquatic macrophytes and invertebrates. Chemical monitoring of littoral waters, sediments and the trans-boundary layer (between water and sediment) has also been explored. Biological monitoring of lake productivity is preferred because of the inherent difficulty of investigating non-point source enrichment in lentic environments. The failure of the Lough Conn mid-lake sampling program to detect the increased productivity and eutrophication of the waterbody (McGarrigle 1993) is an example of the difficulties with chemical monitoring. McGarrigle (*op. cit.*) went on to suggest that a broader ecological base to lake monitoring might be required which would include an assessment of littoral vegetation and the frequency of shoreline blooms and algal accumulations.

2.5.2 Attributes of periphyton monitoring

Lowe and Pan (1996) suggested that benthic algae posses many attributes that make them ideal organisms to employ in water quality monitoring programmes. These would include the following.

(a) Attached algae are autotrophic, occupying a position in the aquatic ecosystem at the interface of the chemical-physical and biotic components of the food web, their disruption can profoundly influence the rest of the aquatic community.

(b) They are sessile and can not migrate to avoid pollutants.

(c) Benthic algae are species-rich. Each species having its own environmental tolerance and sensitivity making it informative as a monitor through its presence or absence.
(d) With a relatively short life-cycle, algae can be representative of current environmental conditions.
(e) Attached algae are spatially compact and can be collected from an area within a few centimetres.
(f) Samples are easy to handle and curate.
(g) Identification is not exceedingly difficult.

The use of such attached benthic algae in the monitoring of primary production is documented in lotic and lentic environments. Welch (1992) and Stevenson, Bothwell and Lowe (1996) have reviewed periphyton and it's monitoring within rivers and streams. The majority of this work is also applicable to lake and standing waters. Wetzel (1979) provides a review of methods for the measurement of the periphyton community along with a comprehensive review of sampling programmes and their limitations.

Periphyton, as defined by Wetzel (1983c), are attached to substrate. These substrata may be living or dead. The attachment mechanics of freshwater algae, along with their effect and host interaction, has been discussed at length by Round in Reisser (1992). Functional interactions between substrata and microflora are greatly influenced by water turbulence both in lakes as well as streams (Wetzel 1983a). Different submerged substrata vary greatly in their physical characteristics and chemical contributions to attached microflora (Lowe and Pan 1996). For example those living on unstable organic rich sediments, in close proximity to toxic endproducts of anaerobic metabolism, are well compensated by the steep nutrient gradient towards the algae and the overlaying water. Because of the dynamics of the substrate one must consider carefully what material is most suitable for the growth of attached biota in a monitoring programme. Aloi (1990) in her critical review of periphyton field methods suggested that studies on attached algal growth could be broadly classified into natural and artificial substrate types.

2.5.3 Natural Substrates

Natural substrates already have an attached microbiotic community present at the point of sampling. Techniques usually used involve the removal of a quantitative volume of biota from the substrate. In discussing epilithic algae (periphyton attached to rock substrates), methods reviewed include the use of 'scraping' from a designated area of the substrate (Jacoby 1987, Hawes and Smith 1993 and Porter *et al.* 1997). 'Syringe sampling' has been explored, where an enclosed surface is syringed clean of its algae (Robinson 1983, Cattaneo 1990, Aloi *op. cit.* and Porter *et al.* 1997). Another method involves the use of a 'bar-clamp sampler', where the sample area was cleaned with an ultrasonic dental cleaner (Gale 1975). In all cases a fixed surface area of a chosen rock(s) was sampled by one of the above methods. Sampling was done *in situ*, which involved identification and sampling of the substrate while submerged. This may be quite unpractical in some cases where low water temperatures prohibit a long exposure period for the analyst.

Concerning the sampling of epiphyton (algae attached to submerged portions of aquatic macrophytes), the literature suggest a different approach to such natural substrates. Quantification and estimation of algae require the removal of the material from the macrophyte (Bohr *et al.* 1983, Jones and Mayer 1983 and Roos 1983). Three main categories have been suggested in the sampling of epiphyton, scraping (Brown 1976, on the cleaned amphibious sedge, *Eleocharis baldwinii* (Torr.) and Karouna and Fuller 1992), agitation (Jones and Mayer 1983) and chemical removal (O'Quinn and Sullivan 1983).

Direct observation of epiphyton at low densities using a light microscope (Silver 1980 and Paterson and Wright 1986 *in* Aloi 1992) or scanning electron microscope (SEM) (Montfrans *et al.* 1982 and Wright 1986 *in* Aloi *op. cit.*). SEM allows direct observation of the entire plant and the community structure of the intact epiphyton (Rogers and Breen 1983). The loss of loosely attached epiphyton when sampling macrophytes, along with methods for their retention, have been outlined and discussed by Burkholder and Wetzel (1989).

Sampling sand and mud substrates for attached microflora predominately involves the removal of an intact sediment core of generally small diameter (Robinson 1983 and Bradbury 1997). From this, it is cross-sectioned into thin layers, which are removed for examination. In the techniques used, Robinson noted Hargraves' (1969) sampler which cut thin layers of sediment for analysis and identification. The use of an aspirator by Eaton and Moss (1966) and the hand held peristaltic pump, employed by Hamala *et al.* (1981), significantly improved the removal of algae from the semi-liquid substrate. Carlton (Carlton and Wetzel 1988, Carlton *et al.* 1989 and Carlton and Klug 1990) has carried out a lot of work on sampling sediments and the separation of their associated benthic algae. Separation by chemical treatment (Hickman 1969, Gons and Van Keulen 1983 and Bradbury 1997) or ultrasonic exposure (Hickman 1969) has been found to be the most effective methods.

2.5.4 Artificial Substrates

An artificial substrate has been defined by Aloi (1990) as a "device placed in an aquatic ecosystem to study colonisation by indigenous organisms". Aloi (*op. cit.*) goes on to review the history of artificial substrates and sampling devices in periphyton monitoring. The collection of benthic algal samples using artificial substrates in lotic systems is thoroughly explored by Lowe and Pan (1996). With the exception of work on flow effects in rivers the majority of this research is applicable to lentic systems.

The use of artificial substrates has been justified for a number of reasons, most commonly to reduce the heterogeneity of the naturally occurring substrate or for a standard means of comparison between two habitats or sites with different substrates (Brown 1976, Wetzel 1979, and Lowe and Pan 1996). The exposure of artificial barren surfaces in a water body allows some control of experimental conditions since the development of attached communities may be closely followed over time (Brown *op. cit.*). Artificial substrates in periphyton monitoring can reduce sampling variability and significantly lower the chlorophyll variation between replicate samples (Morin and Cattaneo 1992). However their ability to detect ecological patterns is quite limited

Other reasons for using artificial substrates include low cost of sampling, minimum disturbance of the habitat and the short time required to obtain a quantitative sample, since the surface area of the substrate is known (Lamberti and Resh 1985). Aloi (1990) also noted that artificial substrates might also be used when naturally occurring firm substrate is absent.

2.5.4.1 Types of artificial substrate

An ideal artificial substrate is one that has less variability than that of the naturally occurring submerged surface. It is one whose colonisation time is short enough to satisfy the design of the experiment and easily retrievable without sample loss. The artificial sampler must accurately substitute the naturally occurring substrate (rock, plant, sand, etc.). However this may not always be the case (Higashi *et al.* 1981 and Hansson 1988). Robinson (1983) found that artificial substrates had clear advantages in that they may be readily manipulated into position, readily sampled and allow adequate replication of samples.

Glass slides are the most commonly used artificial substrate for periphyton colonisation. The method was developed, and popularised with the Catherwood Diatometer (Patrick *et al.* 1954). Many types of glass substrates and customised holders have been suggested and used in studies of epilithic and epiphytic communities (Brown 1976, Hunter 1980, Marcus 1980, Noel *et al.* 1986, McCormick and Stevenson 1991, Van Dijk 1993, Lowe and Pan 1996 and Vinyard 1996). Many of these studies cited the need for a uniform surface in experimental work as the reason for using this artificial substrate.

Glass slides are particularly advantageous because they are inert, inexpensive and periphyton may be removed by scrapping (Aloi 1990). However, as pointed out in the same paper, the following three factors may limit the work carried out and should be considered before undertaking a periphyton sampling programme. Indeed these are factors that must be looked at before choosing any artificial substrate.

(1) The orientation of the slides (horizontal versus vertical and parallel versus perpendicular to current and water movement) can result in a greater accumulation/loss of biomass, often as a result of settling from detritus than growth of microbiota.

(2) The degree of replication required between the same type of artificial substrate must be considered. Wetzel (1979) found statistically significant differences (0-100% variation in biomass) in measurements on glass slides between replicate samples.

(3) Algal communities on glass slides may not be identical to the natural occurring epilithic/epiphytic communities. Some comparative work has shown significantly different results in terms of biomass, chlorophyll and species composition (Brown 1976 and Silver 1977). Robinson (1983), who noted the same problem, suggested that some of the conflicting results between substrates might be due to methodological differences.

When choosing and applying artificial substrates in Lough Gill these points must be considered, particularly in relation to achieving the aims of the project. Although the orientation and replication of the substrate is important, its relationship to the natural occurring assemblages is paramount. The artificial material must be able to replicate the periphyton populations occurring on the natural substrates of the lake. It must be indicative of changing periphyton growth throughout the different seasons of the year.

Other artificial substrates used in attaining the growth of epilithic algae include stones, ceramic material, clay tiles and bricks (Hart and Robinson 1990). Stones or cobbles have been removed from the littoral zone, cleaned and reintroduced into the same aquatic system (Horner and Welch 1981 and Lock *et al.* 1984). Other work includes the introduction of stone substrate from other locations. Blinn *et al.* (1980) compared three geologically different rocks. This work initial colonisation rates varied due to the microsurface morphometry of the rocks. However substrate selection played only a limited role in attached growth over time. Cut stone has been used to provide a flat, clean face for growth and removal of attached biota (Turner, Schindler and Graham 1983). No work could be found on washed stones submerged in trays. Studies predominately used individual stones. Growth and removal of the algae are detailed above.

Clay and ceramic tiles, both glazed and unglazed, have been introduced into waterbodies (Dudley and D'Antonio 1991, Mulholland *et al.* 1991 and Karouna and Fuller 1992). Hoagland and Peterson (1990) used flat unglazed tiles in studies on the effect of light and wave distribution upon vertical zonation of microalgae. The flat surface area of the tile was particularly suited to such work. Aloi (*op. cit.*) also reviewed the use of concrete bricks, styrofoam suspended in the water column (Flint, Richardson and Goldman 1977), aluminium SEM tabs for direct microscopic observations as well as nutrient diffusing substrates. All have all been used in the artificial growth of epilithic and epiphytic communities.

Nutrient diffusing substrates, such as a dialysis membrane (Matlock *et al.* 1995) or clay flowerpots (Fairchild *et al.* 1989, Marks and Lowe 1989 and Niederhauser and Schanz 1993) have been employed as artificial surfaces. Both of which are semi porous which allow the slow release of a nutrient agar. This provides a better means of mimicking non-inert surfaces, such as macrophytes, when growing epiphytic biota. The nature of the substratum is strongly influential on the benthic algal community structure (Wetzel 1983b and Burkholder 1996). The slow release of nutrients means growth would more readily reflect the assemblages that occur on aquatic plants.

In the same vein as glass slides, plastic has also been employed as an artificial substrate. Here its mouldable, inert qualities that allow specific surface areas to be exposed have made it useful in periphytic monitoring. Kettunen (1983) used flat plastic plates in studying the effect of paper pulp waste on the periphyton of Lake Saimaa, Finland. In snail predation trails, plastic strips (Bronmark *et. al.* 1991) and plastic flagging (Bronmark *et al.* 1992) has been successfully used. The degree of algal growth on exposed and controlled areas of a substrate were compared after grazing. Higashi *et al.* (1981) also used rods made of poly-vinyl chloride in grazing trials. These were substituted for reed stems. Aloi (*op cit.*) also noted the use of plastic, glass and wooden rods as substitutes for stems of emergent macrophytes.

A number of studies have used plastic and synthetic aquarium plants as artificial macrophyte substrates (Cattaneo and Kalff 1979, Cattaneo 1983 and Morin 1986). There was little agreement on the effectiveness of these materials. Morin (1986) found that a comparison of species composition on *Myriophyllum* and artificial plants with a similar structure were not much different. However biomass levels were lower on the artificial substrate. Aloi (1990) concluded that the different results maybe attributed to the varying degree of similarity between the artificial substrate and the plant. The results may also be related to trophic levels of the lake. Finally burrowing grazers that would be absent from plastic plant substrates would certainly effect periphyton biomass and species composition on natural macrophyte populations.

2.5.4.2 Substrate exposure periods

The length of exposure period for sampling devices often depends on the waterbody and season as a function of light, temperature, and invertebrate grazing intensity (Lowe and Pan 1996). Water quality and its productivity (longer exposure in less productive waters) along with the purpose of the investigation may would also determine the time period (Aloi 1990).

Patrick et al. (1954) suggested that two weeks exposure was sufficient in summer to obtain a representative benthic algal community. The majority of literature reviewed used exposure periods from one to four weeks (Brown 1976, Higashi et al. 1981, Jacoby 1987 and Hoagland and Peterson 1990). The exposure period appeared not to be dictated by the type of growth substrate. Vinyard (1996) exposed glass slides for one month intervals whereas Hunter (1980) exposed a similar substrate for periods up to 45 days. The growth of thick biofilm, which can occur over a long exposure, may increase the liability to sloughing of over-mature communities (Lowe and Pan 1996). Thereby results from the substrate may underestimate the periphyton population.

Exposure periods of glass slides exposed on the western lakes of Ireland were increased from two to four weeks because the growth levels initially recovered on glass slides were low (McCarthy and Barbiero 1996). Tuchman and Blinn (1979) stated that "artificial substrates, which are used for substitutes when sampling the natural substrate, should be exposed long enough for the community on the artificial substrates to fully develop. The length of time required for the attached community to develop may depend upon the nutrient levels and trophic status of a waterbody".

Exposure periods may be considerably different depending on the artificial substrate and in some cases they may have to be very long. Robinson (1983) felt that the length of time for colonisation should be quite comparable with that provided by the natural substrata, particularly if these are annual macrophytes. This length of time, however, may not be feasible. The length of the exposure period must be a compromise between the period required for colonisation and the feasibility of sampling and analysis of the substrate.

2.5.4.3 Limitations in artificial substrate studies

Several restrictions are inherent in the use of artificial substrata. Wetzel (1983b) noted marked differences in colonisation rates and biomass levels between replicate artificial substrates within a waterbody. He found these were related to the substrates' position and depth in the water column as well as their spatial location within the waterbody. As in Aloi (1990), Wetzel found orientation problems of substrates, poor replication between samples along with a significant difference in growth on natural and artificial substrates might all limit the application of such materials.

However the most serious criticism that Wetzel (1983b) can direct against artificial substrata centres on the implicit assumption that substrata (inorganic or organic, living or non-living) have no appreciable effect on its attached community. Likewise, it is assumed that the metabolism of the attached microflora has no reciprocal effect upon its same substrate. This interaction between substrate and attached community may significantly alter the periphyton structure and result in a real difference between those on natural and artificial materials (Robinson 1983).

On the other hand, when used critically, artificial substrata can be a meaningful tool for the approximate estimation of biomass accrual of many attached microorganisms. Most existing information is already based on these methods (Wetzel *op. cit.*).

2.5.4.4 Studies using artificial substrates in lentic systems

Artificial substrates have been used in numerous lake studies. From this work there has been a greater understanding of the role played by periphyton in the littoral zone. Artificial substrata of uniform composition and colonisable area are commonly used to estimate growth characteristics and species composition of attached algae (Brown 1976 and Wetzel 1983b). The effects of physical and chemical parameters on periphyton attached to artificial materials have been widely researched (Turner, Schindler and Graham 1983, Fairchild *et al.* 1989, Cattaneo 1990 and Hoagland and Peterson 1990). The effects and interaction of grazers on substrata colonisation by attached periphyton populations have also been well documented (Hunter 1980, Higashi *et al.* 1981, Fairchild *et al.* 1989 and Steinman 1996).

Work on littoral productivity (Hansson 1992 and McCarthy and Barbiero 1996) and artificial enrichment (Kettunen 1983 and Hawes and Smith 1993) with *in situ* substrata, although not widely practised, are becoming more inter-linked. Lake littoral zones are the interface between the catchment and the main waterbody of the lake, and as such they are often the first areas where catchment perturbations become visible (Hawes and Smith *op. cit.*). It may be in the littoral zone that algal growth associated with increased enrichment is first perceived as an aesthetic, economic or ecological nuisance (Goldman 1981). The interface retention capacity within the wetland-littoral complex of lentic systems has profound effects upon adjacent fresh water (Wetzel 1990). With these points in mind, the use of artificial substrates may provide much information on the current state of the Lough Gill periphyton community. They may also indicate the wider state of the lake waterbody and identify any potential enrichment that may not be visible through other monitoring methods.

3.0 Material & methods

3.1 Introduction

The initial aim of this project was apply a monitoring programme that would observe, identify and quantify levels of attached material deposited in the littoral zone of Lough Gill. This was for the duration of one complete seasonal cycle. From this, a baseline review of attached material and the current nutrient status of the lake may be better understood. Data and conclusions may allow better predications about the lakes condition in the future. Such work may be useful in assessing the trophic state of other Irish lentic systems. The methods employed could be readily applied by others when assessing the trophic nature of a lakes littoral zone.

Goals of the project include the estimation of the lakes' trophic status. The assessment of the materials impact on the submerged flora and fauna within the littoral zone. The effect this material has on water quality and clarity was also considered important.

In order to achieve these aims a suitable programme with a working structure for the entire length of the study had to be implemented. This had to include the identification and assessment of potential sampling sites around the lake that would be representative of the littoral zone. Sampling methods that were both spatially and temporally comparable over the length of the study. They also had to be representative of the natural conditions occurring within the waterbody. Procedures and analysis had to be statistically competent while comparable with other work done nationally and internationally. From a practical aspect, the number of sites chosen and the volume of analytical work undertaken had to be manageable within the time frame of the project.

The construction of a sampling programme firstly involved the assessment of potential sampling locations. After identifying the sampling methods that would be employed, the layout of each sample site was drafted. While analytical procedures were considered at the same time as sampling methods their details will be dealt with at a later point in this chapter. Finally, a sampling plan was drawn up where work could be feasible undertaken over the course of the study.

3.2 Sample sites

3.2.1 Sample site selection

In order too full-fill the aims of the project it was first necessary to look at the morphology, geology and ecology of the lake basin and surrounding lands. This was with particular interest in the lakes littoral zone where the material occurred. Here, information on the slope and extent of the lake shallows along with its substrate type and ecology could be ascertained. The shape and geology would help to identify areas vulnerable to enrichment from lands surrounding the shore while identifying shading of the shoreline by surrounding hills. These aspects would go to locate potential locations that were representative of the lakes littoral zone.

Potential sample sites around the Lough Gill littoral zone were subsequently visited. Sites had to be accessible by road yet sheltered from public view. This was in order to allow easy placement and retrieval of samples yet provide protection from vandalism. Locations chosen must be representative of shoreline conditions. Points considered include orientation of shoreline and their exposure to sunshine and prevailing winds. Also, the littoral substrate gradient and substrate type, topography and management practices of the surrounding lands along with shoreline vegetation. The time required to visit and sample chosen sites, and the volume of analytical work generated, would also anticipate the eventual number chosen.

Of the potential sites, six were finally chosen (see Table 1). The selected stations differed to a varying degree of the above factors. Thereby it was hoped the study would give an overall picture of the trends in periphytic growth around Lough Gill.

CODE	LOCATION	GRID REF.	SUBSTRATE TYPE	GRADIENT	EXPOSURE
S1	Halfmoon Bay	G 724 344	Course sand & small stones	Flat bay	Semi-exposed
S2	Corwillick	G 769 351	Packed small stones and gravel	Slight gradient	Exposed
S3	Sriff Bay	G 796 344	Large packed stone, rock & sand	Slight gradient	Very exposed
S4	Whites Bay	G 791 335	Packed stone & rock	Steep gradient	Semi-exposed
S5	Bunowen Bay	G 737 319	Packed stone & sand	Steep gradient	Exposed
S6	Tobernalt Bay	G 713 331	Packed stone & rock	Slight gradient	Semi-exposed

Table 1: Lough Gill littoral zone sample sites, sampling code and grid references.

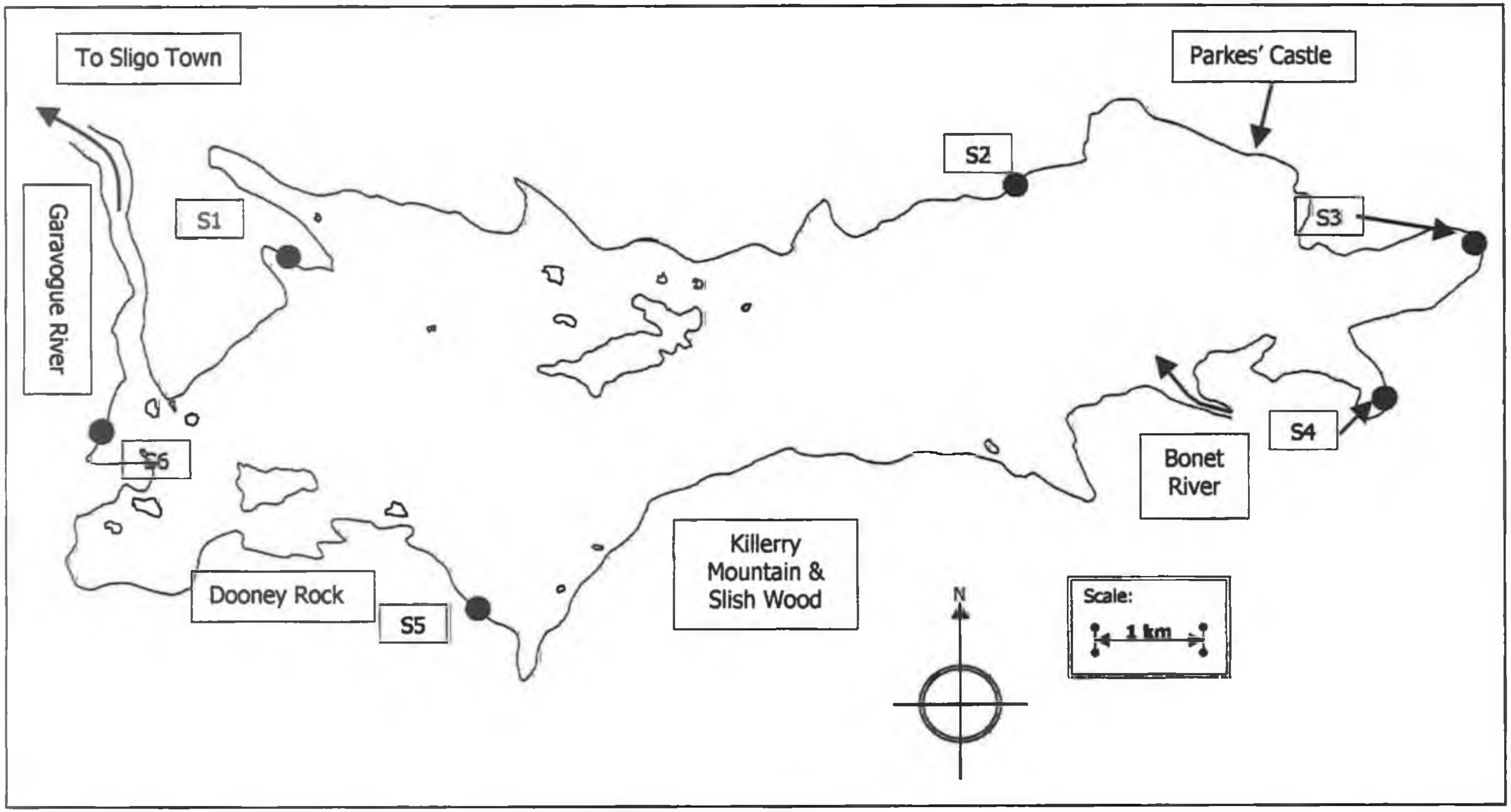


Figure 4: Location and codes of sample sites in the littoral zone of Lough Gill.

3.2.2 Site description

Sites are listed with regard to location, substrate, and degree of exposure in Table 1. Here sites are described giving details of artificial substrate location and position in relation to their degree of shading from shoreline vegetation and orientation to predominant weather patterns. Also a more detailed substrate description along with the slope of the surrounding topography is presented.

All sites received a considerable amount of exposure depending on wind direction and weather patterns. This was due to the open nature of the lake-body, which has no sheltered bays. This also ensures that the waterbody is quite mixed with no spatial variation.

3.2.2.1 Half-moon Bay (S1)

This site, along the northern shore of the bay (see Plate 6, Appendix IX), was semi-exposed to southerly and easterly winds. The site faced southwest across the bay. From this orientation it experienced minimal shading from overhanging vegetation. The surrounding lands of Hazelwood are reasonably flat, with the bay itself being quite shallow in comparison with the rest of the lake. Artificial substrates were positioned approximately 2 to 3 meters from shore. The submerged substrate was predominantly course sand and small packed stones, limestone in origin.

3.2.2.2 Corwillick (S2)

Site S2 was 30 meters northeast of the slipway used by the 'West of Ireland Activity Centre' (see Plate 7, appendix IX). The shoreline, facing southeast, received considerable exposure to southerly around to easterly winds. However, this site was found to be quite sheltered under the predominant westerly weather. On a number of site visits when the main waterbody was visibly rough this site was clam in comparison. Again, because of its southerly orientation, this site received very little shading from shoreline vegetation until late in the day. The surrounding lands are hilly. These steep contours continuing underwater at site S2 resulted in deep water close to shore. The site was positioned immediate to the shoreline. It had a natural substrate of packed limestone and rock.

3.2.2.3 Sriff Bay (S3)

This site is situated on the eastern shore of the lake (see Plate 8, Appendix IX). It faced west-southwest and received winds from south to the northwest. This was the most exposed site around the lake. Under the above wind conditions this area of the lake receives considerable wave action due to the long fetch that is available across the waterbody. Because of the road running along the lakeshore, separating the woods on the adjoining hills from the lake, this site received little shading.

Steep hills run to the shores, north and south of Sriff Bay. Lower lands adjoin the lake along the eastern shore where the sample site was positioned. Although the bay is deep this area is of moderate slope and the site could be positioned approximately 2 meters from shore. This distance could have been greater but for the excessive wave action in the area. Again the natural substrate was tightly packed stone mixed with larger stones, both limestone in origin. However the larger stone may have been a result of fill from road construction in the past.

3.2.2.4 Whites' Bay (S4)

Whites' Bay hooks into the southeastern shore of the lake (see Plate 9, Appendix IX). The site itself was positioned along the eastern shore of the bay, 30 meters south of the slip. The site faces west. However, the bay picked up considerable exposure from the predominant northwesterly wind. On such occasions the eastern shore of the bay was observed receiving considerable wave action. The site received moderate shading from the overhanging vegetation and hilly eastern shore. This made the bay very shaded during the first half of the day.

Whilst sites S1, S2 and S3 were on limestone, S4 was situated on the harder metamorphic rock of the Ox Mountains. Whites' Bay is a hollow indentation into this seem of rock. This results in steep slopes around the bay and its littoral zone. The site was subsequently close to the shoreline. The submerged substrate consisted of packed stone with a little course sand. The stone was metamorphic in origin.

3.2.2.5 Bunowen Bay (S5)

The site in Bunowen Bay was situated on the western shores in a small cove used by the Dooney Rock rowing club (see Plate 10, Appendix IX). The site had an easterly orientation. It received considerable exposure to wave action from westerly around to northeasterly winds. Although reasonably enclosed the cove was not as sheltered as it initially appeared, receiving considerable wash from the predominant winds. The site got a moderate amount of shading from the overhanging vegetation of the westerly shore. This was more noticeable in the latter half of the day.

The northeastern slopes of Slieve Daeane slope gradually down to meet Killerry Mountain at Bunowen Bay and Slishwood Stream. This results in Bunowen Bay gradually sloping of to deep water, however site S5 had a steep gradient with a 4 meter trench in the middle of the cove. The substrate was predominantly packed stone and rock with course sand closer in at the mouth of the cove. This site was very close to exposed metamorphic bedrock.

3.2.2.6 Tobernalt Bay (S6)

This site was 15 meters north-northeast of the slip in Tobernalt Bay (see Plate 11, Appendix IX). It had a southeasterly orientation. This bay is reasonably enclosed from Stony Point to the south and Nut Point on the southern tip of Hazelwood. Easterly, around to northeasterly wind conditions can penetrate the bay. Land around the shoreline becomes quite steep when moving from the slip towards the site location. Regardless of this fact the site received little shading from the shoreline vegetation and hilly topography until the latter part of the day.

The steep slopes of the bay under Carns Hill extend into the water with a moderate slope of the lakebed. The site itself was positioned as far out as possible due to the volume of people visiting this area of the lake. The littoral zone had a limestone substrate of packed small stone and sand with a few scattered boulders. South of the slip the substrate was silt and sand supporting a bank of emergent macrophytes.

3.3 Experimental procedures

3.3.1 Substrate selection

While looking at potential sampling locations it was also necessary to consider methods of periphyton quantification and identification. These had to be reproducible and comparable from site to site over the duration of the project. In order to achieve these aims artificial substrates were chosen over those naturally occurring around the lake. This would eliminate the variation in site substrate that was so apparent. The impact of the surrounding lands, and the effects of the varying land uses, may also become more obvious.

Periphyton occurs on almost all submerged substrates, stone substrate and aquatic macrophytes are the predominant submersed surfaces around the lake. Artificial materials had to mimic these. They also had to be comparable with other studies. Analytical methods would include quantification and identification of attached material, therefore the substrates had to removable. Biomass determination from gravimetric analysis would not be sufficient on its own. It had to be backed up with chlorophyll estimation (which would help to separate the photosynthesising fraction of the materials collected on substrates) and periphyton enumeration. Materials used had to be able to provide this information yet be manageable during sampling and inexpensive to obtain.

To achieve these requirements three artificial substrates were chosen. All three were positioned at each of the six sites previously identified around the lake. The substrates were as follows:

1. Washed stones
2. Cut portions of plastic netting
3. Glass slides

The washed stone would be indicative of the natural occurring stone substrate. Plastic netting would represent the aquatic macrophyte *Littorella uniflora*, which is the predominant submerged plant around the lake. Both substrates would provide gravimetric biomass figures. Glass slides would provide similar information, however they could also provide information on chlorophyll levels along with algal numeration and identification (this would be done using replicate slides). Sampling submerged stones and plastic materials has been applied in different forms within the literature. Glass slides are widely employed and give good comparability between studies.

3.3.2 Site layout

Lough Gill water levels were known to vary considerably. From observations at the pump house gauge in Tobernalt Bay lake levels ranged from 0.60 meters to 1.60 meters over the study period (see Table 50, Appendix II). Such variation would result in the artificial substrates being submerged at different depths depending on the levels of rainfall within the Lough Gill catchment. The glass slides, suspended in the water column, could be positioned to a near constant depth under water. However, the stones and netting could prove to be more difficult to control. They were part of the littoral zone, lying on the substrate. With this in mind all six sample sites were positioned around the lake at the same depth. Although submersion depth would be hard to control this would minimise variation between sites.

Layout of all sampling sites took place on the 30 January 1997 when the water level at the Tobernalt pump house measures 0.70 meters. This level occurred after a month of low rainfall. All sites were laid out in a similar manner. This consisted of a rectangular roped out area, 10 meters by 1 meter (see Figure 5). This had ten $1m^2$ plots. The ten plots ran parallel to the shore, 1 to 2 meters from the waters' edge. The exact distance depended on the slope of the shore. At this distance from shore the inside rope would be at a depth of 40cm on this date. It was assumed that water levels in the lake would rarely fall bellow this level during the study period. The sampling substrates would then be submerged during the entire duration of the study, as was the case.

Using a 'Stratified Random Method' of distribution (Lewis & Taylor 1979), the stone trays and *Littorella* netting was randomly placed within the ten quadrats. Five plots were randomly chosen to contain trays of washed stone with the remaining five containing plastic *Littorella* plots. They were placed in the centre of their designated quadrat one meter apart from adjacent substrates.

Originally, there was twenty $1m^2$ quadrats in a roped area 10 meters by 2 meters. Both types of submerged artificial substrate had nine plots exposed at all times. Both the stones and the *Littorella* were exposed in triplicate for three different exposure periods. Exposure periods ran for one-month, two-month and three-month stretches simultaneously. However this was found to be unsuitable after one month of fieldwork. The time taken to position, collect and analysis such a volume of samples from six sites was not feasible. Also the value in obtaining results from two and three-month exposure-periods were not considered very significant.

Initially it was feared that substantial variation in biomass would be encountered between replicate plots within the same site. With only three substrate plots present per site the loss of one through wind or wave action would considerably enlarge the deviation between results. An increase in the number of replicate artificial plots to five per site, per exposure period, was more statistically sound. This would help to provide a better mean biomass result per site.

Glass slides were positioned on the left-hand side of the roped area when viewed from the shore. This was at the same depth as the deepest point of the roped quadrats (see Figure 5). Two the left of the slide holder, at the same depth as the rectangular roped area, two $1m^2$ metal quadrats were fixed to the bed of the littoral zone, one meter apart. Their distance from the slide holder and roped area was dependent on achieving good *L. uniflora* cover within the quadrats. The macrophytes within the quadrat furthest from the slide holder were brushed weekly to remove attached material from their surface. The other quadrat was untouched.

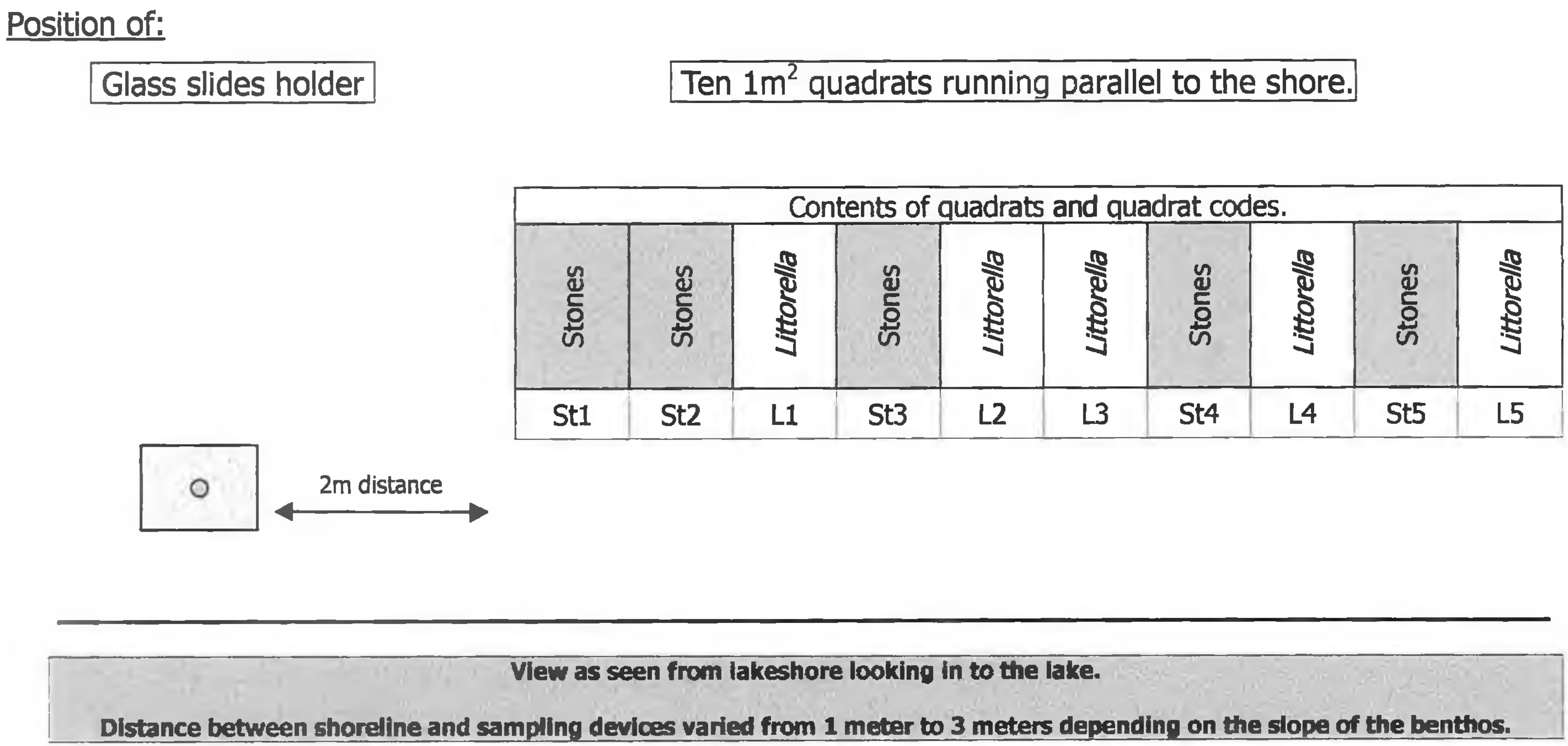


Figure 5: Layout of glass slides holder and ten 1m^2 Quadrats, holding artificial stone and *Littorella* substrates at six sample sites around the shores of Lough Gill.

3.3.3 Exposure periods

All artificial substrates, stones, netting and glass slides were exposed for approximately one-month periods over the entire duration of the program. Placement and retrieval of the different artificial substrates on the same date of each month was not feasible due to time constraints. Substrates were positioned and collected at intervals over a calendar month, while all were exposed for the one-month time period. For example, slides were retrieved in the first week of the month while stone were collected on the second week. This allowed sufficient time for analysis. (Placement and retrieval dates for the different substrates are listed in Appendix I.)

Exposure period of glass slides vary within the literature (see Section 2.5.4.2). Barbiero increased the exposure period of glass slides in the western lakes of Ireland from 2 weeks to one month because of the low biomass volumes he initially obtained (McCarthy and Barbiero 1996). With this in mind one month exposure periods was considered suitable for Lough Gill. In order to investigate periphyton colonisation rates a shorter exposure period was also considered. From April to June 1997 additional sets of glass slides were exposed for two-week intervals. This ran in conjunction with the normal one month slides. Four sets of these slides were exposed which resulted in the generation of four sets of results. Exposure and retrieval dates for these slides are also listed in Appendix I. The biomass collected on biweekly and monthly slides during the same period could be compared to investigate the rate of colonisation.
Initial exposure periods of 1, 2 and 3 months for stones and plastic plots in triplicate were not feasible. With all three periods running simultaneously most months would see two exposure periods of each substrate being removed. This volume of analysis, along with the large variation in results between replicate plots, was unacceptable. For these reasons a one-month exposure period, with five replicates, was employed for both the plots of netting and stone trays. This would be sufficient to show trends in attached material over time and yet prove very manageable to collect and analyse.

3.4 Glass slides

3.4.1 Exposure and retrieval methods of glass sides

Eight glass slides (dimensions of 76mm by 52mm by 1.35mm) were held vertically in the lake water column 30cm below the surface by a previously cut rubber bung (diameter of 58mm). The rubber bung was suspended on a reinforced metal pole (diameter of 12mm, length 1.0m). (These are illustrated in Plates 12 and 13, Appendix IX) The pole and slides were supported by insertion into a drilled hole of a concrete block. This was placed flat on its side on the bed of the lake (see Figure 6). The pole was not permanently fixed to the block. This allowed the pole to be removed from the concrete block and facilitated the replacement of slide sets at the end of exposure periods. The whole apparatus was in water no deeper than one meter to facilitate access from the shore. Glass slides have been used for a considerable time (Patrick *et. al.* 1954). This method is similar to one used on the western lakes of Ireland by Dr. Rick Barbiero (pers. comm.).

This free-standing structure allowed maximum exposure of the slides in a circular formation. While retaining them in this position the apparatus could also withstand weather and water movement along the littoral zone of the lake. The position of the rubber bung could be adjusted according to fluctuations in the height of the lakes water column by sliding it up or down the metal pole. This allowed the slides to be kept at a relatively constant depth of 30cm with minimal movement of the slide structure. Sudden, vigorous movement of the holder was observed to result in the loss of some loosely attached algae from the slides. This adjustment method resulted in minimal loss of algae with the retention of the slides at a desired level.

Retrieval of exposed slides was done by lifting the pole and attached slide structure out of the water. Slide the bung off the supporting pole and replace it with a clean set of slides and slide holder. All fresh slides were washed and rinsed three times with redistilled water. They were then dried and placed on a clean bung. Slides removed after an exposure period were retained on the bung while been transported, in darkness, to the laboratory for analysis. Slides were in contact with the air for a maximum of two hours before preservation or analysis. During this period they were enclosed in black plastic to prevent exposure to light or desiccation.

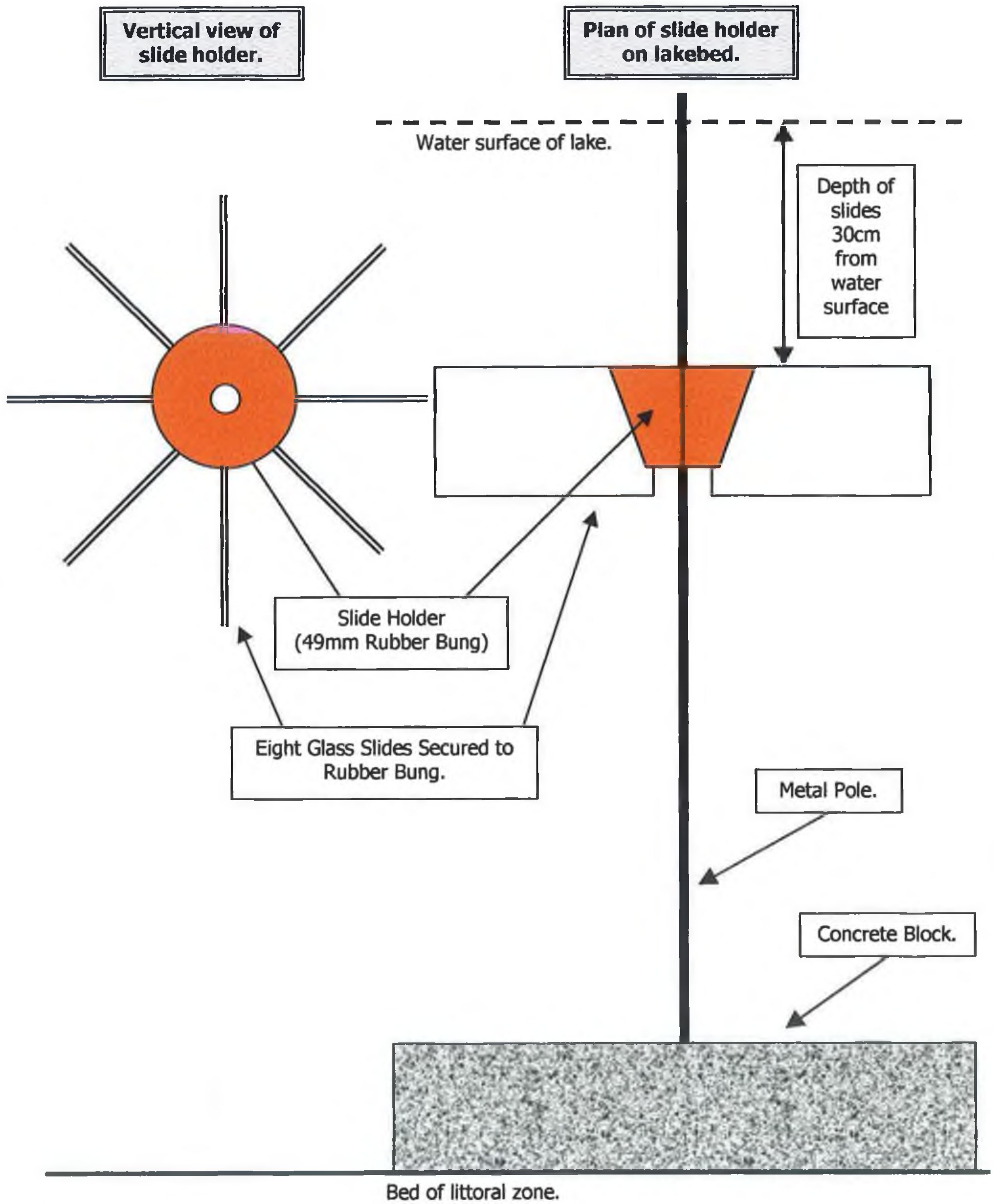


Figure 6: Layout of glass slides and supporting apparatus used at six sampling stations around the littoral zone of Lough Gill during 1997 and the first half of 1998. (Note: diagram and images not to scale)

The slides were subsequently used for the following purposes:

(a) Algal Identification
(b) Diatom Mounts
(c) Chlorophyll Estimation
(d) Dry Weights and Ash Free Dry Weights (Biomass Accumulation)

Of the eight slides present on each slide holder one was used for algal identification and another for diatom mounts. Of the remaining six slides, three were used for chlorophyll estimation and three for biomass accumulation.

Initially it was planned to rotate the slide structure once a week to change the orientation of the eight slides on the holder. The position of the substrate to wind, water current and sunshine might result in disparity between the biomass on the eight slides. However these movements resulted in the loss of loosely attached algae. For this reason a 'Stratified Random Method' identified the analytical procedure to be carried out on each of the eight slides. A mark was placed on the rubber bung next to one slide. The bung had no particular orientation in the water. The sequence of slides used in analysis varied for each set. It was hoped that such procedures would reduce variance between replicate analysis. Also the choice of slide would not bias one method of analysis against another.

3.4.2 Removal of algae from glass slides

Attached algae were scraped from the glass substrate using a flat safety blade and jets of distilled water from a wash bottle. The removed algae were eluted into a beaker for subsequent preservation and analysis.

Slides for identification, diatom mounts and chlorophyll estimation were handled first in order to minimise any possible changes in the species distribution or the chemical structure of attached algae. The other slides, for biomass accumulation, could be left to air dry and were stored overnight before subsequent processing. The following day the slides were re-hydrated with distilled water before being scraped into a beaker. These could then be gravimetrically analysed.

3.4.3 Analysis carried out on attached algae removed from glass slides

The following parameters were investigated using glass slides as an artificial substrate for periphyton growth. These four monitoring methods were employed using sets of eight slides, removed from each site.

3.4.3.1 Algal Identification

Identification and enumeration of periphyton was carried out according to Standard Methods, section 10300 C; part 1. This involved the use of a 'Leica' compound microscope and a 'Sedgwick-Rafter' counting chamber at 100X magnification. Periphyton identification was achieved using a number of keys and guides (Prescott 1978, Bellinger 1992 and Canter-Lund and Lund 1996).

Scraped elute from the slides were thoroughly mixed before a representative volume was taken. Where necessary the sample volume was diluted so less than 300 algal cells are present per field. This was to facilitate identification and algal counts.

Three 'Sedgwick-Rafter' chambers were filled for each sample counted. Five fields were randomly chosen in each chamber. All genera present were identified and the total number of cells per genera was estimated. Counts were expressed as cells per square millimetre (cells/mm^2). Calculation methods are detailed in Figure 39, Appendix III.

3.4.3.2 Diatom Mounts

Diatoms had to be cleaned prior to mounting. This was done in accordance with Patrick and Reimer (1966). The eluted algae were placed in a 35ml vial. A small volume of concentrated sulphuric acid was added to the vial. The vial was sealed and shaken vigorously before been allowed to stand for some days. After total oxidation of all organic matter appeared to be complete potassium dichromate was added slowly until the solution turned brown. After the solution settled, when the frustules of the cleaned diatoms moved out of suspension, the clear supernatant was discarded and distilled water was added as a wash. This was repeated until the solution reached pH 7.0. Alcohol was then added as a final wash after most of the water has been decanted.

Mounting of the diatoms was done by placing some of the cleaned suspension on a cover slip. A small amount of the mounting medium 'Styrax' was placed on a glass slide and the cover slip inverted on it. The cover glass was pressed down carefully in order to make as thin and even a mount as possible. A hard permanent mount was achieved by placing the slide on a slow heat to evaporate all the solvent.

3.4.3.3 Chlorophyll Estimation

This method was carried out in accordance the Irish Environmental Protection Agency (EPA) in-house procedure for chlorophyll estimation from phytoplankton. This was done in order to compare results with those obtained by the EPA from Lough Gill phytoplankton samples, as part of the Lough Gill Life Project.

In the case of chlorophyll in periphyton, the elute of scraped algae is passed through an 11.0cm GF/C Whatman glass filter paper. The filter was placed into a test-tube. Chlorophyll was extracted into 14.0mls of 96.4% methanol at 70° C. After one hour cooling in the dark the supernatant was centrifuged at 2200 rpm for five minutes. The clear supernatants absorbence was determined using a spectrophotometer at 665 nm and 750 nm. This was corrected with a blank containing 90% methanol.

Calculations for chlorophyll a (total pigment uncorrected for the presence of phaeophytins) is carried out in accordance with Standard Methods, section 10200 H; part 2c, Trichromatic Method (APHA 1985). Chlorophyll levels for periphyton are expressed per surface area of substrate (mg/m^2). Calculation methods are detailed in Figure 38, Appendix III.

3.4.3.4 Biomass Accumulation

Dry weight and ash free dry weight (AFDW) was carried out on algae previously scraped from slides in accordance with Standard Methods, section 10300 C; part 5.

The scraped algal elute was passed through a pre-washed and pre-weighed 11.0 cm GF/C Whatman glass filter paper. The paper and algal elute was dried at 103° C for one hour. It was then allowed to cool, weighed and the dry weight was calculated. The same filter was then ashed at 500° C, and again allowed to cool before weighing. The ash free dry weight was then calculated.

Gravimetric analysis determines the volume of biomass per surface area of the glass slide. The surface area of the glass slides used was calculated to be $0.00787m^2$ (see Figure 36, Appendix III). This figure was then converted to the volume of biomass per meter square, g/m^2, (Figure 37, Appendix III).

3.4.3.5 Autotrophic Index (AI)

The trophic nature of the periphyton community was estimated using the Autotrophic Index (AI). This is a ratio of biomass (ash free dry weight) to chlorophyll (see Figure 43, Appendix III). Normal values range from 50 to 200: large values indicate heterotrophic associations or poor quality water (in Standard Methods, APHA 1985).

3.5 Phytoplankton

Phytoplankton samples were taken at monthly intervals in conjunction with the collection of glass slides. Two litre volumes were collected. Previously cleaned sampling containers were rinsed with lake-water prior to collection. The sample was taken below the surface at a depth of 15 to 20cm. Care was taken not collect surface scum. Phytoplankton were preserved on site with 7.0mls of Lugol's iodine per two litres of sample.

Subsequent concentration, enumeration and identification techniques was carried out according to Standard Methods, sections 10200 C; part 1 and 10200 E; part 1. This involved using the 'Sedgwick-Rafter' counting chamber and a 'Leica' compound microscope, at 100x magnification. Phytoplankton counting was carried out according to Standard Methods, section 10200 F. using a 'Total Cell Count' enumeration method. Cells were counted as 'cells per millilitre of original sample volume'. Phytoplankton identification was achieved using a number of keys and guides (Prescott 1978, Bellinger 1992 and Canter-Lund and Lund 1996).

In general, algal volumes were at a level that strip counts could be employed. Three 'Sedgwick-Rafter' chambers were filled with the concentrated sample and one strip per chamber was counted and identified. Calculations are detailed in Figure 40, Appendix III.

3.6 Artificial plastic *Littorella* plots

Plastic fruit netting was used to mimic the macrophyte *Littorella uniflora*. This was cut and bound in such a way as to loosely sit on the littoral zone sediment, covering a surface area of $10cm^2$.

Lengths of netting, 6 meters long and 4 meters wide, were rolled in a rope-like length and cut into strips 10cm long. Three strips were laid on top of each other and the middle was bound with a plastic cable-tie. Another cable-tie was attached to this, binding the netting to a metal weight. This weight would anchor the cut plastic on the bed of the littoral zone.

On the lake bed the nettings' form and textures would act in a similar manner as *L. uniflora* growing along the shore of the lake. Attached organic matter levels growing on the artificial substrate could be determined and seasonal trends investigated. The plots of netting had an exposure period of one month. At each site around the lake there was five plots submerged. The arrangement of plots at each site can be seen in Figure 5.

At the end of each exposure period the netting and attached weights were collected, bagged, labelled and returned to the laboratory for analysis on the same day. It was important to bag the netting with the minimum amount of agitation to prevent any loss of attached algae. This was done by entrapping the netting in a plastic bag while it was still siting on the lake bed.

In the laboratory, each plot had its metal weight removed before been placed in a 500ml-stoppered graduated cylinder. A 150ml volume of distilled water was added to the cylinder and the contents shaken vigorously. This wash water was decanted to another 500ml graduated cylinder. This process was repeated three times with 150ml volumes of water. The washings removed all attached material on the lengths of netting. Volumes of water became clearer with each cycle. The wash water in the second cylinder was then made up to the 500ml mark, shaken and a representative 100ml portion was decanted for filtration. This volume was passed through a pre-washed and pre-weighed 11.0cm Whatman GF/C filter paper, under vacuum.

Dry weight and ash free dry weight determination of attached material from artificial *Littorella* plots were carried out in the same manner as with that of biomass from glass sides, using

Standard Methods section 10300 C; part 5. This involved gravimetric analysis of cooled, dried filter papers before and after being exposed to specified temperatures.

In the case of the netting, each plot was taken to represent a $10cm^2$ patch of *L. uniflora* growing on the bed of the littoral zone. Gravimetric determinations of dry weights and ash free dry weights were thus determined to grams of attached biomass per $10cm^2$ areas of macrophyte. This was extrapolated up to grams per meter square (g/m^2) macrophyte. Calculations are detailed in Figure 41, Appendix VIII.

3.7 Stone trays

The growth of attached material on the non-living substrate in the littoral zone of Lough Gill was replicated using trays of washed stones. The replication and exposure period of the trays were the same as the plots of plastic netting.

The biomass levels obtained from the netting would be comparable with that occurring on macrophytes around the lake. The use of stones in trays would indicate the levels of attached material collecting on the inorganic substrate in the littoral zone of the lough.

The lake itself is mainly sited on limestone but laps against a non-calcareous rock (Mac Dermot, Long and Harney 1996). This geological occurrence exerts a very slight effect on the waters of the lake (Feeney 1996). The six sampling sites around the lake were on geologically different areas. Sites S1, S2, S3 and S6 were on limestone formations while the remaining two sites were on an older metamorphic rock. In order to minimise variability between sites the same stone was used in all trays submerged around the lake.

Stones were collected from a quarry within the Lough Gill catchment. These were loose limestone aggregate that was separated from soils. There smooth, worn surface, possible glacial in origin, was in keeping with stones found along the northern shore of Lough Gill.

Stones were graded, and those of a diameter between 2 and 6cm were retained for use while the rest were discarded. This was achieved by sieving the stones through a plastic basin that had been previously perforated with holes, 2cm in diameter. Those stones that passed through were rejected as too small. Stones with a diameter greater than 6cm were removed by hand.

The retained aggregate was washed with a hose and deck brush to remove all soils and other organic matter. Stones were then placed on a steel mesh trough to dry. These were then washed, in the above procedure, a second time. The volume of stones placed in each tray was standardised by filling a circular sieve (25.0cm diameter and 3.5cm deep) to the brim with a random portion of washed stone. Stones were then placed in plastic trays (see Plate 14, Appendix IX).

The trays internal dimensions were 221mm by 261mm. The base of the trays were sealed to prevent any loss of matter upon their retrieval from the water. The volume of stones measured out by the sieve was sufficient to fully cover the base of the plastic trays.

Using these trays, the volume of materials attached to inorganic substrates in the littoral zone of the lough could be determined. This is looking at an area of substrates in the littoral zone and determining their periphytic biomass (g/m^2) over an exposure period. In comparison other artificial substrates looked specifically at a surface area of a substrate within the littoral zone. Each tray, because of the random selection of stones, had a different surface area of aggregate within but had a similar volume. Positioning of the trays, the number of replications and exposure period has been outlined previously (see Figure 5 and Table 47, Appendix I).

Upon collection of trays, water and other sediments were retained with minimal loses. Trays were returned to the laboratory and analysed within 24 hours.

Biomass collected in the tray and on the stones was separated from the inorganic aggregate by passing portions of the stones and trapped lake water into a 2.0mm sieve. Distilled water and a small brush were used to remove attached material. This was collected in a plastic bucket. Portions of washed stone were transferred to a separate, clean tray for returning to the lake at a future date. The volume and nature of this work was painstaking.

The volume of wash water and attached material collected in the bucket was measured. A representative volume of these washings was taken (approximately 100mls) and the exact quantity recorded. This was passed through an 11.0 cm Whatman GF/C glass filter paper in the same manner as the washings from the plastic netting. Biomass levels were carried out with the same procedures as was used on the glass slides and plastic netting, using Standard Methods; Section 10300 C, part 5. Again, gravimetric determination of cooled, dried filters before and after exposures to specified temperatures.

Dry weight and ash free dry weights were gravimetrically determined and results were expressed in grams per volume of washings filtered. This was extrapolated to the total volume of washings obtained per tray. These biomass levels were expressed in grams per surface area of the tray and this was converted to grams of biomass per meter square (g/m^2). Calculations are outlined in Figure 42, Appendix III.

3.8 Statistics

During the course of this study a large body of data was generated from the quantitative estimation of periphyton levels and their identification. In order to present this it was necessary to interpret and condense it to a manageable form. The following analysis was carried out on data collected during the monitoring programme.

- **Standard error**

  It was recognised that the variation between replicate samples would be important. In all analysis there would be three to five replicates. This is a very small population number when estimating the mean. In order to establish the standard error with 95% confidence the sample standard deviation would have to be determined and this would be multiplied by the *t*-value. The *t*-value should be estimated from the number of replicate samples or degrees of freedom. Calculations are outlined in Figure 44, appendix III.

- **Wilcoxons' Rank Sum for Two Samples**

  Wilcoxons' rank sum test for two samples was applied to data from the six sites in order to assertion if there was any variation between sites and subsequently identify the level of significance between them using the normal distribution. Calculations are outlined in Figure 45, Appendix III.

- **Principal component analysis**

  Principal Components Analysis (PCA) was used to help understand and unravel a correlation matrix from the data collected at the six sample sites. It would identify the number of components, and percentage influence of each component, associated with the variance between the six sites. Analysis was carried out using SPSS® Base 7.5 for Windows® (Statistics Package for Social Science), details in Figure 46, Appendix III.

- **Cluster Analysis**

  This multivariate procedure was used to detect groupings within the data. This would allow the identification of spatially different sites. Using a similarity index the spatially different sites could be visually presented in a dendrogram (or tuning fork diagram). Cluster analysis was carried out using SPSS® Base 7.5 for Windows®. Theoretical details can be found in SPSS® statistical application manuals. All computer based statistical procedures were checked independently by Mr. Paddy Greer of the Institute of Technology Dundalk.

4.0 Results

4.1 Introduction

Investigation into periphyton and its associated organic and inorganic material took place at six sites around the littoral zone of Lough Gill. Field work started in January 1997 and finished in May 1998, 16 months later. During this time the monitoring programme used different artificial substrates in order to provide a means of quantifying and identifying the attached periphyton around the littoral zone of Lough Gill. The artificial substrates were glass slides, bound and cut portions of plastic netting (that could imitate the macrophyte *Littorella uniflora*) and washed stones (held in plastic trays).

Predominantly a one-month exposure period was used for all artificial substrates. However, between April and June 1997 sets of glass slides were simultaneously exposed for two-week periods. During any one calendar month the positioning and collection dates of different substrates were staggered. This allowed the collection and analysis of artificial substrates to be carried out in a manageable time frame during each exposure period. All dates can be found in Appendix I.

Glass slides are considered to be a representative way of comparing periphyton from different locations. From their known surface-area the analysis can be carried out quantitatively and qualitatively. Results from monthly glass slides are presented in Section 4.2 with biweekly glass slides in Section 4.3. Phytoplankton samples were taken in conjunction with the collection of monthly glass slides (results can be found in Section 4.4).

The *Littorella* plots and trays of washed stone presented a reproducible means of investigating trends in levels of periphyton collecting on similar submerged surfaces within the lake. That is, the surfaces of the macrophyte *L. uniflora* and inorganic benthic materials around the littoral zone. Results from this work can be found in Sections 4.5 and 4.6.

Sites were visited once every week where upon the water temperature at each location was noted. A record of the fluctuations in the height of the Lough Gill water column was also recorded at each visit. This was taken from a fixed gauge, situated at the Sligo County Council domestic water supply pump house, Tobernalt Bay. These figures along with weather patterns during the course of the study can be found in Appendices II.

In the tables that follow the results from the six sites are presented for each exposure period. These figures are the average results from replicate samples or replicate analysis. The individual data can be found in the appendices. An average lake result for each exposure period is not presented. During each exposure period results from sites were spatially different (see Section 5.3). To present the figures in such a manner would incur bias and be misleading. Over the course of the project exposure periods varied slightly because of sampling logistics and prevailing weather patterns. Data sets with fluctuating exposure periods can not be dependably compared. For this reason data was converted to an average exposure period (30 days). Tables of adjusted data follow the original data set.

4.2 Monthly glass slide results

4.2.1 Introduction

Glass slides were used to determine biomass (which included dry-weight, ash free dry weight and organic matter levels), chlorophyll and algal identification and enumeration. With the exception of algal identification, the above parameters are presented in a similar manner. For example, with periphyton dry weight the first table contains the average dry weight levels obtained from three replicate glass slides (Table 2). These are the results from the six sites around the lake during each exposure period. In order to allow for the small variation in the length of each exposure period all results from monthly glass slides were also adjusted to an average exposure length of 30 days. This data can be found in the second table (Table 3). Temporal trends at each site are then graphed using a retrieval date axis. This is done for the average result and the adjusted result where upon they can be visually compared (Figures 7 and 8).

This layout is used for all glass slide parameters with the exception of algal identification, where a list of algal genera found attached to slides during each period can be seen in Table 12). A breakdown of algal genera and their numbers during each exposure period can be seen in Appendix IV.d. Graphs are not presented for the percentile organic matter figures. The individual replicate results for glass slides are found in Appendix IV. The calculations used to obtain these figures can be seen in Appendix III.

The Autotrophic Indices (AI) for glass slides can be found in Table 13. Figures are calculated for the six sites during each exposure period. The index values are visually presented in Figure 15. AI calculations are described in Figure 40, Appendix III.

The macroinvertebrates found on glass slides over the study period can be found in Table 14. The species and number of grazing snails found on glass slides are detailed in Table 15. A more detailed breakdown of snail species and numbers found at each sample site can be found in Appendix IV.e.

4.2.2 Experimental difficulties

In the results that follow some blank spaces are presented within the tables. These indicate slides being lost during their exposure period. This may be a result of vandalism or turbulence through wind and wave action. Although slides were positioned during December 1997 and January 1998 high rainfall during the latter part of December resulted in the slides and slide holder being submerged to a depth that did not allow retrieval. To compound the problem, work started on the Broken Weir along the Garavogue River at the same time. This was part of the Sligo and Environs Water Supply Scheme. The resulting works impaired the flow of water (Patrick Carty, Site Engineer. pers. comm.). This forced the lake to an extreme height. On completion of this work it is unlikely that the lake will reach this level again.

It was noted during the course of the project that loosely attached algae were lost when the slide holding apparatus was adjusted or moved with moderate force. This was most noticeable during periods of peak growth. This sudden movement would appear to be more damaging than the fluid motion of wind and waves. Loss of some algae appeared to be unavoidable. To reduce loses the slide holder was handled as little as possible. It could only be assumed that the loss of algae was consistent at all sites and levels lost were proportionately small to volumes present.

There were concerns that the periphyton found on glass slides were not comparable with that occurring on the natural substrates of the lake. From visual observations, the peak growth of attached algae in the littoral zone of the lake occurred at the same time as peak growth on the slides. It was assumed that the glass slides were indicative of periphyton trends occurring on the natural substrates around the lake. While a difference between substrate types may occur the glass slides at different sites were spatially comparable. The algal genera found upon the slides were also assumed to be the same as those on natural inert substrates.

The slides did not have a fixed orientation at each site within the lake. Their position in the carousel relative to the sun and wind may influence growth levels. Some slides may have received more shade or wind disturbance than others. During analysis the slides were chosen randomly from the structure, however it must be noted that growth may vary between the eight individual slides. This may have a particular effect on algal identification and enumeration where only one slide was chosen. Chlorophyll and biomass analysis was carried out using three slides.

The standard error interval was estimated on all glass slide data. This estimated the 95% confidence interval from the mean. The small number of replicate glass slides and the subsequent small sample population resulted in a higher standard error. In the case of algal enumeration the standard error between 'Sedgwick-Rafter' field counts was estimated. Again as only three counting slides were used the standard error would be elevated. Standard error values for biomass, chlorophyll and algal enumeration can be found in Sections a, b and c of Appendix IV. Standard error calculations are outlined in Figure 41, Appendix III.

Biomass analysis had a standard error equal or less than the average value. The error decreased as biomass levels increased. With the exception of a few instances chlorophyll levels showed an error that was less than half the average value. The error between 'Sedgwick-Rafter' slides was lower than that of chlorophyll. Algal counts came from one glass slide. Standard error was estimated from replicate total cell count carried out. Clumps of cells that were not homogeneously mixed cased variation in field counts.

4.2.3 Figures and tables

See following pages.

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	g/m²	g/m²	g/m²	g/m²	g/m²	g/m²
1997	March	29	9.6	19.0	17.9	8.1	10.6	1.9
	April	26	7.0	7.1	16.5	3.1	13.8	2.8
	May	35	1.8	10.1	24.6	14.6	9.7	5.1
	June	29	1.8	Slides lost*	5.0	11.8	15.3	1.9
	July	34	1.6	4.7	1.7	2.1	2.8	2.3
	August	35	2.5	2.1	Slides lost*	0.8	1.8	1.1
	September	27	5.3	3.0	3.5	2.0	3.8	2.4
	October	28	1.0	0.8	0.3	1.1	2.8	1.1
	November	28	0.3	0.2	0.3	0.4	0.6	0.7
	December	37	Slides lost due to poor climatic conditions					
1998	January	28	Slides lost due to poor climatic conditions					
	February	27	0.3	1.1	0.9	0.2	0.1	0.1
	March	29	1.8	8.7	11.6	1.4	4.8	3.7
	April	34	27.8	36.0	23.6	33.0	26.5	27.5
	May	28	11.0	14.8	23.2	11.8	8.2	8.8

Table 2: Dry weight levels obtained from glass slides submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
			g/m²	g/m²	g/m²	g/m²	g/m²	g/m²
1997	March	30 days (average exposure length of artificial substrates)	9.9	19.7	18.5	8.4	11.0	2.0
	April		8.1	8.2	19.0	3.6	15.9	3.2
	May		1.5	8.7	21.1	12.5	8.3	4.4
	June		1.9	Slides lost*	5.2	12.2	15.8	2.0
	July		1.4	4.1	1.5	1.9	2.5	2.0
	August		2.1	1.8	Slides lost*	0.7	1.5	0.9
	September		5.9	3.3	3.9	2.2	4.2	2.7
	October		1.1	0.9	0.3	1.2	3.0	1.2
	November		0.3	0.2	0.3	0.4	0.6	0.8
	December		Slides lost due to poor climatic conditions					
1998	January		Slides lost due to poor climatic conditions					
	February		0.3	1.2	1.0	0.2	0.1	0.1
	March		1.9	9.0	12.0	1.4	5.0	3.9
	April		24.5	31.8	20.8	29.1	23.4	24.3
	May		11.8	15.9	24.9	12.6	8.8	9.4

Table 3: Adjusted dry weight levels obtained from glass slides submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Figure 7: Dry weight levels from glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and 1998.

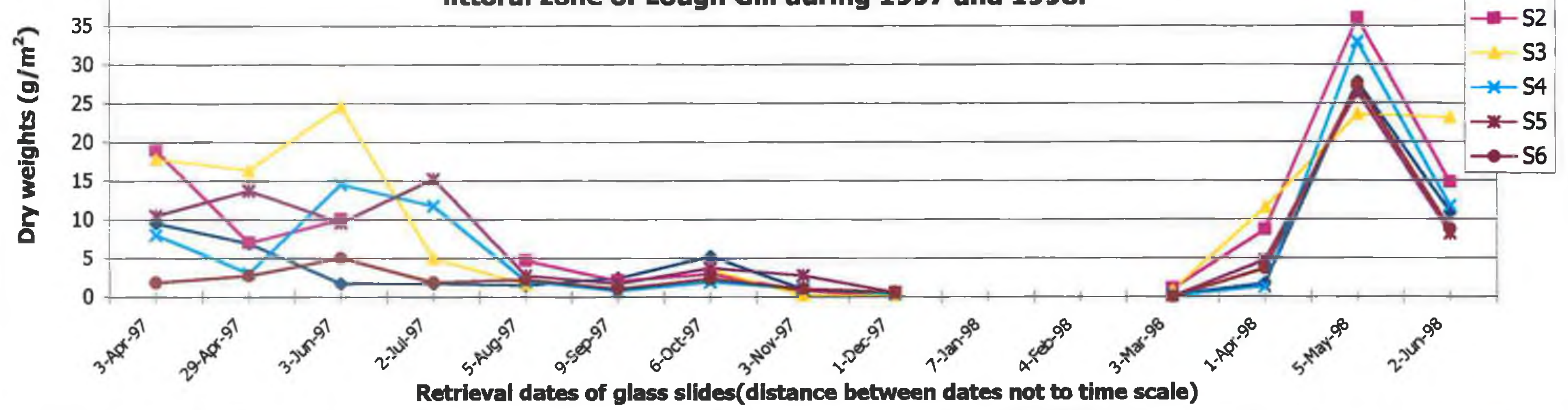
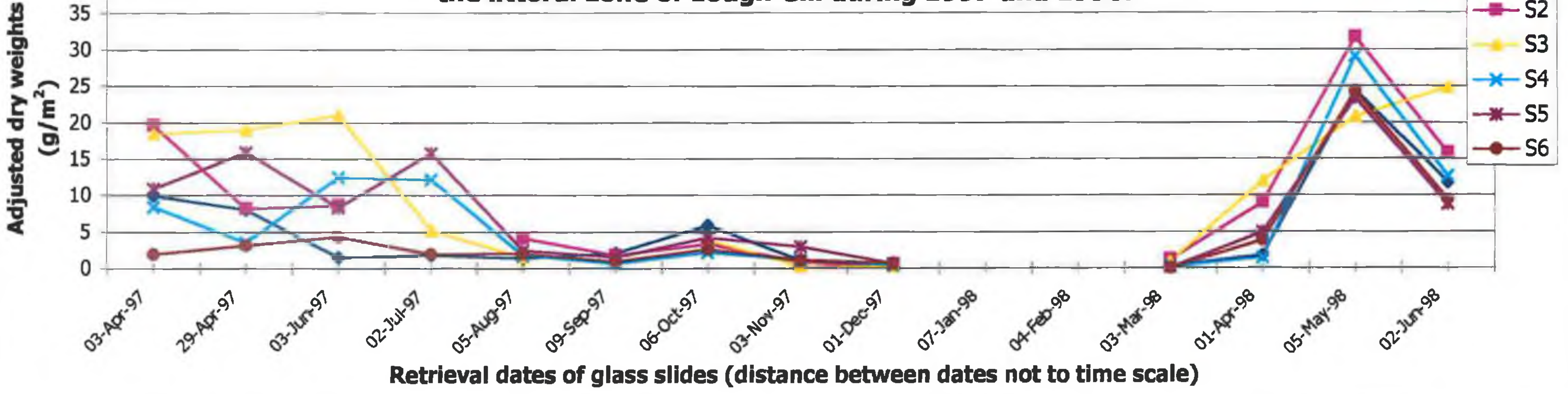


Figure 8: Adjusted dry weight levels from glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and 1998.



Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	March	29	4.0	6.7	7.5	3.6	4.2	1.3
	April	26	2.1	2.6	6.9	1.6	5.5	1.5
	May	35	1.2	5.4	13.8	12.7	4.7	4.0
	June	29	1.1	Slides lost*	3.8	5.5	6.3	1.8
	July	34	1.0	2.6	1.2	1.5	1.6	1.5
	August	35	1.7	1.4	Slides lost*	0.6	1.3	1.0
	September	27	2.4	1.3	2.3	1.4	1.8	2.1
	October	28	0.8	0.7	0.3	1.0	1.6	1.0
	November	28	0.3	0.2	0.3	0.4	0.5	0.6
	December	37	Slides lost due to poor climatic conditions					
1998	January	28	Slides lost due to poor climatic conditions					
	February	27	0.3	0.9	0.7	0.2	0.1	0.1
	March	29	1.2	3.5	6.0	1.2	3.2	2.0
	April	34	12.5	18.8	10.9	15.9	14.8	14.7
	May	28	5.3	8.7	12.7	7.4	4.5	5.7

Table 4: Ash free dry weight (AFDW) levels obtained from glass slides submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vadalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
			g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	March	**30 days** (average exposure length of artificial substrates)	4.1	6.9	7.8	3.7	4.3	1.3
	April		2.4	3.0	8.0	1.8	6.3	1.7
	May		1.0	4.6	11.8	10.9	4.0	3.4
	June		1.1	Slides lost*	3.9	5.7	6.5	1.9
	July		0.9	2.3	1.1	1.3	1.4	1.3
	August		1.5	1.2	Slides lost*	0.5	1.1	0.9
	September		2.7	1.4	2.6	1.6	2.0	2.3
	October		0.9	0.8	0.3	1.1	1.7	1.1
	November		0.3	0.2	0.3	0.4	0.5	0.6
	December		Slides lost due to poor climatic conditions					
1998	January		Slides lost due to poor climatic conditions					
	February		0.3	0.9	0.8	0.2	0.1	0.1
	March		1.3	3.6	6.2	1.2	3.3	2.1
	April		11.0	16.6	9.6	14.0	13.1	13.0
	May		5.7	9.3	13.6	7.9	4.8	6.1

Table 5: Adjusted ash free dry weight (AFDW) levels obtained from glass slides submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

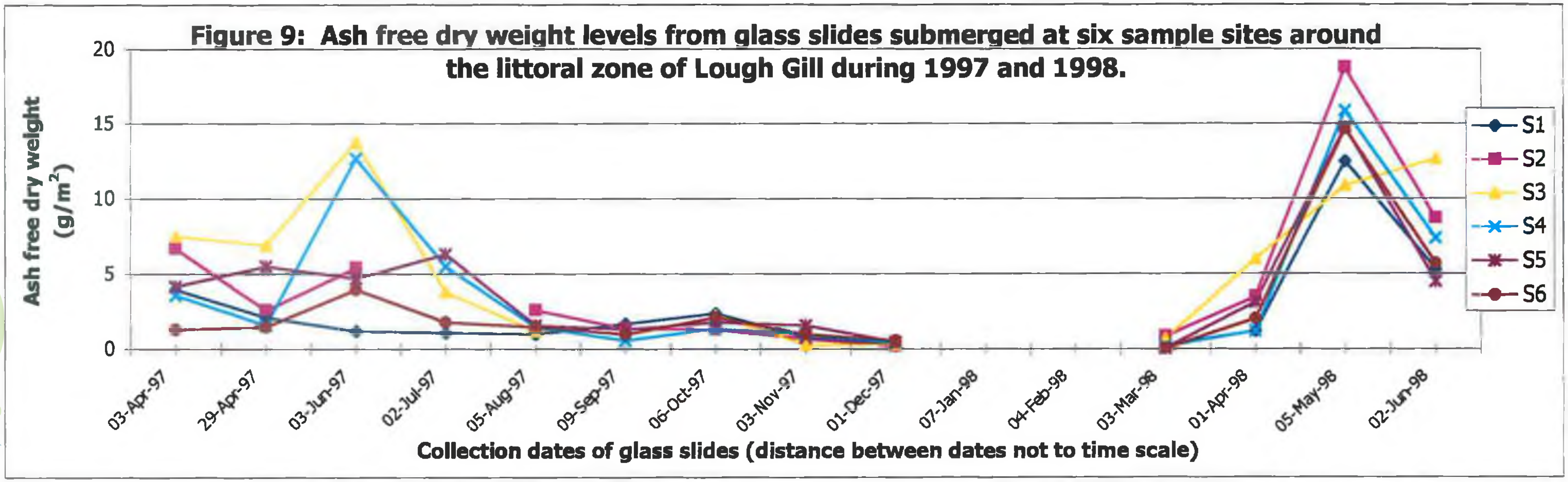


Figure 9: Ash free dry weight levels from glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and 1998.

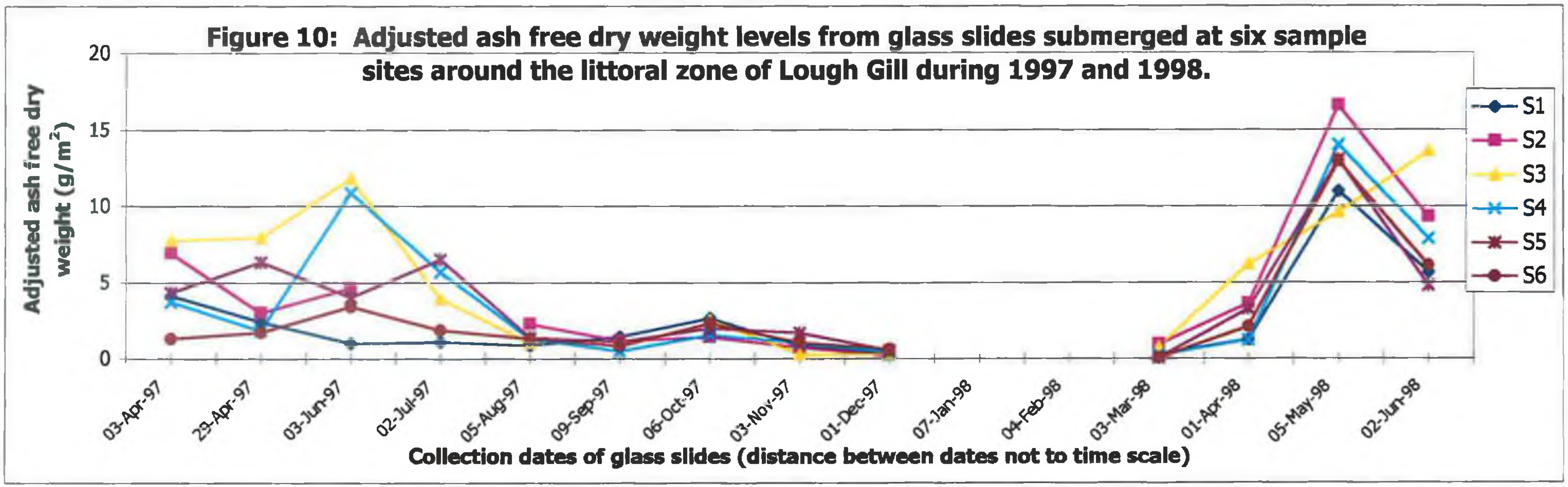


Figure 10: Adjusted ash free dry weight levels from glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and 1998.

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	%	%	%	%	%	%
1997	March	29	41.2	35.1	41.8	44.3	39.8	67.2
	April	26	30.3	36.6	41.9	52.2	39.5	54.1
	May	35	69.8	53.6	56.0	87.0	48.3	78.9
	June	29	64.2	Slides lost*	76.0	46.3	41.5	91.4
	July	34	64.6	54.9	69.2	70.3	56.0	67.6
	August	35	65.8	68.3	Slides lost*	75.0	70.9	90.6
	September	27	45.0	44.0	64.8	72.9	47.8	87.3
	October	28	82.8	91.3	80.0	93.0	58.3	88.2
	November	28	100.0	100.0	100.0	92.3	94.1	95.2
	December	37	Slides lost due to poor climatic conditions					
1998	January	28	Slides lost due to poor climatic conditions					
	February	27	100.0	76.5	81.5	100.0	100.0	100.0
	March	29	67.9	40.2	52.0	83.3	66.0	46.4
	April	34	45.1	52.2	46.3	48.3	55.9	53.6
	May	28	48.5	58.8	54.6	62.8	54.8	65.1

Table 6: Percentage organic matter found attached to glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
			%	%	%	%	%	%
1997	March	30 days (average exposure length of artificial substrates)	42.6	36.3	43.2	45.8	41.2	69.5
	April		35.0	42.2	48.3	60.2	45.6	62.4
	May		59.8	45.9	48.0	74.6	41.4	67.6
	June		66.4	Slides lost*	78.6	47.9	42.9	94.6
	July		57.0	48.4	61.1	62.0	49.4	59.6
	August		56.4	58.5	Slides lost*	64.3	60.8	77.7
	September		50.0	48.9	72.0	81.0	53.1	97.0
	October		88.7	97.8	85.7	99.6	62.5	94.5
	November		100.0	100.0	100.0	100.0	100.8	102.0
	December		Slides lost due to poor climatic conditions					
1998	January		Slides lost due to poor climatic conditions					
	February		100.0	85.0	90.6	100.0	100.0	100.0
	March		70.2	41.6	53.8	86.2	68.3	48.0
	April		39.8	46.1	40.9	42.6	49.3	47.3
	May		52.0	63.0	58.5	67.3	58.7	69.8

Table 7: Adjusted percentage organic matter found attached to glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	mg/m^2	mg/m^2	mg/m^2	mg/m^2	mg/m^2	mg/m^2
1997	March	29	42.0	67.9	75.2	42.1	47.9	5.5
	April	26	27.3	52.8	74.4	14.7	68.1	27.5
	May	35	2.0	43.8	42.1	28.0	50.2	29.6
	June	29	7.1	Slides lost*	31.6	46.7	88.2	5.0
	July	34	8.0	28.9	17.2	19.0	11.2	15.6
	August	35	32.7	14.6	Slides lost*	2.9	8.8	4.8
	September	27	22.1	21.9	23.7	27.6	21.3	23.3
	October	28	7.0	7.8	1.0	7.1	26.9	8.3
	November	28	2.8	0.8	1.3	2.3	8.2	6.4
	December	37	Slides lost due to poor climatic conditions					
1998	January	28	Slides lost due to poor climatic conditions					
	February	27	2.6	7.6	6.0	2.1	0.6	1.0
	March	29	21.1	65.7	35.4	21.0	53.4	57.3
	April	34	36.5	69.6	75.1	55.4	41.3	37.1
	May	28	66.6	70.6	67.9	60.4	52.3	59.8

Table 8: Chlorophyll levels obtained from periphyton growth upon glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
			mg/m²	mg/m²	mg/m²	mg/m²	mg/m²	mg/m²
1997	March	30 days (average exposure length of artificial substrates)	43.4	70.2	77.8	43.6	49.6	5.7
	April		31.5	60.9	85.8	17.0	78.6	31.7
	May		1.7	37.5	36.1	24.0	43.0	25.4
	June		7.3	Slides lost*	32.7	48.3	91.2	5.2
	July		7.1	25.5	15.2	16.8	9.9	13.8
	August		28.0	12.5	Slides lost*	2.5	7.5	4.1
	September		24.6	24.3	26.3	30.7	23.7	25.9
	October		7.5	8.4	1.1	7.6	28.8	8.9
	November		3.0	0.9	1.4	2.5	8.8	6.9
	December		Slides lost due to poor climatic conditions					
1998	January		Slides lost due to poor climatic conditions					
	February		2.9	8.4	6.6	2.3	0.6	1.1
	March		21.8	68.0	36.6	21.7	55.2	59.3
	April		32.2	61.4	66.3	48.9	36.4	32.7
	May		71.4	75.6	72.8	64.7	56.0	64.1

Table 9: Adjusted chlorophyll levels obtained from periphyton growth upon glass slides submerged at six sample sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

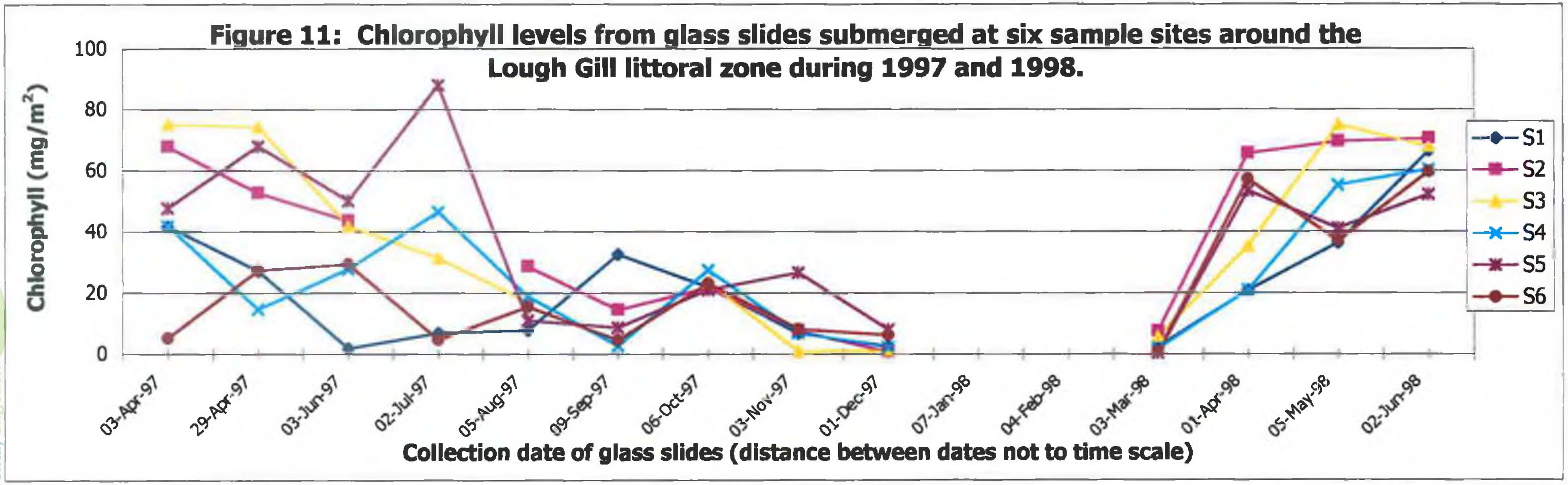


Figure 11: Chlorophyll levels from glass slides submerged at six sample sites around the Lough Gill littoral zone during 1997 and 1998.

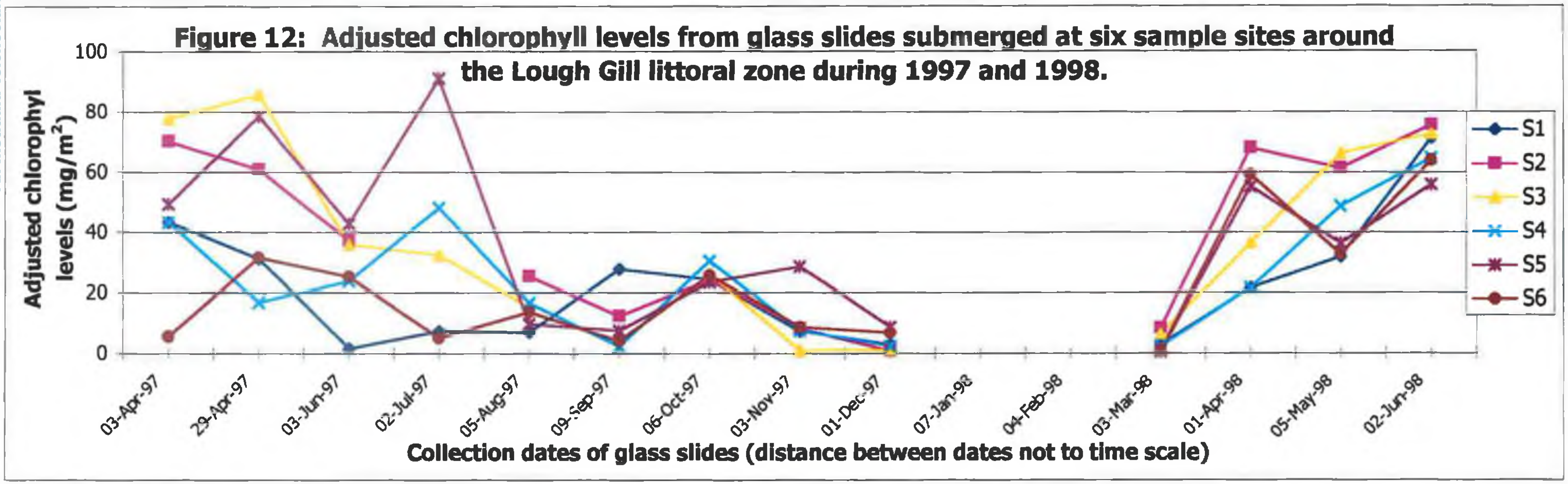


Figure 12: Adjusted chlorophyll levels from glass slides submerged at six sample sites around the Lough Gill littoral zone during 1997 and 1998.

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
1997	March-97	29	1696	8152	9732	5811	4997	1046
	April	26	2736	4341	9191	1883	6034	2507
	May	35	5492	13885	16193	31327	12213	9558
	June	29	2315	Slides lost*	6909	9776	14274	1662
	July	34	1531	5372	4150	3426	2878	5078
	August	35	1474	2733	1705	564	2935	1230
	September	27	4169	2629	5293	3867	4301	4656
	October	28	1133	904	338	782	4181	1076
	November	28	476	124	166	291	841	479
	December	37	Slides lost due to poor climatic conditions					
1998	January-98	28	Slides lost due to poor climatic conditions					
	February	27	329	870	947	420	77	62
	March	29	3026	6779	7373	4300	7928	5515
	April	34	27638	25844	18864	41726	28532	31849
	May	28	13290	15822	12429	20197	6550	9171

Table 10: Periphyton numbers found on glass slides submerged for one month periods at six sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
			cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
1997	March-97	30 days (average exposure length of artificial substrates)	1754	8433	10068	6011	5169	1082
	April		3157	5009	10605	2173	6962	2893
	May		4707	11901	13880	26852	10468	8193
	June		2395	Slides lost*	7147	10113	14766	1719
	July		1351	4740	3662	3023	2539	4481
	August		1263	2343	1461	483	2516	1054
	September		4632	2921	5881	4297	4779	5173
	October		1214	969	362	838	4480	1153
	November		510	133	178	312	901	513
	December		Slides lost due to poor climatic conditions					
1998	January-98		Slides lost due to poor climatic conditions					
	February		366	967	1052	467	86	69
	March		3130	7013	7627	4448	8201	5705
	April		24386	22804	16645	36817	25175	28102
	May		14239	16952	13317	21640	7018	9826

Table 11: Adjusted periphyton numbers found on glass slides submerged for one month periods at six sites around the littoral zone of Lough Gill during 1997 and the first half of 1998. (* = slides vandalised)

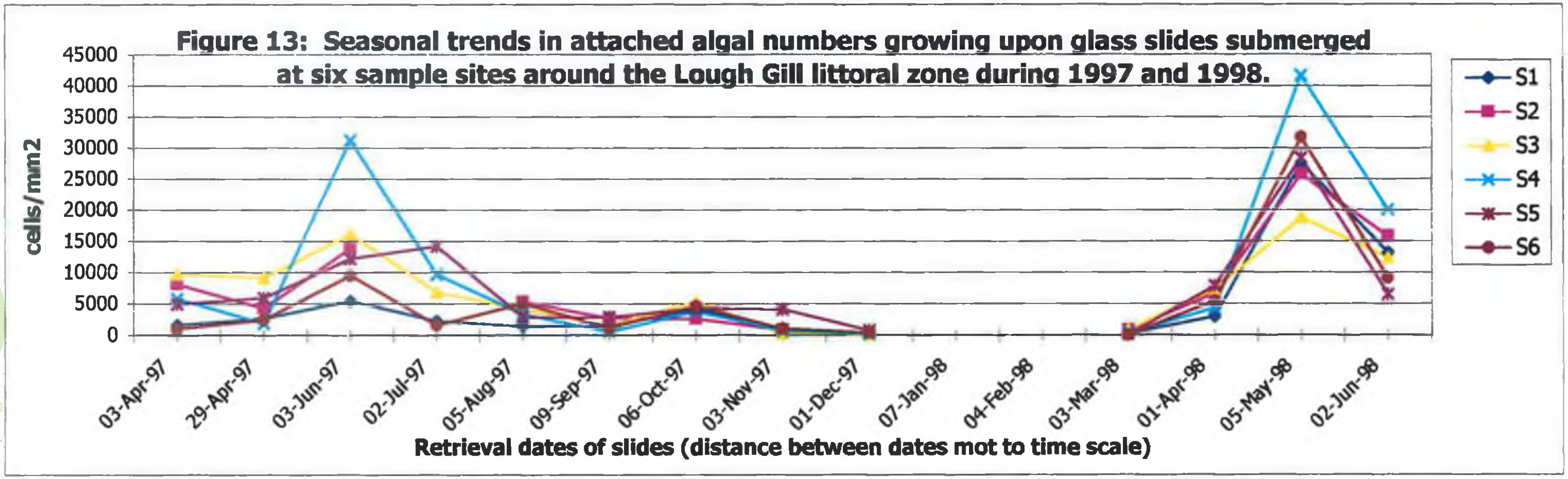


Figure 13: Seasonal trends in attached algal numbers growing upon glass slides submerged at six sample sites around the Lough Gill littoral zone during 1997 and 1998.

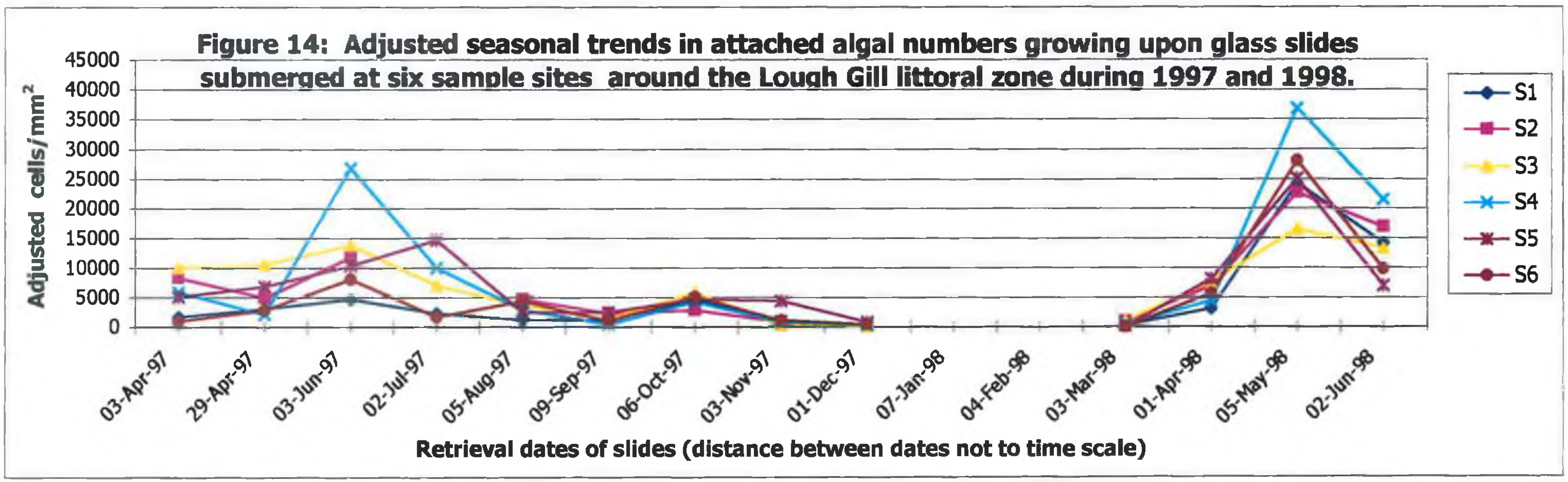


Figure 14: Adjusted seasonal trends in attached algal numbers growing upon glass slides submerged at six sample sites around the Lough Gill littoral zone during 1997 and 1998.

Code:	M1	M2	M3	M4	M5	M6	M7	M8	M9	M12	M13	M14	M15
Exposure period:	March-97	April-97	May-97	June-97	July-97	August-97	September-97	October-97	November-97	February-98	March-98	April-98	May-98
Cyanophyta:				Anabaena	Anabaena	Anabaena	Anabaena						Anabaena
				Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa				
						Aphanothece		Aphanothece					
					Chroococcus								
				Gomphosphaeria	Gomphosphaeria	Gomphosphaeria	Gomphosphaeria		Gomphosphaeria				
				Merismopedia	Merismopedia	Merismopedia	Merismopedia	Merismopedia	Merismopedia				
						Microcystis							
		Oscillatoria	Oscillatoria			Oscillatoria	Oscillatoria					Oscillatoria	Oscillatoria
Chlorophyta:	Ankistrodesmus	Ankistrodesmus										Ankistrodesmus	
	Chaetophora	Chaetophora	Chaetophora	Chaetophora	Chaetophora	Chaetophora	Chaetophora	Chaetophora	Chaetophora				Chaetophora
						Cladophora	Cladophora						
	Microspora	Microspora											
	Oocystis												
												Scenedesmus	Scenedesmus
		Stigeoclonium	Stigeoclonium										Stigeoclonium
												Tetrastrum	
							Ulothrix						
Bacillariophyta:					Achnanthes	Achnanthes	Achnanthes	Achnanthes	Achnanthes		Achnanthes	Achnanthes	Achnanthes
											Amphipleura	Amphipleura	
										Amphora	Amphora	Amphora	Amphora
	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis
												Craticula	
						Cyclotella						Cyclotella	
	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella
	Diatoma	Diatoma	Diatoma	Diatoma		Diatoma	Diatoma		Diatoma		Diatoma	Diatoma	Diatoma
	Fragilaria	Fragilaria	Fragilaria	Fragilaria		Fragilaria	Fragilaria	Fragilaria		Fragilaria	Fragilaria	Fragilaria	Fragilaria
	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema
	Gyrosigma	Gyrosigma	Gyrosigma		Gyrosigma							Gyrosigma	
		Melosira	Melosira	Melosira					Melosira		Melosira	Melosira	Melosira
	Meridion	Meridion	Meridion										
	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula
	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia
	Pinnularia	Pinnularia	Pinnularia			Pinnularia					Pinnularia		
	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia
	Surirella		Surirella	Surirella							Surirella	Surirella	
	Synedra	Synedra	Synedra	Synedra			Synedra	Synedra		Synedra	Synedra	Synedra	Synedra
		Tabellaria				Tabellaria			Tabellaria				Tabellaria
			Zygnema										
Unknowns:			Unknown A							Unknown B	Unknown C		
Genera per month:	17	19	19	16	14	21	18	13	15	10	16	21	18

Table 12: List of algal genera found upon glass slides submerged around the littoral zone of Lough Gill from March 1997 to May 1998.

Year	Sampling period	Exposure period	Sample Site					
			S1	S2	S3	S4	S5	S6
		(no. of days exposed)	AI value	AI value	AI value	AI value	AI value	AI value
1997	March	29	95	99	100	86	88	236
	April	26	77	49	93	109	81	55
	May	35	600	123	328	454	94	135
	June	29	155	Slides lost*	120	118	71	360
	July	34	125	90	70	79	143	96
	August	35	52	96	Slides lost*	207	148	208
	September	27	109	59	97	51	85	90
	October	28	114	90	300	141	59	120
	November	28	107	250	231	174	61	94
	December	37	Slides lost					
1998	January	28	Slides lost					
	February	27	109	112	121	95	105	62
	March	29	58	53	169	57	59	36
	April	34	342	270	145	287	358	396
	May	28	80	123	187	123	86	95

Table 13: Autotrophic Index values from monthly glass slides submerged at six sites around the littoral zone of Lough Gill. Autotrophic calculations detailed in Appendix III. (* = slides vandalised)

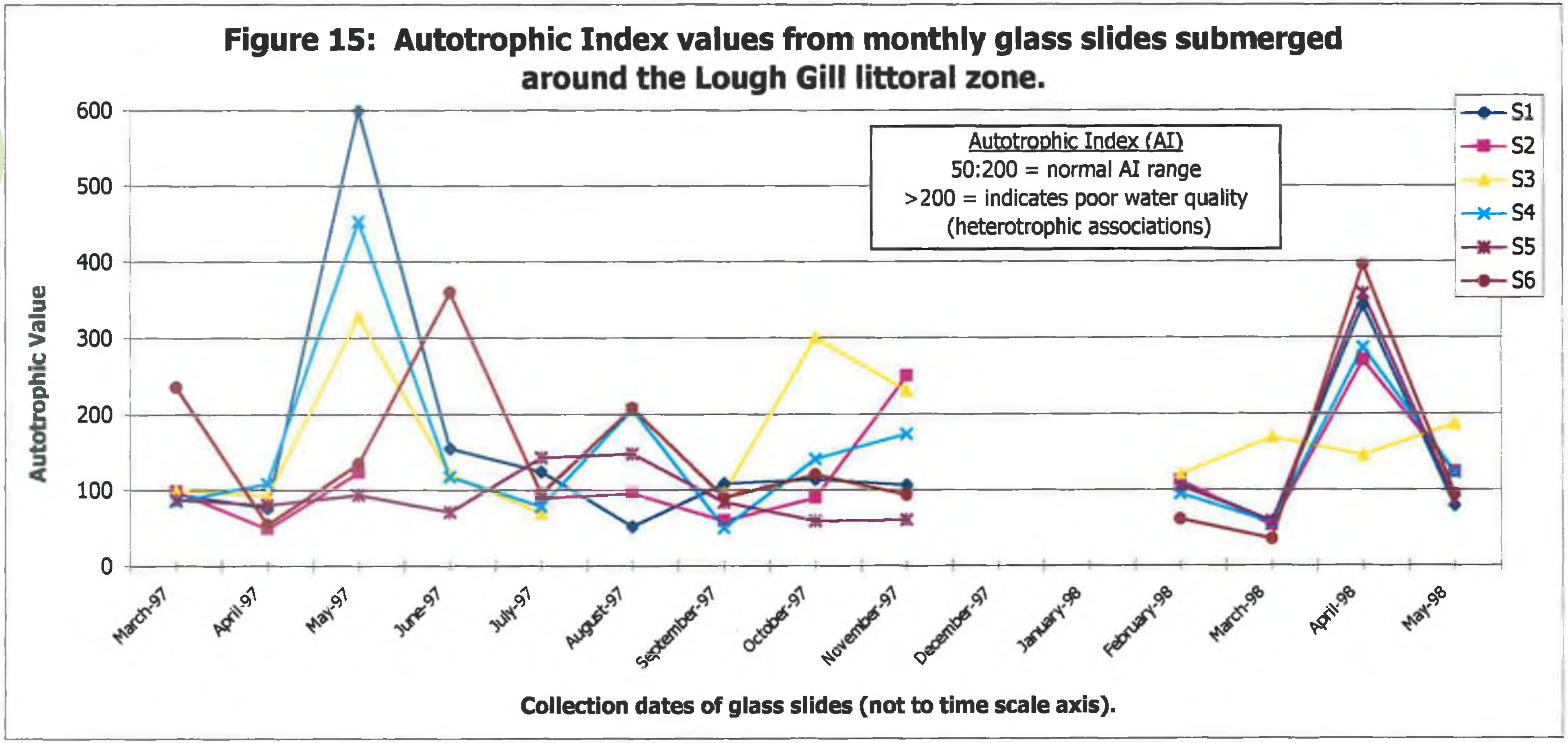


Figure 15: Autotrophic Index values from monthly glass slides submerged around the Lough Gill littoral zone.
Autotrophic Index (AI)
50:200 = normal AI range
>200 = indicates poor water quality
(heterotrophic associations)
Autotrophic Value
600
500
400
300
200
100
0
S1
S2
S3
S4
S5
S6
March-97
April-97
May-97
June-97
July-97
August-97
September-97
October-97
November-97
December-97
January-98
February-98
March-98
April-98
May-98
Collection dates of glass slides (not to time scale axis).

Table 14: Maroinvertebrates found on glass slides submerged within the littoral zone of Lough Gill.

Uniramia:		
	Ephemeroptera	
	Trichoptera	
		Limnephilus sp.
	Diptera	
		Chironomidae
Mollusca		
	Neritidae	*Theodoxus fluviatilis* (Linn.)
	Hydrobiidae	*Potamopyrgus jenkinsi* (Smith)
		Bithynia tentaculata (Linn.)
	Lymnaeidae	*Lymnaea stagnalis* (Linn.)
		Lymnaea peregra (Mull.)
	Physidae	*Physa fontinalis* (Linn.)
	Planorbidae	*Planorbis carinatus* (Mull.)
	Ancylidae	*Ancylus fluviatilis* (Mull)

Species	1997														1998			
	3-Apr	10-Apr	24-Apr	29-Apr	8-May	28-May	3-Jun	12-Jun	2-Jul	5-Aug	9-Sep	6-Oct	3-Nov	1-Dec	3-Mar	1-Apr	5-May	2-Jun
Theodoxus fluviatilis				3		3	3	4		3	3	8	12	11		1	3	13
Potamopyrgus jenkinsi							10		71		7			4				11
Bithynia tentaculata	15	20	12	7	24	22	9	24	15	23	15	22		1		7	17	25
Lymnaea stagnalis							1	2		2					1			1
Lymnaea peregra	7	1	3	1	2	4	5	1		3	19	14	8	9	2	3	12	
Physa fontinalis	1				1						1				1			
Planorbis carinatus											5		2					
Ancylus fluviatilis													1					
Total snails found on slide collection dates:	23	21	15	11	27	29	28	31	86	31	50	44	23	25	4	11	32	50

Table 15: Species of Mollusca found on glass slides submerged around the littoral zone of Lough Gill during 1997 and early 1998.

4.3 Biweekly glass slide results

4.3.1 Introduction

Four sets of glass slides exposed for 2 week periods were positioned at the six sites in conjunction with the monthly glass slides. These were exposed consecutively April to early June 1997 (see placement and retrieval dates, Table 45, Appendix I). They were used to observe periphyton colonisation rates. Results could be compared to monthly slides of that same period. All analysis was identical to that carried out on monthly slides (i.e. biomass, chlorophyll and algal enumeration and identification). Results are tabulated in a similar manner to monthly slide results. Results were also presented in an adjusted format. The adjusted format had an average exposure period of 16 days. A list of algal genera found on the glass slides is also presented (Table 26). The data for biweekly glass slides can be found in Appendix V. The calculations used to obtain these figures can be seen in Appendix III.

4.3.2 Experimental difficulties

As with monthly glass slides, some biweekly slides were lost. This was primarily due to vandalism. Biweekly slides presented problem similar to the monthly slides. Loosely attached algae were noticed on biweekly slides. Again minimum contact with the slides helped to reduce loses. There was concern about the validation of comparing periphyton on natural and artificial substrates. The orientation of slides on the slide holder was a similar problem. The biweekly slide holder was positioned 5 meters to the left of the monthly slide holder. This distance would ensure a minimal effect upon each other. Both apparatus would have the same orientation. Both sets of slides would experience the same physical conditions.

The 95 percent standard error was estimated for biweekly slides. These figures can be found in Appendix V. The standard error is quite comparable with monthly slides.

4.3.3 Figures and tables

See following pages

Table 16: Dry weight levels from glass slides exposed for two week periods.

Year	Sampling period		Exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
	Placement	Retrieval	(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	10-Apr	24-Apr	14	3.8	4.1	3.9	1.0	5.5	2.5
	24-Apr	8-May	14	2.5	16.0	7.5	3.5	7.6	1.6
	8-May	28-May	20	2.2	5.8	7.4	3.4	6.0	3.5
	28-May	12-Jun	15	1.0	Slides lost*	Slides lost*	1.2	3.2	1.9

Table 17: Adjusted dry weight levels from glass slides exposed for two week periods.

Year	Sampling period		Exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
	Placement	Retrieval		g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	10-Apr	24-Apr	**16 days** (average exposure length of bi-weekly glass slides)	4.3	4.7	4.5	1.1	6.3	2.9
	24-Apr	8-May		2.9	18.3	8.6	4.0	8.7	1.8
	8-May	28-May		1.8	4.6	5.9	2.7	4.8	2.8
	28-May	12-Jun		1.1	Slides lost*	Slides lost*	1.3	3.4	2.0

Table 16 and 17: Dry weights and adjusted dry weights obtained from periphyton growth upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill from April to June 1997. (* = slides vadalised)

Table 18: Ash free dry weight levels from glass slides exposed for two week periods.

Year	Sampling period		Exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
	Placement	Retrieval	(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	10-Apr	24-Apr	14	1.6	1.5	1.8	0.7	2.2	1.1
	24-Apr	8-May	14	1.3	6.3	3.3	1.5	3.2	1.0
	8-May	28-May	20	1.2	2.9	3.8	2.7	3.4	2.0
	28-May	12-Jun	15	0.4	Slides lost*	Slides lost*	1.0	1.6	1.8

Table 19: Adjusted ash free dry weight levels from glass slides exposed for two week periods.

Year	Sampling period		Exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
	Placement	Retrieval		g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	10-Apr	24-Apr	**16 days** (average exposure length of bi-weekly glass slides)	1.8	1.7	2.1	0.8	2.5	1.3
	24-Apr	8-May		1.5	7.2	3.8	1.7	3.7	1.1
	8-May	28-May		1.0	2.3	3.0	2.2	2.7	1.6
	28-May	12-Jun		0.4	Slides lost*	Slides lost*	1.1	1.7	1.9

Table 18 and 19: AFDW and adjusted AFDW levels obtained from periphyton growth upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill from April to June 1997. (* = slides vandalised)

Table 20: Percentage organic matter from glass slides exposed for two week periods.

Year	Placement	Retrieval	Exposure period (no. of days exposed)	S1 %	S2 %	S3 %	S4 %	S5 %	S6 %
1997	10-Apr	24-Apr	14	41.6	36.5	45.4	78.0	39.0	46.5
	24-Apr	8-May	14	52.3	39.6	43.8	42.5	41.9	62.5
	8-May	28-May	20	56.1	49.8	51.4	79.9	56.4	58.1
	28-May	12-Jun	15	40.6	Slides lost*	Slides lost*	82.4	50.6	97.7

Table 21: Adjusted percentage organic matter from glass slides exposed for two week periods.

Year	Placement	Retrieval	Exposure period	S1 %	S2 %	S3 %	S4 %	S5 %	S6 %
1997	10-Apr	24-Apr	**16 days** (average exposure length of bi-weekly glass slides)	47.5	41.7	51.9	89.1	44.6	53.1
	24-Apr	8-May		59.8	45.3	50.1	48.6	47.9	71.4
	8-May	28-May		44.9	39.8	41.1	63.9	45.1	46.5
	28-May	12-Jun		43.3	Slides lost*	Slides lost*	87.9	54.0	104.2

Table 20 and 21: Percentage organic matter and adjusted levels obtained from periphyton growth upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill from April to June 1997. (*=slides vandalised)

Table 22: Chlorophyll levels from glass slides exposed for two week periods.

Year	Sampling period: Placement	Sampling period: Retrieval	Exposure period (no. of days exposed)	Sample Site S1 mg/m²	S2 mg/m²	S3 mg/m²	S4 mg/m²	S5 mg/m²	S6 mg/m²
1997	10-Apr	24-Apr	14	19.1	18.3	31.5	2.6	24.8	6.9
	24-Apr	8-May	14	18.3	168.1	45.4	20.7	37.1	12.8
	8-May	28-May	20	7.9	33.3	42.0	13.1	28.8	15.7
	28-May	12-Jun	15	3.0	Slides lost*	Slides lost*	8.8	23.1	9.6

Table 23: Adjusted chlorophyll levels from glass slides exposed for two week periods.

Year	Sampling period: Placement	Sampling period: Retrieval	Exposure period	Sample Site S1 mg/m²	S2 mg/m²	S3 mg/m²	S4 mg/m²	S5 mg/m²	S6 mg/m²
1997	10-Apr	24-Apr	**16 days** (average exposure length of bi-weekly glass slides)	21.8	20.9	36.0	3.0	28.3	7.9
	24-Apr	8-May		20.9	192.1	51.9	23.7	42.4	14.6
	8-May	28-May		6.3	26.6	33.6	10.5	23.0	12.6
	28-May	12-Jun		3.2	Slides lost*	Slides lost*	9.4	24.6	10.2

Table 22 and 23: Chlorophyll and adjusted chlorophyll levels obtained from periphyton growth upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill from April to June 1997. (*=slides vandalised)

Table 24: Periphyton numbers found on glass slides exposed for two week periods.

Year	Sampling period: Placement	Sampling period: Retrieval	Exposure period (no. of days exposed)	Sample Site S1 cells/mm^2	S2 cells/mm^2	S3 cells/mm^2	S4 cells/mm^2	S5 cells/mm^2	S6 cells/mm2
1997	10-Apr	24-Apr	14	1239	2120	3259	415	3972	1148
	24-Apr	8-May	14	1754	9132	8059	5554	5544	1563
	8-May	28-May	20	2509	3720	4489	4744	5166	5932
	28-May	12-Jun	15	693	Slides lost*	Slides lost*	3597	6430	1612

Table 25: Adjusted periphyton numbers found on glass slides exposed for two week periods.

Year	Sampling period: Placement	Sampling period: Retrieval	Exposure period	Sample Site S1 cells/mm^2	S2 cells/mm^2	S3 cells/mm^2	S4 cells/mm^2	S5 cells/mm^2	S6 cells/mm2
1997	10-Apr	24-Apr	**16 days** (average exposure length of bi-weekly glass slides)	1416	2423	3725	474	4539	1312
	24-Apr	8-May		2005	10437	9210	6347	6336	1786
	8-May	28-May		2007	2976	3591	3795	4133	4746
	28-May	12-Jun		739	Slides lost*	Slides lost*	3837	6859	1719

Table 24 and 25: Periphyton and adjusted periphyton numbers found attached to glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill from April to June 1997. (*=slides vandalised)

Code:	W1	W2	W3	W4
	Exposure period:			
Placement date	10-Apr-97	24-Apr-97	8-May-97	28-May-97
Retrieval date	24-Apr-97	8-May-97	28-May-97	12-Jun-97
Phylum	**Genera**			
Cyanophyta:			*Aphanocapsa*	*Aphanocapsa*
			Oscillatoria	*Oscillatoria*
Chlorophyta:		*Ankistrodesmus*		
			Closterium	
		Scenedesmus		
			Stigeoclonium	*Stigeoclonium*
Bacillariophyta:		*Achnanthes*	*Achnanthes*	*Achnanthes*
	Amphora	*Amphora*	*Amphora*	*Amphora*
	Cocconeis	*Cocconeis*	*Cocconeis*	*Cocconeis*
	Craticula			
	Cyclotella	*Cyclotella*		
	Cymbella	*Cymbella*	*Cymbella*	*Cymbella*
	Diatoma	*Diatoma*	*Diatoma*	*Diatoma*
		Fragilaria	*Fragilaria*	*Fragilaria*
	Gomphonema	*Gomphonema*	*Gomphonema*	*Gomphonema*
			Gyrosigma	
	Melosira	*Melosira*	*Melosira*	
	Navicula	*Navicula*		
	Nitzschia	*Nitzschia*	*Nitzschia*	*Nitzschia*
	Pinnularia		*Pinnularia*	
	Rhoicosphenia	*Rhoicosphenia*	*Rhoicosphenia*	
		Surirella	*Surirella*	
	Synedra	*Synedra*	*Synedra*	*Synedra*
				Tabellaria
Unknowns:			Unknown C	
Genera per month:	14	16	19	13

Table 26: List of algal genera found upon glass slides submerged for two week periods at six sample sites around the littoral zone of Lough Gill from April to June 1997.

4.4 Phytoplankton results

4.4.1 Introduction

Phytoplankton samples were taken in conjunction with the collection of monthly glass slides between March 1997 and February 1998. Samples were counted and algal genera identified. Table 27 lists the number of algal cells per millilitre found at the six sites around the lake during the sampling period. The algal genera found in each sample set are listed in Table 28. The numbers of phytoplankton found at each site are illustrated on a time scale axis in Figure 16. The same data is presented with a log scale axis in Figure 17. 'Sedgwick-Rafter' counts can be found in Appendix VI.a. Phytoplankton genera, and numbers per genera for each site and sample set, can be found in Appendix VI.b.

4.4.2 Experimental difficulties

One water sample was used for phytoplankton enumeration. After sedimentation three 'Sedgwick-Rafter' slides were filled. One strip was counted per 'Sedgwick-Rafter' slide. The standard error was estimated between the three 'Sedgwick-Rafter' slides. The standard error along with the cell counts per 'Sedgwick-Rafter' slide can be found in Appendix VI.a. Once again the sample population used to estimate the error was small (3 strip count). This resulted in the confidence interval being nearly as great as the average result in some cases. However the majority of the figures had an error interval less than its own value.

4.4.3 Figures and tables

See following pages.

Year	Sampling date	Sampling code	Sample Site					
			S1	S2	S3	S4	S5	S6
			cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
1997	5-Mar	P1	2547	6404	4248	6885	14243	2356
	3-Apr	P2	1583	45622	47391	55093	56703	22719
	29-Apr	P3	21705	11719	71376	34449	86788	47024
	3-Jun	P4	27147	64214	174933	18630	113270	237798
	2-Jul	P5	45862	58042	112099	110576	70758	63846
	5-Aug	P6	90061	32313	12092	25646	11852	55455
	9-Sep	P7	35887	149091	153122	200644	99713	105143
	6-Oct	P8	150986	161135	186367	87289	45511	101223
	3-Nov	P9	385354	746667	40000	95378	42358	1224583
	1-Dec	P10	89071	100175	35388	53922	89080	37013
1998	7-Jan	P11	24234	15585	17963	6108	19792	5267
	4-Feb	P12	5181	8438	13023	3939	9067	8198

Table 27: Phytoplankton counts from the littoral zone water column at six sites around Lough Gill. Samples taken during 1997 and early 1998.

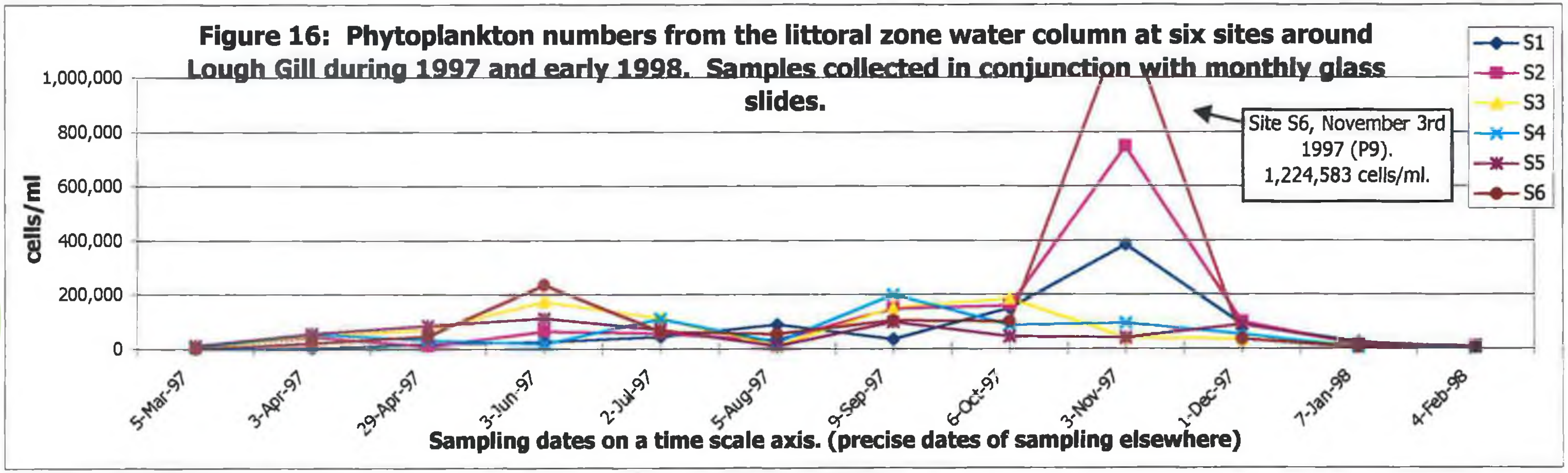


Figure 16: Phytoplankton numbers from the littoral zone water column at six sites around Lough Gill during 1997 and early 1998. Samples collected in conjunction with monthly glass slides.
cells/ml
1,000,000
800,000
600,000
400,000
200,000
0
Site S6, November 3rd 1997 (P9). 1,224,583 cells/ml.
S1
S2
S3
S4
S5
S6
5-Mar-97
3-Apr-97
29-Apr-97
3-Jun-97
2-Jul-97
5-Aug-97
9-Sep-97
6-Oct-97
3-Nov-97
1-Dec-97
7-Jan-98
4-Feb-98
Sampling dates on a time scale axis. (precise dates of sampling elsewhere)

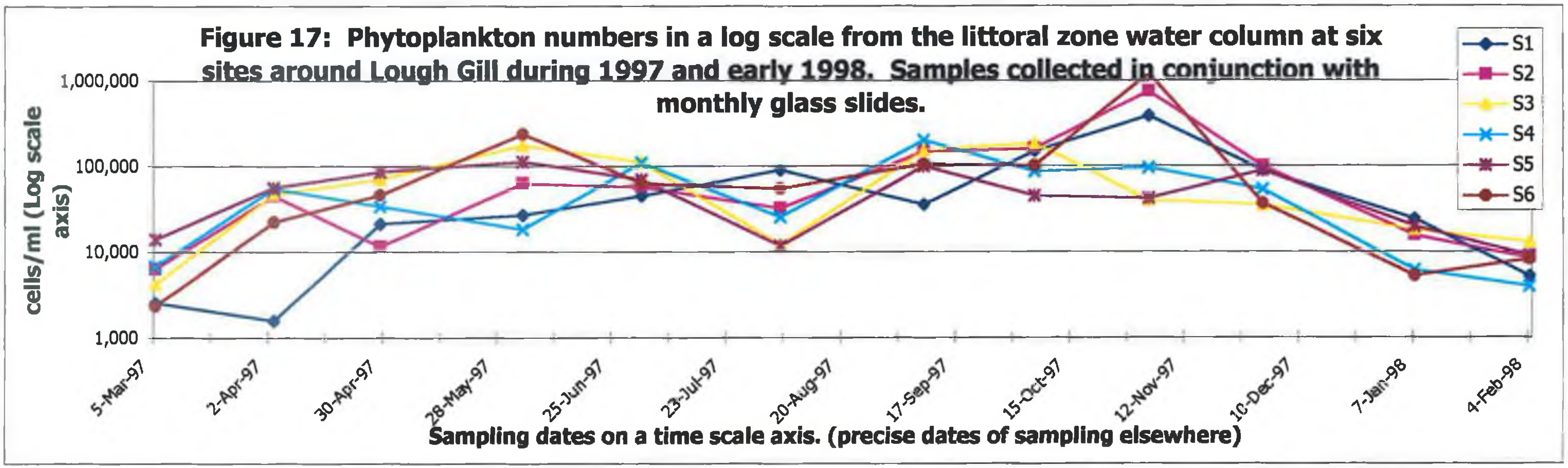


Figure 17: Phytoplankton numbers in a log scale from the littoral zone water column at six sites around Lough Gill during 1997 and early 1998. Samples collected in conjunction with monthly glass slides.
cells/ml (Log scale axis)
1,000,000
100,000
10,000
1,000
S1
S2
S3
S4
S5
S6
5-Mar-97
2-Apr-97
30-Apr-97
28-May-97
25-Jun-97
23-Jul-97
20-Aug-97
17-Sep-97
15-Oct-97
12-Nov-97
10-Dec-97
7-Jan-98
4-Feb-98
Sampling dates on a time scale axis. (precise dates of sampling elsewhere)

Code:	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Sampling date:	5-Mar-97	3-Apr-97	29-Apr-97	3-Jun-97	2-Jul-97	5-Aug-97	9-Sep-97	6-Oct-97	3-Nov-97	1-Dec-97	7-Jan-98	4-Feb-98
Slides collected:		M1	M2	M3	M4	M5	M6	M7	M8	M9		
Cyanophyta:		Anabaena	Anabaena	Anabaena	Anabaena	Anabaena	Anabaena	Anabaena	Anabaena	Anabaena		
				Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa	Aphanocapsa			
				Aphanothece					Aphanothece			
		Chroococcus	Chroococcus	Chroococcus	Chroococcus							
				Cyanothece			Cyanothece					
	Gomphosphaeria			Gomphosphaeria	Gomphosphaeria		Gomphosphaeria	Gomphosphaeria	Gomphosphaeria	Gomphosphaeria	Gomphosphaeria	
			Merismopedia	Merismopedia		Merismopedia		Merismopedia				
				Microcystis		Microcystis	Microcystis	Microcystis	Microcystis			
			Nostoc						Nostoc			
	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria
	Spirulina											Spirulina
Chlorophyta:	Actinastrum	Actinastrum	Actinastrum	Actinastrum			Actinastrum			Actinastrum		Actinastrum
	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus	Ankistrodesmus		
								Asterococcus	Asterococcus			
		Ceratium	Ceratium	Ceratium	Ceratium		Ceratium					
				Chaetophora								
						Characium						
	Chlamydomonas	Chlamydomonas	Chlamydomonas									
						Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis	Closteriopsis
						Closterium						
				Coelastrum	Coelastrum			Coelastrum		Coelastrum		
								Crucigenia				
			Cryptomonas	Cryptomonas	Cryptomonas	Cryptomonas	Cryptomonas		Cryptomonas	Cryptomonas		
					Gloeocystis							
			Gonium									
	Haematococcus	Haematococcus	Haematococcus	Haematococcus	Haematococcus	Haematococcus	Haematococcus					
				Micrasterias			Micrasterias					
					Mougeotia	Mougeotia						
						Oedogonium	Oedogonium					
									Pediastrum			
		Scenedesmus	Scenedesmus		Scenedesmus	Scenedesmus	Scenedesmus	Scenedesmus	Scenedesmus	Scenedesmus	Scenedesmus	
				Spirogyra								
						Staurastrum		Staurastrum				
	Stigeoclonium											
								Tetrastrum	Tetrastrum		Tetrastrum	Tetrastrum
	Volvox	Volvox		Volvox	Volvox	Volvox	Volvox					
Chrysophyta:										Uroglena		Uroglena
Euglenophyta:	Euglena	Euglena		Euglena			Euglena					
Bacillariophyta:			Achnanthes								Achnanthes	
					Amphora	Amphora		Amphora	Amphora	Amphora	Amphora	Amphora
			Asterionella					Asterionella	Asterionella		Asterionella	
	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis	Cocconeis
	Craticula	Craticula		Craticula		Craticula	Craticula	Craticula	Craticula	Craticula		
		Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella	Cyclotella
	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella	Cymbella
	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	Diatoma	
			Epithemia									
	Fragilaria	Fragilaria	Fragilaria	Fragilaria	Fragilaria	Fragilaria	Fragilaria	Fragilaria		Fragilaria		
										Frustulia		
	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema	Gomphonema
		Gyrosigma		Gyrosigma	Gyrosigma		Gyrosigma	Gyrosigma	Gyrosigma	Gyrosigma		
	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira	Melosira
	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula	Navicula
	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	Nitzschia	
	Pinnularia											
	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia	Rhoicosphenia
	Surirella	Surirella	Surirella	Surirella	Surirella		Surirella	Surirella	Surirella	Surirella		Surirella
	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra	Synedra
			Tabellaria									
Unknowns:						Unknown D			Unknown E		Unknown F	
Genera per month:	23	25	29	34	28	30	31	30	30	26	19	16

Table 28: List of algal genera found in phytoplankton samples taken in conjunction with the collection of glass slides during 1997 and early 1998 from the littoral zone of Lough Gill.

4.5 Artificial *Littorella* results

4.5.1 Introduction

Artificial *Littorella* plots were analysed for biomass levels. This includes dry weight, AFDW and percentage organic matter levels. Results are presented in a similar manner to biomass from glass slides. The initial table shows the average results from replicate substrate analysis. This lists the average value found at each of the six sites during each exposure period. Again, the length of exposure period varied slightly and the second table shows adjusted figures to the average exposure length of 30 days. Trends at the six sites over the study period are subsequently charted using a retrieval date axis. Dry weight results are presented first (Tables 29 and 30, Figures 18 and 19), this is followed by AFDW results (Tables 31 and 32, Figures 20 and 21) and finally organic matter (Tables 33 and 34). Biomass data from replicate plots are presented in Appendix VII.

4.5.2 Experimental difficulties

As previously mentioned in Section 3.0 material could be lost when plots are lifted from the lake bed. Great care was taken to place the plots into bags while submersed. This was done with minimal agitation of attached materials. However, it did not work very well and some periphyton was lost. During winter, careful collection proved to be nearly impossible because of the difficulties of working in water of a low temperature. The small plot size ($10cm^2$) and the green colour of the netting made them hard to identify and subsequently their retrieve was very difficult. For these reasons a large number of plots were lost and, subsequently, standard error increased at those sites. During December and January 1998 the above factors, combined with poor weather and work on the Broken Weir, resulted in loss of all plots at the six sites.

The large variation in biomass between plots at each site influenced the increase in replicate plots from three to five. While the standard error decreased with the larger number of plots, the error interval had a notable seasonal pattern. Error levels increased during winter compared with the summer months. The plots' position on the lake bed and increased winter wave action, stirring up sediment, may account for this variation.

4.5.3 Figures and tables

See following pages.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
			(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	February	L1	40	54.6	28.0	42.0	31.0	30.3	32.8
	March	L2	30	66.6	94.3	78.0	51.0	57.5	35.8
	April	L3	34	48.1	75.0	105.0	54.9	68.3	65.1
	May	L4	42	40.7	25.5	29.4	30.4	42.1	45.8
	June	L5	26	30.0	30.0	20.5	29.0	62.2	48.8
	July	L6	27	51.7	31.0	32.0	21.9	30.0	38.7
	August	L7	29	63.0	49.0	36.6	29.4	39.2	31.0
	September	L8	28	49.5	40.7	38.1	23.9	25.3	37.3
	October	L9	28	20.2	24.9	17.5	20.9	19.2	24.2
	November	L10	28	17.6	20.6	14.3	15.7	14.4	20.6
	December	L11	36	Plots lost due to poor climatic conditions					
1998	January	L12	27	Plots lost due to poor climatic conditions					
	February	L13	28	25.8	25.3	22.5	18.1	23.7	27.1
	March	L14	29	49.2	51.7	49.8	33.7	44.3	50.9

Table 29: Dry weight data from plastic *Littorella* plots submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				g/m²	g/m²	g/m²	g/m²	g/m²	g/m²
1997	February	L1	**30 days** (average exposure length of artificial substrates)	41.0	21.0	31.5	23.3	22.7	24.6
	March	L2		66.6	94.3	78.0	51.0	57.5	35.8
	April	L3		42.4	66.2	92.6	48.4	60.3	57.4
	May	L4		29.1	18.2	21.0	21.7	30.1	32.7
	June	L5		34.6	34.6	23.7	33.5	71.8	56.3
	July	L6		57.4	34.4	35.6	24.3	33.3	43.0
	August	L7		65.2	50.7	37.9	30.4	40.6	32.1
	September	L8		53.0	43.6	40.8	25.6	27.1	40.0
	October	L9		21.6	26.7	18.8	22.4	20.6	25.9
	November	L10		18.9	22.1	15.3	16.8	15.4	22.1
	December	L11		Plots lost due to poor climatic conditions					
1998	January	L12		Plots lost due to poor climatic conditions					
	February	L13		27.6	27.1	24.1	19.4	25.4	29.0
	March	L14		50.9	53.5	51.5	34.9	45.8	52.7

Table 30: Adjusted dry weight data from plastic *Littorella* plots submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

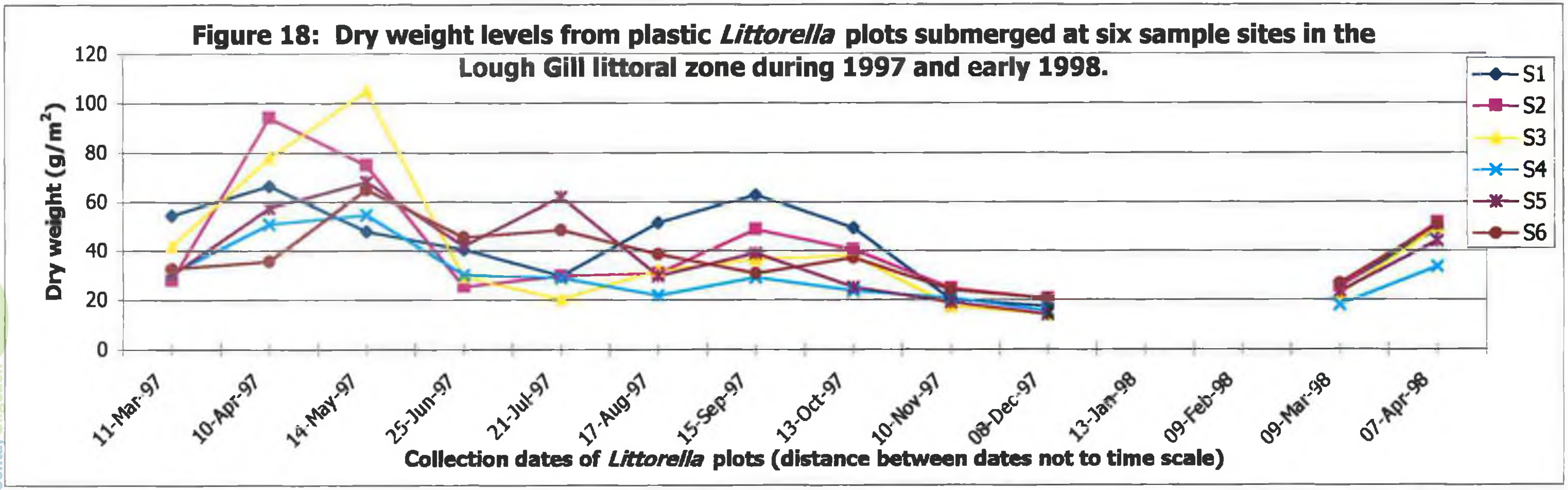


Figure 18: Dry weight levels from plastic *Littorella* plots submerged at six sample sites in the Lough Gill littoral zone during 1997 and early 1998.

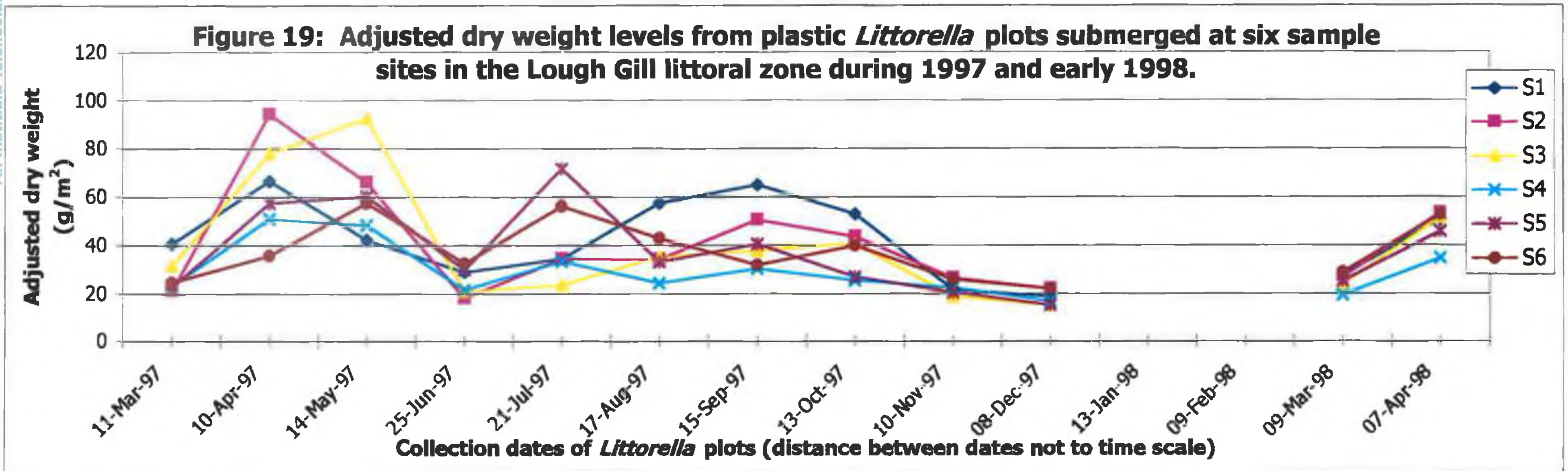


Figure 19: Adjusted dry weight levels from plastic *Littorella* plots submerged at six sample sites in the Lough Gill littoral zone during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
			(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	February	L1	40	14.3	6.3	10.1	7.1	9.2	9.1
	March	L2	30	15.1	21.8	18.1	13.4	17.2	11.3
	April	L3	34	25.6	24.3	30.8	17.3	19.9	20.3
	May	L4	42	10.2	10.8	14.4	14.6	14.3	17.2
	June	L5	26	9.8	12.6	8.8	10.8	18.8	18.4
	July	L6	27	16.7	13.5	11.9	9.6	12.0	15.3
	August	L7	29	15.1	14.2	12.4	10.3	13.2	9.9
	September	L8	28	15.8	15.5	13.5	13.8	9.4	14.4
	October	L9	28	7.1	9.3	6.5	7.4	6.1	11.3
	November	L10	28	6.1	8.8	5.2	6.8	5.8	7.9
	December	L11	36	Plots lost due to poor climatic conditions					
1998	January	L12	27	Plots lost due to poor climatic conditions					
	February	L13	28	6.9	8.2	7.6	8.3	11.0	9.6
	March	L14	29	12.3	19.7	15.4	7.1	14.9	13.7

Table 31: Ash free dry weight (AFDW) from plastic *Littorella* plots submerged for one month periods at six sample sites in the littoral zone of Lough Gill during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				g/m²	g/m²	g/m²	g/m²	g/m²	g/m²
1997	February	L1	30 days (average exposure length of artificial substrates)	10.7	4.7	7.6	5.3	6.9	6.8
	March	L2		15.1	21.8	18.1	13.4	17.2	11.3
	April	L3		22.6	21.4	27.2	15.3	17.6	17.9
	May	L4		7.3	7.7	10.3	10.4	10.2	12.3
	June	L5		11.3	14.5	10.2	12.5	21.7	21.2
	July	L6		18.6	15.0	13.2	10.7	13.3	17.0
	August	L7		15.6	14.7	12.8	10.7	13.7	10.2
	September	L8		16.9	16.6	14.5	14.8	10.1	15.4
	October	L9		7.6	10.0	7.0	7.9	6.5	12.1
	November	L10		6.5	9.4	5.6	7.3	6.2	8.5
	December	L11		Plots lost due to poor climatic conditions					
1998	January	L12		Plots lost due to poor climatic conditions					
	February	L13		7.4	8.8	8.1	8.9	11.8	10.3
	March	L14		12.7	20.4	15.9	7.3	15.4	14.2

Table 32: Adjusted ash free dry weight (AFDW) from plastic *Littorella* plots submerged for one month periods at six sample sites in the littoral zone of Lough Gill during 1997 and early 1998.

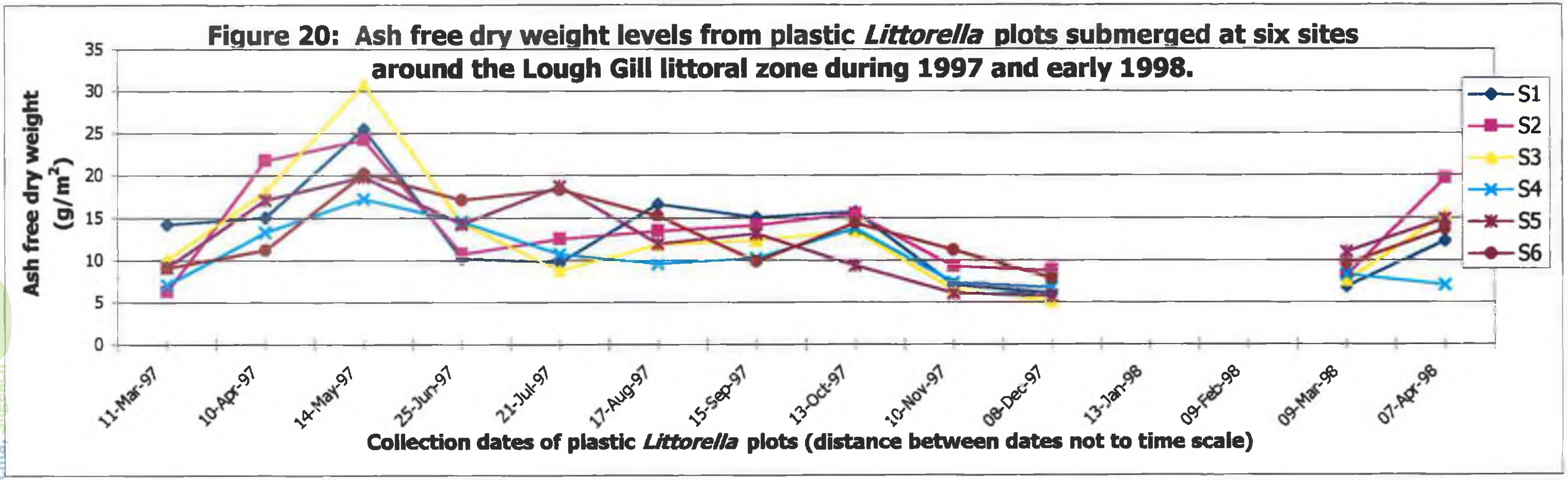


Figure 20: Ash free dry weight levels from plastic *Littorella* plots submerged at six sites around the Lough Gill littoral zone during 1997 and early 1998.

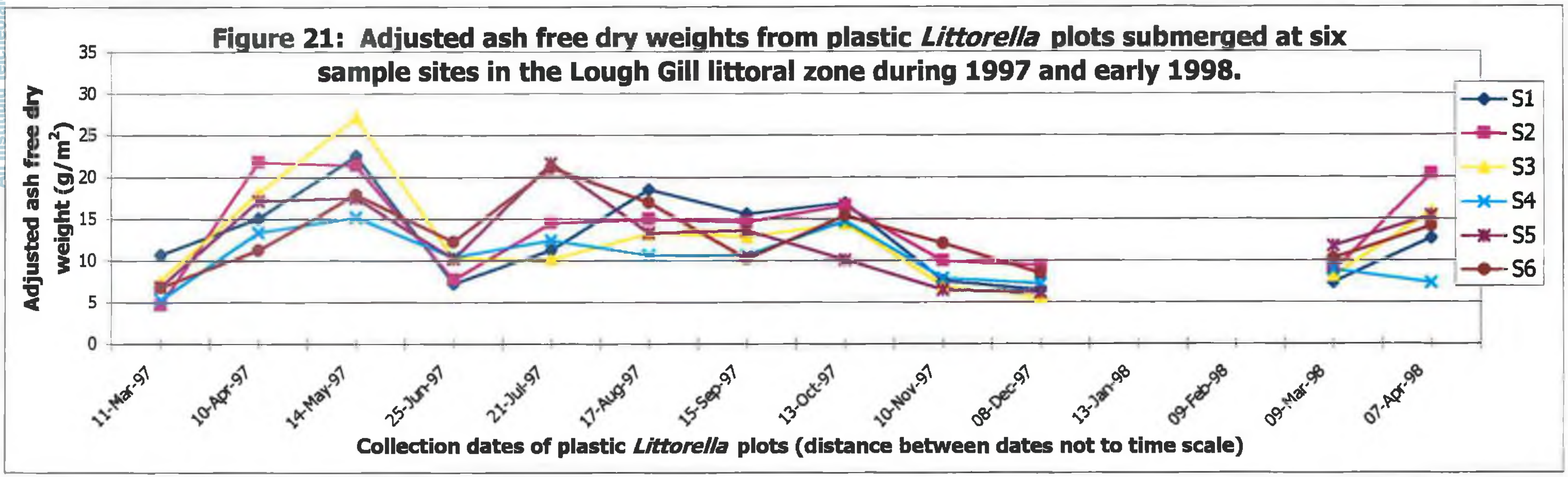


Figure 21: Adjusted ash free dry weights from plastic *Littorella* plots submerged at six sample sites in the Lough Gill littoral zone during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
			(no. of days exposed)	%	%	%	%	%	%
1997	February	L1	40	26.1	22.5	24.0	23.0	30.3	27.8
	March	L2	30	22.7	23.1	23.2	26.3	30.0	31.4
	April	L3	34	53.2	32.4	29.3	31.4	29.2	31.2
	May	L4	42	25.1	42.4	49.0	48.2	33.9	37.5
	June	L5	26	32.5	42.0	42.8	37.4	28.4	38.0
	July	L6	27	32.3	43.4	37.1	43.7	40.1	39.4
	August	L7	29	23.9	29.0	34.0	34.9	33.5	31.9
	September	L8	28	31.9	38.2	35.5	57.7	37.2	38.5
	October	L9	28	35.3	37.2	37.2	35.5	31.5	46.7
	November	L10	28	34.8	42.4	36.5	43.0	39.9	38.1
	December	L11	36	Plots lost due to poor climatic conditions					
1998	January	L12	27	Plots lost due to poor climatic conditions					
	February	L13	28	26.8	32.6	33.6	45.5	46.5	35.3
	March	L14	29	24.9	38.1	30.9	20.9	33.6	26.9

Table 33: Percentage organic matter levels from plastic *Littorella* plots submerged for one month periods at six sample sites around the Lough Gill littoral zone during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				%	%	%	%	%	%
1997	February	L1	30 days (average exposure length of artificial substrates)	19.6	16.9	18.0	17.3	22.7	20.9
	March	L2		22.7	23.1	23.2	26.3	30.0	31.4
	April	L3		46.9	28.6	25.9	27.7	25.8	27.5
	May	L4		17.9	30.3	35.0	34.4	24.2	26.8
	June	L5		37.5	48.5	49.4	43.2	32.8	43.8
	July	L6		35.9	48.2	41.2	48.6	44.6	43.8
	August	L7		24.7	30.0	35.2	36.1	34.7	33.0
	September	L8		34.2	40.9	38.0	61.8	39.9	41.3
	October	L9		37.8	39.9	39.9	38.0	33.8	50.0
	November	L10		37.3	45.4	39.1	46.1	42.8	40.8
	December	L11		Plots lost due to poor climatic conditions					
1998	January	L12		Plots lost due to poor climatic conditions					
	February	L13		28.7	34.9	36.0	48.8	49.8	37.8
	March	L14		25.8	39.4	32.0	21.6	34.8	27.8

Table 34: Adjusted percentage organic matter levels from plastic *Littorella* plots submerged for one month periods at six sample sites around the Lough Gill littoral zone during 1997 and early 1998.

4.6 Washed stone results

4.6.1 Introduction

As with the artificial *Littorella* plots, trays of washed stone were analysed for biomass levels. This included dry weight, AFDW and percentage organic matter levels. Results are laid out in the following order. The first table contains the average biomass levels for the six sites during each exposure period. Again the length of the exposure periods varied slightly. The second table has results adjusted to a 30 day exposure interval. Both sets of data are subsequently illustrated using a substrate retrieval date axis. Dry weight results are presented first (Tables 35 and 36, Figures 22 and 23). This is followed by ash free fry weight results (Tables 37 and 38, Figures 24 and 25) and percentage organic matter data (Table 39 and 40). Washed stone data can be found in Appendix VIII.

4.6.2 Experimental difficulties

The numbers of replicate trays was increased after the first exposure period. This was to reduce the error interval between replicate trays at each of the six sites. It would also decrease the likelihood of losing all trays from a site because of climatic conditions or vandalism.

A large number of trays were lost over the course of the project. Trays were found to be unstable during rough conditions. Wind and wave action lifted the stone plots off the littoral bed. The tray would wash ashore while the contents would be lost. This happened under adverse climatic conditions and most often during the winter months. Only on rare occasions were all trays lost from a site. This ensured a result from each site. However this also increased the standard error interval.

All trays were lost from the December 1997 exposure period. The poor climatic conditions combined with a severe storm late in the month resulted in the loss of most trays. With elevated lake levels the remaining trays proved impossible to retrieve. Spare sets of trays were positioned for January 1998. Such action ensured that results were not also lost during this month.

As with glass slides and *Littorella* plots, the removal of the artificial substrate without loss of some loosely attached algae proved most difficult. Upon lifting the tray from the lake bed filaments of algae detached from the stones and were lost into the water column. Great care was taken to minimise this, however losses were inevitable. As with other artificial substrates losses were primarily during peak growth with greater detachment from more substantial biomass.

The error interval for trays of washed stone was considerable. This was a result of the low sample population (3 to 5 trays exposed during each period) and the loss of trays during these exposure periods. Apart from this, a large variation in results was observed at most sites. This was most pronounced during November 1997 and January 1998. Periphyton levels were very low during this period and wind induced turbulence, lifting substrate materials off the substrate into the trays, may help to account for this error interval.

4.6.3 Figures and tables

See following pages.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
			(no. of days exposed)	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	April	St 1	27	324.3	212.3	1108.5	422.6	932.2	242.2
	May	St 2	33	1717.3	457.6	840.4	131.3	923.4	97.6
	June	St 3	35	347.1	80.8	217.5	332.0	691.0	134.2
	July	St 4	27	255.2	32.9	96.6	44.1	29.2	98.8
	August	St 5	29	647.1	151.0	71.1	73.6	254.2	65.1
	September	St 6	28	36.1	18.4	122.3	23.2	29.0	22.5
	October	St 7	28	43.3	20.2	24.3	9.4	37.9	20.6
	November	St 8	28	41.1	36.3	28.9	18.7	12.3	3.5
	December	St 9	36	No samples collected due to poor climatic conditions					
1998	January	St 10	27	40.6	41.5	5.7	11.1	19.1	12.6
	February	St 11	28	94.6	195.6	Trays lost	31.8	106.5	22.0
	March	St 12	29	139.4	147.0	Trays lost	Trays lost	97.1	49.9
	April	St 13	34	79.6	215.8	49.3	86.3	260.6	51.4

Table 35: Dry weight data from trays of washed stone submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				g/m²	g/m²	g/m²	g/m²	g/m²	g/m²
1997	April	St 1	30 days (average exposure length of artificial substrates)	360.3	235.9	1231.7	469.6	1035.8	269.1
	May	St 2		1561.2	416.0	764.0	119.4	839.5	88.7
	June	St 3		297.5	69.3	186.4	284.6	592.3	115.0
	July	St 4		283.6	36.6	107.3	49.0	32.4	109.8
	August	St 5		669.4	156.2	73.6	76.1	263.0	67.3
	September	St 6		38.7	19.7	131.0	24.9	31.1	24.1
	October	St 7		46.4	21.6	26.0	10.1	40.6	22.1
	November	St 8		44.0	38.9	31.0	20.0	13.2	3.8
	December	St 9		No samples collected due to poor climatic conditions					
1998	January	St 10		45.1	46.1	6.3	12.3	21.2	14.0
	February	St 11		101.4	209.6	Trays lost	34.1	114.1	23.6
	March	St 12		144.2	152.1	Trays lost	Trays lost	100.4	51.6
	April	St 13		70.2	190.4	43.5	76.1	229.9	45.4

Table 36: Adjusted dry weight data from trays of washed stone submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

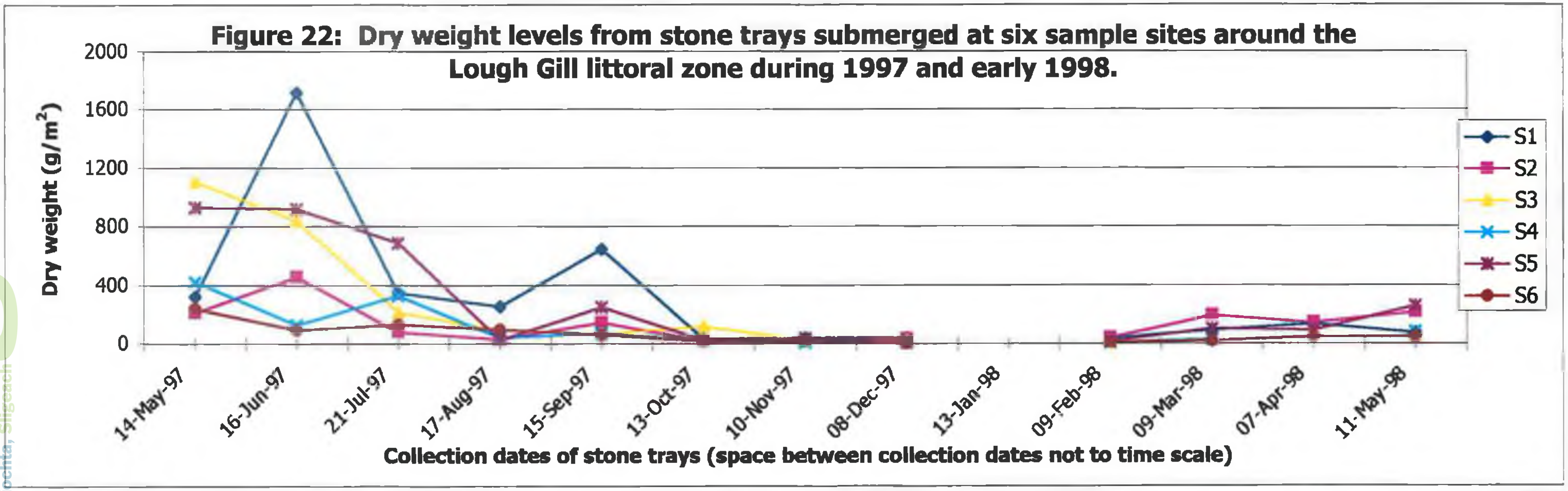


Figure 22: Dry weight levels from stone trays submerged at six sample sites around the Lough Gill littoral zone during 1997 and early 1998.
Dry weight (g/m²)
2000
1600
1200
800
400
0
14-May-97
16-Jun-97
21-Jul-97
17-Aug-97
15-Sep-97
13-Oct-97
10-Nov-97
08-Dec-97
13-Jan-98
09-Feb-98
09-Mar-98
07-Apr-98
11-May-98
Collection dates of stone trays (space between collection dates not to time scale)
S1
S2
S3
S4
S5
S6

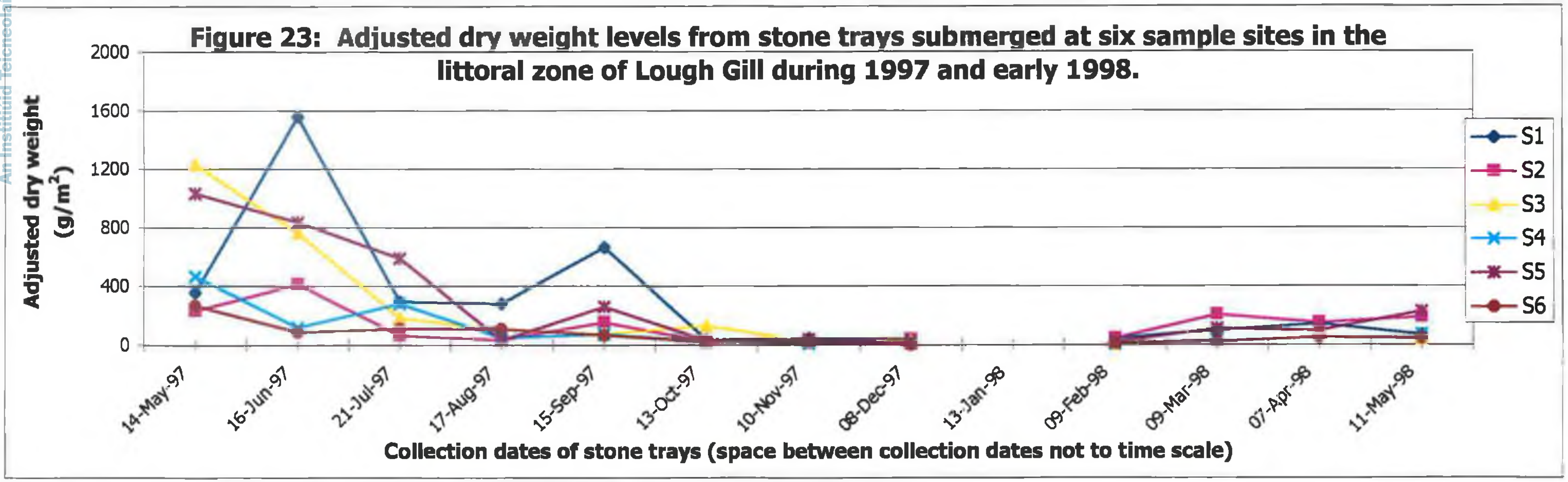


Figure 23: Adjusted dry weight levels from stone trays submerged at six sample sites in the littoral zone of Lough Gill during 1997 and early 1998.
Adjusted dry weight (g/m²)
2000
1600
1200
800
400
0
14-May-97
16-Jun-97
21-Jul-97
17-Aug-97
15-Sep-97
13-Oct-97
10-Nov-97
08-Dec-97
13-Jan-98
09-Feb-98
09-Mar-98
07-Apr-98
11-May-98
Collection dates of stone trays (space between collection dates not to time scale)
S1
S2
S3
S4
S5
S6

Year	Sampling period	Sample code	Avg. exposure period (no. of days exposed)	Sample Site S1 g/m²	S2 g/m²	S3 g/m²	S4 g/m²	S5 g/m²	S6 g/m²
1997	April	St 1	27	20.1	31.0	276.1	21.9	65.4	36.0
	May	St 2	33	50.0	54.0	66.4	15.0	33.6	17.9
	June	St 3	35	18.6	17.8	24.3	28.8	42.6	25.4
	July	St 4	27	16.9	8.0	14.5	14.9	7.1	26.4
	August	St 5	29	33.6	31.9	11.9	12.7	46.4	11.0
	September	St 6	28	3.6	4.4	15.1	4.6	7.1	4.9
	October	St 7	28	4.0	3.1	6.0	2.3	4.9	4.4
	November	St 8	28	4.3	5.8	8.5	4.0	2.2	1.2
	December	St 9	36	No samples collected due to poor climatic conditions					
1998	January	St 10	27	8.8	18.4	1.8	3.1	6.9	5.2
	February	St 11	28	19.4	55.8	Trays lost	8.5	18.1	4.0
	March	St 12	29	30.9	30.5	Trays lost	Trays lost	13.8	10.0
	April	St 13	34	9.7	60.5	14.0	21.8	29.1	11.0

Table 37: Ash free dry weight (AFDW) data from trays of washed stones submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				g/m^2	g/m^2	g/m^2	g/m^2	g/m^2	g/m^2
1997	April	St 1	**30 days** (average exposure length of artificial substrates)	22.3	34.4	306.8	24.3	72.7	40.0
	May	St 2		45.5	49.1	60.4	13.6	30.5	16.3
	June	St 3		15.9	15.3	20.8	24.7	36.5	21.8
	July	St 4		18.8	8.9	16.1	16.6	7.9	29.3
	August	St 5		34.8	33.0	12.3	13.1	48.0	11.4
	September	St 6		3.9	4.7	16.2	4.9	7.6	5.3
	October	St 7		4.3	3.3	6.4	2.5	5.3	4.7
	November	St 8		4.6	6.2	9.1	4.3	2.4	1.3
	December	St 9		No samples collected due to poor climatic conditions					
1998	January	St 10		9.8	20.4	2.0	3.4	7.7	5.8
	February	St 11		20.8	59.8	Trays lost	9.1	19.4	4.3
	March	St 12		32.0	31.6	Trays lost	Trays lost	14.3	10.3
	April	St 13		8.6	53.4	12.4	19.2	25.7	9.7

Table 38: Adjusted ash free dry weight (AFDW) data from trays of washed stones submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

Figure 24: Ash free dry weight levels from stone trays submerged at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

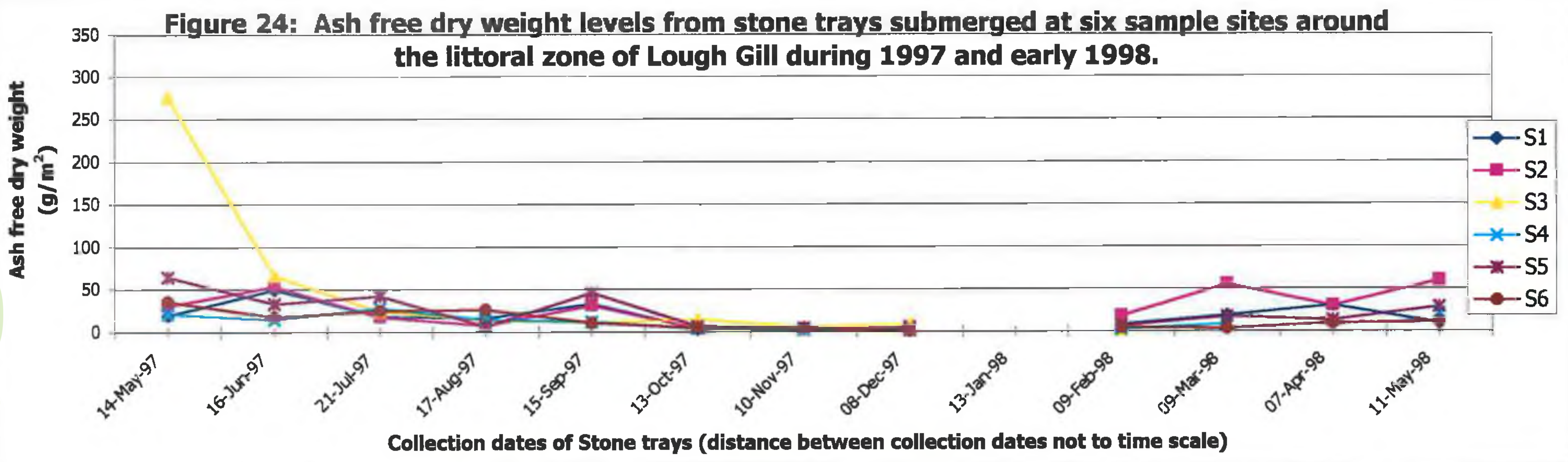
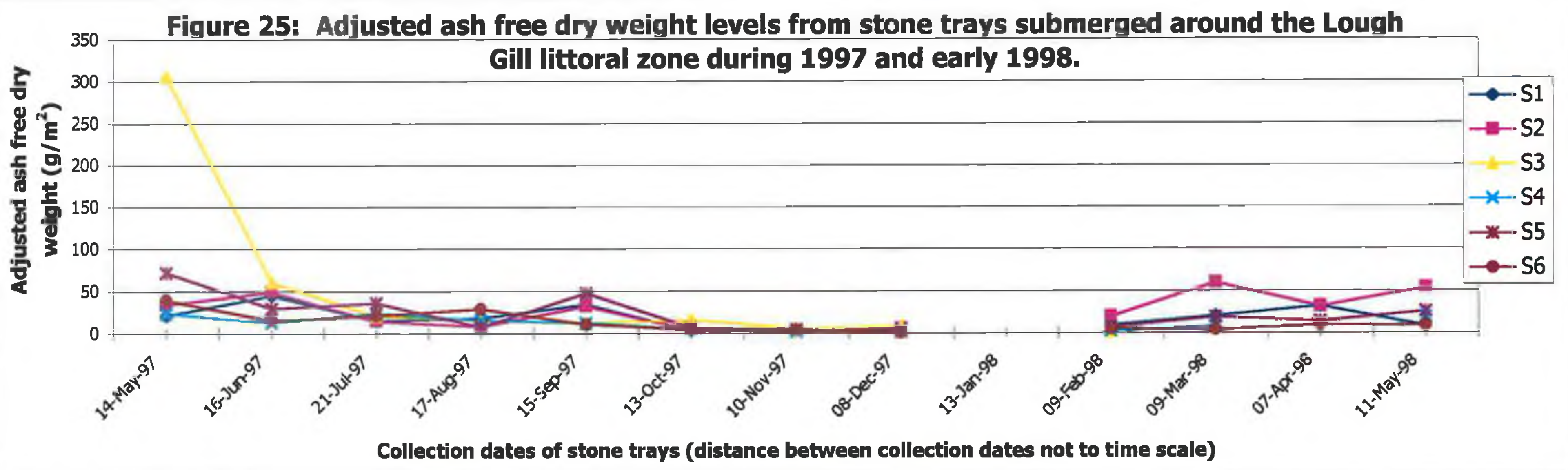


Figure 25: Adjusted ash free dry weight levels from stone trays submerged around the Lough Gill littoral zone during 1997 and early 1998.



Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
			(no. of days exposed)	%	%	%	%	%	%
1997	April	St 1	27	6.2	14.6	24.9	5.2	7.0	14.9
	May	St 2	33	2.9	11.8	7.9	11.4	4.0	18.3
	June	St 3	35	5.4	22.0	11.1	8.7	6.2	18.9
	July	St 4	27	6.6	24.3	15.0	33.8	24.2	26.7
	August	St 5	29	5.2	21.1	16.8	17.3	18.3	16.9
	September	St 6	28	9.9	23.6	12.3	19.7	24.6	21.8
	October	St 7	28	9.2	15.3	24.7	24.6	12.9	21.3
	November	St 8	28	10.5	15.8	29.3	21.4	18.0	33.9
	December	St 9	36	No samples collected due to poor climatic conditions					
1998	January	St 10	27	21.8	44.5	31.0	27.7	35.8	41.7
	February	St 11	28	20.5	28.5	Trays lost	26.6	17.0	18.1
	March	St 12	29	22.1	20.7	Trays lost	Trays lost	14.2	20.0
	April	St 13	34	12.2	28.0	28.4	25.3	11.2	21.4

Table 39: Percentage organic matter found in trays of washed stone submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

Year	Sampling period	Sample code	Avg. exposure period	Sample Site					
				S1	S2	S3	S4	S5	S6
				%	%	%	%	%	%
1997	April	St 1	30 days (average exposure length of artificial substrates)	6.9	16.2	27.7	5.8	7.8	16.6
	May	St 2		2.6	10.7	7.2	10.4	3.6	16.6
	June	St 3		4.6	18.9	9.5	7.5	5.3	16.2
	July	St 4		7.3	27.0	16.7	37.6	26.9	29.7
	August	St 5		5.4	21.8	17.4	17.9	18.9	17.5
	September	St 6		10.6	25.3	13.2	21.1	26.4	23.4
	October	St 7		9.9	16.4	26.5	26.4	13.8	22.8
	November	St 8		11.3	16.9	31.4	22.9	19.3	36.3
	December	St 9		No samples collected due to poor climatic conditions					
1998	January	St 10		24.2	49.4	34.4	30.8	39.8	46.3
	February	St 11		22.0	30.5	Trays lost	28.5	18.2	19.4
	March	St 12		22.9	21.4	Trays lost	Trays lost	14.7	20.7
	April	St 13		10.8	24.7	25.1	22.3	9.9	18.9

Table 40: Adjusted percentage organic matter found in trays of washed stone submerged for one month periods at six sample sites around the littoral zone of Lough Gill during 1997 and early 1998.

5.0 Discussion

5.1 Introduction

Artificial substrates were used to study the seasonal growth patterns and biomass of periphyton around the littoral zone of Lough Gill. As stated in the aims of the project, the analysis was required to get an insight into the volumes and distribution of the attached material identifying its major constituents. This is to give a better picture about the processes occurring in the lakes' littoral zone. It also identifies what part periphyton plays in the trophic state of Lough Gill and how the lake compares with similar studies done nationally.

In order to obtain this information three different types of artificial substrates were exposed at six sites around the littoral zone of the lake. These were glass slides, trays of washed stones and artificial plots simulating the macrophyte *Littorella uniflora*. These substrates were representative of different submerged surfaces within the waters of the lake. Temporal and spatial trends in attached periphyton were identified over the 16-month study period. The influence of site location, its physical features and orientation to prevailing wind and other weather patterns was examined.

Comparison of growth levels on the three substrates provided information not only on the suitability of artificial materials, but also on the influence of the substrate and the variations in natural periphyton growth. The practical application of different artificial substrates was assessed with regard to the type of substrate used, its surface texture, position in the waterbody and ease of sampling. Phytoplankton samples taken in conjunction with the collection of monthly glass slides provided information on the effect of weather patterns inducing periphyton re-suspension. A comparison of attached and free floating algal species with prevailing weather conditions indicated the potential effects of the periphyton mat on water clarity. As well as investigating the effects of periphyton on water clarity, limited aspects of its influence on the flora and fauna of a waterbody was also pursued. This is with particular reference to submerged macrophytes and aquatic macroinvertebrates around the shores of the lake.

This work furthers the use of periphyton as a means of monitoring the trophic state of a waterbody. As one of the most comprehensive Irish periphyton studies (attached to artificial substrates) results may be beneficial in assessing the application of such a monitoring method to the lakes of Ireland.

5.2 Temporal variations in periphyton levels

5.2.1 Monthly glass slides

Glass slides held in an apparatus (see Figure 6, Section 3) were exposed for approximately one-month periods from March 1997 to May 1998. The length of the exposure period varied from month to month, averaging out to a 30-day interval (placement and retrieval dates are presented in Table 44, Appendix I). The following analysis was carried out; dry weight, ash free dry weight, chlorophyll estimation and periphyton enumeration and identification.

With exposure periods varying slightly from month to month average site results from the above analysis were adjusted to a common 30-day exposure period (see Section 4.1). When the data and the adjusted data are graphed side by side very little variation is observed. Figures 7 and 8 compare the dry weight and adjusted dry weight levels from glass slides over the study period. The adjusted time frame has the effect of increasing or reducing dry weight levels during months when the exposure period varies from the mean 30 day average. Dry weight and ash free dry weight peaks decreased during May 1997 and April 1998 when adjusted because of their long 35 and 34-day exposure periods. The reverse occurred during April 1997 when a 26-day exposure period resulted in analysis levels being increased. Visually the plotted data appears to be quite similar (see Figures 7 and 8 and Figures 9 and 10).

5.2.1.1 Temporal dry weight trends

From Figure 7 it can be seen that considerable growth occurred during the first month of the study (March 1997). This growth pattern extended on to June 1997 before biomass slowed over the remaining summer months. Previous to March 1997 trial slides and natural substrates showed no indication of periphyton biomass. It was assumed that the March 1997 slides caught the start of this growth pulse. Growth of periphyton during March 1997 ranged from 1.9 g/m^2 in Tobernalt Bay (site S6) to 19.0 g/m^2 in Corwillick (site S2). A similar range was seen during June 1997 (see Table 2, Section 3). Levels tapered off during July 1997 with the lowest dry weight of the summer occurring in August. A notable increase in biomass during September 1997 can be seen in Figures 7 and 8. Following this small pulse dry weight during October and November 1997 dipped to less than 1.0 g/m^2 (see Table 2). Such growth trends during spring and autumn concur with seasonal diatom patterns as described in the literature.

Glass slides were lost due to bad weather for both December 1997 and January 1998. Periphyton growth patterns seen on rocks during this period were not observed to change. A comparison of adjusted dry weight from November 1997 and February 1998 shows no greater than 1.0 g/m^2 between the two exposure periods at any one site (see Table 3). It is assumed that growth stayed consistently low during this time. Periphyton levels subsequently increase after the winter of 1997/1998 with growth patterns corresponding to the same spring pulse observed twelve months previously.

Spring growth during 1997 was reasonably consistent from March to May with biomass levels in Sriff Bay (site S3) peaking at 24.6 g/m^2 during May (21.1 g/m^2 adjusted dry weight). Similar growth pulses were observed in the spring 1998 just before the study ended. However, dry weight patterns differed during these periods. March 1998 had lower growth levels compared with the previous year but in the following month of (April 1998) the most intense growth of the 15-month study took place. Dry weight levels ranged from 23.6 g/m^2 in Sriff Bay (site S3) to 36.0 g/m^2 in Corwillick (site S2) (20.8 g/m^2 to 31.8 g/m^2 adjusted dry weight). During the final month of the project (May 1998) dry weight levels dropped but were still marginally higher than the same period twelve months previously. Overall, biomass levels during spring 1998 were higher than in Spring 1997. A continuation of this trend from year to year would point towards a system becoming enriched.

5.2.1.2 Temporal ash free dry weight trends

As one would expect ash free dry weight (AFDW) levels from glass slides, indicating the organic content of the periphyton mat, are quite comparable with dry weight levels. Figures 9 and 10 suggest that there is little difference between AFDW and adjusted AFDW. Growth from March 1997, ranging from 1.3 g/m^2 to 7.5 g/m^2 (1.3 g/m^2 to 7.8 g/m^2 adjusted AFDW), stayed high until June 1997 (see Tables 4 and 5). During this time, growth peaked during May (Sriff Bay and Whites' Bay had AFDW levels of 13.8g/m^2 and 12.7g/m^2 respectively). As with dry weights, periphyton growth dropped to a low level during August 1997 before increasing marginally in September. During this month AFDW ranged from 1.3 g/m^2 to 2.4 g/m^2 (1.6 g/m^2 to 2.7 g/m^2 adjusted AFDW).

AFDW and adjusted AFDW were less than 1.0 g/m^2 during November 1997 and February 1998. It was assumed that periphyton growth during December 1997 and January 1998, when both sets of samples were lost, are comparable with the months before and after.

Again, trends in organic material collected on glass slides during the spring 1998 were similar to dry weight. Growth increased sharply between February and March 1998 (see Figures 7 and 9) when AFDW ranged from 0.1 g/m^2 to 0.9 g/m^2 during February (0.1 g/m^2 to 0.9 g/m^2 adjusted AFDW) and from 1.2 g/m^2 to 6.0 g/m^2 during March (1.3 g/m^2 to 6.2 g/m^2 adjusted AFDW). Again organic matter levels during April 1998 were the highest of the 15 month study with AFDW ranged from 10.9 g/m^2 to 18.8 g/m^2 (11.0 g/m^2 to 13.6 g/m^2 adjusted AFDW). The following month (May 1998) levels dropped to a value similar to those seen twelve months previously.

In Table 6 the proportion of organic matter in the periphyton on glass slides went up from approximately 40% during March and April 1997 (April 1997 ranged from 30.3% to 54.1%) to 60% during July (54.9% to 70.3% organic matter). The lower organic content coincides with the spring periphyton pulse. As the pulse dissipates over the summer the percentage organic matter increases. Levels again decrease in time with the September periphyton pulse. Low organic content of the periphyton mat would appear to coincide with periphyton growth and may be explained by the high diatom content of the mat. The frustule of the diatom is made of inert silica which remain even after exposure to temperatures exceeding 500°C (silica was observed in ashed periphyton during the course of the study).

80% of the periphyton mat during the winter of 1997/1998 was organic in nature (see Table 6). This would indicate that the majority of the material collected on the slides (>1.1 g/m^2 dry weight) was associated with organic particles suspended in the water column attaching to slides during the course of the exposure period. With the spring bloom of 1998 percentage organic content again decreased. Adjusted organic matter levels show a similar trend with little deviation from the original figures.

5.2.1.3 Temporal trends in chlorophyll

From Figures 11 and 12 it can be seen that chlorophyll levels varied considerably over the 15 months of the study. Levels ranged from 0.8 mg/m^2 at Corwillick (site S2) during November 1997 (0.9 mg/m^2 adjusted chlorophyll) to 88.2 mg/m^2 at Bunowen Bay (site S5) in June 1997 (91.2 mg/m^2 adjusted chlorophyll) (see Tables 8 and 9). Chlorophyll can be very unstable and its precarious nature prior to and during analysis was quite obvious from the erratic results throughout the study. Overall temporal trends in chlorophyll were comparable with those of dry weight and AFDW levels from the same glass slides (see Figures 8, 10 and 12). Increased chlorophyll content within the periphyton mat again coincides with spring and autumn blooms.

Chlorophyll trends during the spring of 1997 and 1998 different from dry weight and AFDW. Temporal biomass and chlorophyll trends during the spring 1997 extend from March into July. However chlorophyll levels during April 1998 do not correspond with the exceptional levels of biomass and are more comparable with the results from spring 1997 (see Table 8). Chlorophyll during March 1998 ranged from 21.0 mg/m^2 to 65.7 mg/m^2 (21.7 mg/m^2 to 68.0 mg/m^2 adjusted chlorophyll levels) with April 1998 going from 36.5 mg/m^2 to 75.1 mg/m^2 (32.2 mg/m^2 to 61.8 mg/m^2 adjusted chlorophyll levels). While biomass may indicate the weight of all attached materials, including live and dead algal cells, chlorophyll only estimates the pigment content of live algae. The failure of chlorophyll to concur with elevated biomass during April 1998 may imply that periphytic algal populations reach a plateau beyond which live cell numbers do not increase.

5.2.1.4 Temporal trends in periphyton numbers

Cell numbers per month are presented in Table 10 with adjusted figures in Table 11. As was expected periphyton numbers show seasonal blooms during the spring and autumn. Trends in numbers and adjusted numbers, which are presented in Figures 13 and 14, are seen show quite little variation. During March 1997 numbers ranged from 1,046 $cells/mm^2$ to 9,732 $cells/mm^2$ (1,082 to 10,068 $cells/mm^2$ adjusted cell numbers) before increasing during April 1997 and peaking through May, when cells ranged from 5,492 to 31,327 $cells/mm^2$ (adjusted numbers raged from 4,707 to 26,852 $cells/mm^2$). Numbers subsequently decreased over the summer, with a slight elevation in September, before dropping to a winter low from November 1997 onwards (see Tables 10 and 11). Cell numbers were below 1,000 cells/mm^2 during November 1997 and February 1998 (adjusted cell numbers peaked at 1,052 cells/mm^2 in Whites Bay). With no results obtained during December 1997 and January 1998 it is assumed that populations were also below 1,000 cells/mm^2 for that time.

After the winter, March 1998 saw a dramatic increase in periphyton numbers with cells ranging from approximately 3,000 to 8,000 cells/mm^2. However cell numbers exploded during April with cell densities varying from approximately 19,000 to 42,000 cells/mm^2 (see Figures 13 and 14) with adjusted cell numbers ranging from approximately 16,500 to 37,000 cells/mm^2. Cell numbers (like biomass levels) during April 1998 were the highest of the study and after observations over two spring growth pulses it would appear that periphyton levels are increasing over time. A continuation of this trend would indicate a waterbody undergoing increased nutrient enrichment.

5.2.1.5 Temporal trends in periphyton genera

Periphytic algae found on glass slides at the six sites around the littoral zone of Lough Gill consisted of three phyla; those were Cyanophyta, Chlorophyta and Bacillariophyta. From Table 12 it can be seen that the diversity of diatoms (Bacillariophyta) attached to glass slides is substantially greater than blue/green (Cyanophyta) and green algae (Chlorophyta). It is these diatoms that are responsible for the spring and autumn periphyton pulse. Figures 26, 27 and 28 clearly shows the dominance of these diverse diatoms, accounting for over 70% of the entire periphyton mat even when the spring bloom gives way during the summer months.

Table 12 shows the increasing diversity of cyanophytic genera from June 1997 to November 1997. Chlorophyta diversity decreased from four genera during April and May 1997 to just *Chaetophora* and *Cladophora*, both filamentous in nature. These were the only green algae found on slides during the rest of the summer. Desmids such as *Ankistrodesmus* and *Scenedesmus* are typically found only in spring. Diatoms, as mentioned, are the most diverse group having the largest number of genera and the greatest cell density during the spring bloom. Genera such as *Cocconeis*, *Cymbella*, *Gomphonema*, *Navicula*, *Nitzschia* and *Rhoicosphenia* were present throughout the study

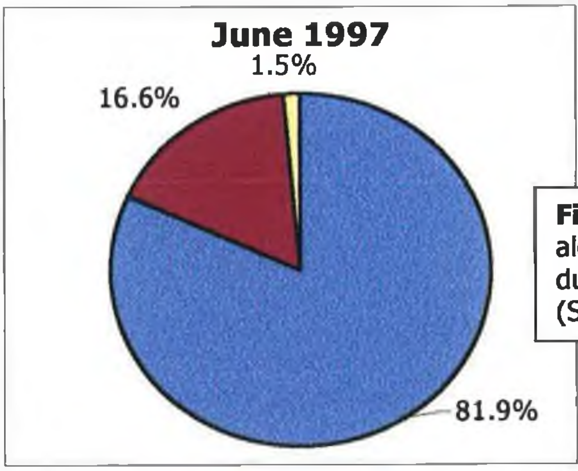


Figure 26: Breakdown of algal phyla found upon slides during June 1997 (M4). (Same legend as Figure 27)

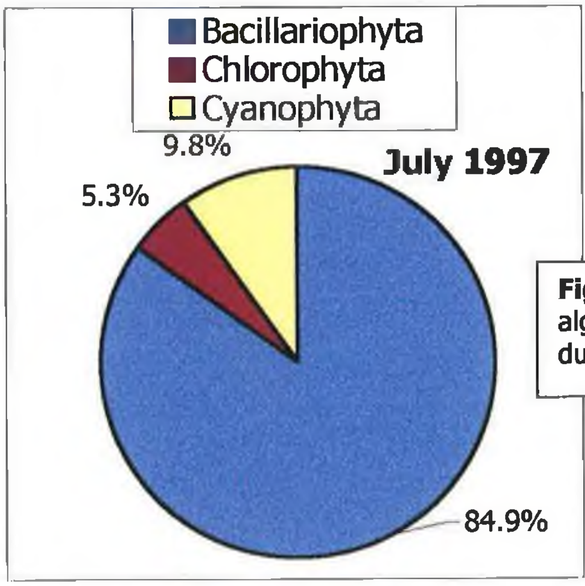


Figure 27: Breakdown of algal phyla found upon slides during July 1997 (M5).

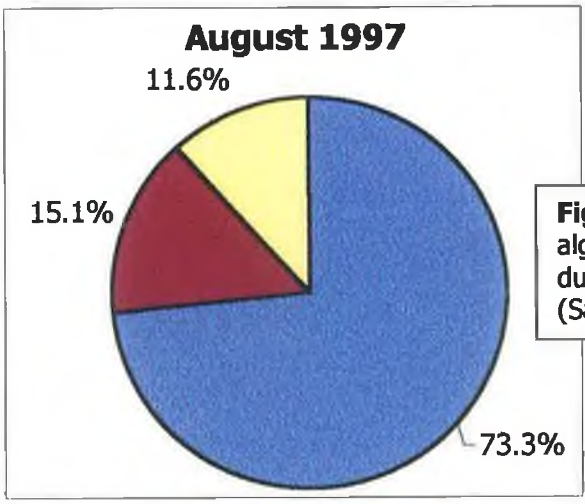


Figure 28: Breakdown of algal phyla found upon slides during August 1997 (M6). (Same legend as Figure 27)

period. The attached diatoms *Gomphonema*, *Fragilaria*, *Synedra*, *Cocconeis* and *Rhoicosphenia* are presented in Plates 15 to 19, Appendix IX.

Diatoms were found on slides during November 1997 and February 1998, and with no results for the intervening period it was assumed that they were present throughout the entire winter. While diatom numbers are low, cells are not dormant throughout this period. Green and blue/green genera were found on the November slides however none were observed during February or March 1998.

Of all the diatom genera found on the glass slides *Gomphonema* (see Plate 15, Appendix IX) dominated throughout the study (see Appendix IV.d). During March 1997 it accounted for 54.4% of all cells found in Sriff Bay (site S3) (5,303 cells of *Gomphonema* per mm^2 out of a total 9,723 cells/mm^2). This dominance continued throughout 1997 and while *Achnanthes* over took it from August to October 1997 *Gomphonema* controlled the following winter period. Other genera such as *Cocconeis*, *Cymbella* and *Nitzschia* were consistent through the whole study period. *Rhoicosphenia*, although it occurred in small numbers, was present on all slides over the 15 months of the study (see Plate 19, Appendix IX).

The green filamentous algae, *Chaetophora* consistently appeared on slides through the whole study with numbers peaking in May 1997 (cells ranged from 119 to 3,299 cells/mm^2 across the six sites). During the summer and autumn of 1997 *Anabaena*, *Aphanocapsa* and *Merismopedia* were consistently found on slides (see Table 12). In Appendix IV.d cell numbers indicate that *Aphanocapsa* was found in the highest densities (numbers ranged from 116 to 450 cells/mm^2 during September 1997; Table 96, Appendix IV.d). The green and blue/green algae found on glass slides during the study period were greatly overshadowed by the dominant diatom population. It is these diatoms that are responsible for the substantial periphyton mat found on Lough Gill during spring through early summer and again in September.

5.2.2 Bi-weekly glass slides

Four sets of slides were exposed for 2-week intervals between the 10th April 1997 and the 12th June 1997. As with the monthly glass slides, length of exposure varied and results were subsequently adjusted to a 16-day average exposure period. Of the four sets, the third set of slides (exposed from the 8th to the 28th of May 1997) had the longest exposure period, lasting 20 days. The other three sets of slides were all exposed for periods less than 16 days (14 and 15 day periods).

Even though the third set of slides had the longest exposure period, the second set (from the 24th April to the 8th May) had the highest dry weight, chlorophyll estimate and attached cell numbers (see Tables 16 to 25). AFDW and percentage organic matter was lower and this may be due to the high levels of siliceous diatoms like *Cocconeis*, *Gomphonema* and *Nitzschia*. It is assumed that peak periphyton growth during the spring of 1997 occurred during this two week period. Biomass levels decreased marginally during the third exposure period (8th to the 28th of May). While maximum biomass on monthly glass slides was recorded during May it would appear that the majority of growth took place early in the month.

Chlorophyll levels from bi-weekly slides are comparatively as high as monthly slides exposed during April and May (see Tables 8 and 22). Bi-weekly chlorophyll during the second exposure period ranged from 12.8 mg/m^2 to 45.4 mg/m^2 (Corwillick [site S2] was exceptionally higher reached 168.1 g/m^2). Chlorophyll during April went from 27.3 mg/m^2 to 74.4 mg/m^2 while May was between 2.0 mg/m^2 and 50.2 mg/m^2. This would indicate that pigment production in the algal mat reaches an optimum level during the first two weeks of exposure after which it arrives at a stationary phase. Periphyton numbers on monthly glass slides are much greater than bi-weekly slides (see Tables 10 and 24), cells continue to divide even though pigment production ceases. This would suggest that chlorophyll levels initially increase proportionally to cell numbers in the periphyton mat. Photosynthesis and chlorophyll production, however, reach a point where factors such as the availability of light and nutrients limit production. Phototrophs continue to grow, divide and manufacture pigments on the outer layers of the mat while older organisms are trapped within its structure. Optimum chlorophyll levels may be found on the outer light exposed surface of the mat and biomass can continue to increase with the formation of new algal cells, the entrapment of old cells and the collection of organic detritus from the water column.

Slides exposed at Corwillick (site S2), from the 24th of April to the 8th of May 1997 indicated periphyton levels more inline with slides submerged for a one month period. It can be seen from

Tables 16, 18 and 22 that dry weight (16.0 g/m^2), AFDW (6.3 g/m^2) and chlorophyll levels (168.1 mg/m^2) were as high as any found on monthly slides exposed during April and May 1997. It was initially feared that periphyton growth would reach a level where the mat would slough off glass slides and biomass would be under estimated. The accumulation of such volumes during a 14 day exposure period, combined with the intensive growth collected during April 1998, indicates that glass slides experienced minimal sloughing from the observed biomass range. This accumulation over a 14 day period also provides some information into the colonisation pattern of periphyton upon newly submerged objects; after initial growth biomass tapers off into a slower phase.

5.2.3 Temporal phytoplankton trends

Phytoplankton samples were collected in conjunction with monthly glass slides from March 1997 to February 1998. Algal cells were counted and all genera identified. Phytoplankton numbers varied considerably over the course of the investigation (see Table 27). From Figure 16 seasonal patterns indicate that numbers went from a winter low on the 5th March 1997 (counts ranged from 2,547 cells/ml and 14,243 cells/ml) up to a spring peak on the 3rd June 1997 (numbers ranged from 27,147 cells/ml to 237,798 cells/ml). Levels dropped off over the summer months before a second pulse occurred in early autumn that lasted right through to winter. This pulse, which was associated with a blue/green algal bloom, eclipsed all levels seen over the duration of the study. Cell densities on the 9th September 1997 were from 35,887 cells/ml to 200,644 cells/ml. A similar high range was seen on the 6th October 1998 with figures peaking on the 3rd November 1998 when cell numbers ranged from 42,358 cells/ml in Bunowen Bay (site S5) to 1,224,583 cells/ml in Tobernalt Bay (site S6). In the days prior to the 6th of November Tobernalt Bay was sheltering from a light south easterly wind. This along with mild weather, and a falling water level, may have compounded the bloom intensity within this bay.

Weather conditions on and around the date of sampling can play a vital role in dictating a blooms concentration. During the autumn of 1997 sampling dates fell on reasonably calm days where winds speeds did not exceed Force 2 (see Table 50, Appendix II). The very nature of the lake, with its many bays, may allow more sheltered areas to become conducive to the collection of algae. Tobernalt Bay (site S6), which underwent an intensive bloom, was one such area that escaped the winds during the predominant north-westerly weather pattern. Its enclosed nature may also retain trapped cells compounding the blooms' intensity. Corwillick (site S2) also escaped these winds but the sites open nature may have hindered cell collection.

Following the autumn pulse numbers fell away over the following three sampling dates to a winter low on the 4th February 1998, when counts ranged between 3,939 cells/ml and 13,023 cells/ml (this is clearly visible in Figure 17 wherein cell numbers are presented on a log scale).

Distinctive algal growth patterns during the study period are clearly illustrated in Table 28. Approximately ten chlorophyte genera were consistently found in phytoplankton samples throughout the spring and summer of 1997 (see Appendix VI.b). Cyanophyta and Bacillariophyta populations greatly overshadowed them during this time. Other algae identified include Chrysophyta, *Uroglena* (found during the winter months of 1997 and 1998) and Euglenophyta, *Euglena* (noted during the spring and summer months). Both were present in very low numbers. Cyanophyta, which have the lowest genus diversity but the highest cell density, were highly concentrated from the 3rd June to the 3rd November 1997. *Anabaena*, *Oscillatoria*, *Microcystis* and the cellular mass of *Gomphosphaeria* were the most prominent genera dominating the phytoplankton of the littoral zone from the 3rd June to the 3rd November (see Tables 135 to 140, Appendix VI.b).

The Bacillariophyta were the most diverse group found in the littoral zone phytoplankton throughout the project. Diatom populations dominated from the 5th March (P1) to the 3rd June (P4) 1997 (see Tables 132 to 135, appendix VI.b). This concurs with phytoplankton work done in the open waters of the lake by staff working on the Lough Gill Environmental Management Project. Here diatom dominance in spring gave way to green and subsequently blue/green populations during summer. However samples taken in the littoral zone of the lake indicate diatom dominance giving way to Cyanophyta in early summer with diatom cell densities greatly exceeding green algal populations during this time (see Tables 136 to 140, Appendix VI.b). Bacillariophyta were the more diverse group throughout the study with cell numbers dominating littoral population during the winter months (see Tables 141 to 143, Appendix VI.b).

5.2.4 Artificial *Littorella* plots

Artificial *Littorella* plots were exposed for approximately one month periods between February 1997 to March 1998 at six sites around the littoral zone of Lough Gill (placement and retrieval dates in Table 46, Appendix I). These were analysed for dry weight and ash free dry weight. Again the exposure length varied, with periods from 26 days to 40 days. Results were subsequently adjusted to an average exposure period of 30 days. The adjustment had a negligible effect on biomass trends (see Figures 18 and 19 and Figures 20 and 21).

Diatom pulses during the spring and autumn of 1997 was quite evident from artificial *Littorella* plots. The volume of material collected on the plots was reasonably consistent through February 1997, with approximately 30.0 g/m^2 dry weight (Half-moon Bay and Sriff Bay were the exception with 54.6 g/m^2 and 42.0 g/m^2 respectively). Levels increased during March 1997 with dry weights ranging from 35.8 g/m^2 in Tobernalt Bay (site S6) to 94.3 g/m^2 in Bunowen Bay (site S2). This upward trend continued through April 1997 (biomass going from 48.1 g/m^2 to 105.0 g/m^2) before levels tapered off during May 1997 (biomass from 29.4 g/m^2 to 45.8 g/m^2) (see Figure 18). After this, the volume of dry material obtained on plots remained consistent up to August 1997 (approximately 20 g/m^2 to 50 g/m^2). There followed a small pulse during September before levels subsequently dropped to approximately 20 g/m^2 with the advent of winter. As with glass slides, samples were also lost during the months of December 1997 and January 1998. Levels during this period were assumed to be consistent with the periods before and after. Early in 1998, after sampling resumed, increased dry weights coinciding with the spring diatom pulse were recorded.

Again as expected AFDW levels from the plastic plots show temporal trends similar to dry weight (see Figures 18 and 20). Again periphyton AFDW peaked during March 1997 (AFDW 11.3 g/m^2 to 21.8 g/m^2) and April 1997 (levels from 17.3 g/m^2 to 30.8 g/m^2) before dropping off in the following months (see Tables 31 and 32). As with dry weights, AFDW levels during the rest of the summer into early autumn (June to October 1997) stayed reasonably consistent with levels ranging from 10.0 g/m^2 to 17.0 g/m^2 approximately. The autumn pulse was not obvious from AFDW levels. Periphyton AFDW declined over the following months to a winter low in December 1997. Of particular interest to the study was the *Littorella* plots poor ability to collect material that would clearly define the expected spring and autumn periphyton pulses. AFDW levels and adjusted AFDW levels (which were slightly greater than the original data) did not show the strong periphyton growth peaks that were so evident from glass slides.

The organic matter content of periphyton obtained from *Littorella* plots ranged from approximately 20% to 50% during the 14-month trials. Percentage organic levels increased marginally during the summer months coinciding with the growth of green algae. Percentage organic matter (see Table 33) and adjusted organic matter (see Table 34) were considerably lower than anything found on monthly glass slides (see Table 6).

5.2.5 Trays of washed stone

Trays of washed stone were exposed from April 1997 to April 1998 (placement and retrieval dates can be found in Table 47, Appendix I). Once again exposure periods varied in length because of sampling logistics, yet the average exposure period turned out to be 30 days. Because the exposure periods varied from 27 days to only 34 days adjustment of biomass figures resulted in little deviation from the original values (see Tables 35 and 36). Presentation of dry weight and adjusted dry weight trends in Figures 22 and 23 show small differences between both sets of data.

During the first exposure period (April/May 1997) dry weight ranged from 212.3 g/m^2 to 1108.5 g/m^2. It can be clearly seen in Figure 22 that dry weights stayed the same or decreased from May to July 1997. Half-moon Bay (site S1) was the exception and this may be a result of littoral sediments being deposited within the trays. Levels continued to drop away over the next two months before a slight increase in biomass occurred through August/September 1997. During the same period Half-moon Bay (site S1) showed a considerable increase in dry weight, going from 255.2 g/m^2 to 647.1 g/m^2. This again was related to course littoral sediments found within the bay, which were observed to accumulate in trays. From late summer into early autumn levels fell away to a winter low with dry weight in November 1997 ranging from 3.5 g/m^2 to 41.1 g/m^2.

All trays were lost during December 1997. Strong winds caused considerable turbulence in the littoral zone, lifting trays and spilling the stone contents. Results during January 1998 were similar to November 1997 and from this it was assumed that December fell into the same pattern. Dry weights from trays of washed stones were lower during the spring of 1998 than those twelve months previously. Dry weight from February to April 1998 (St 11 to St 13) ranged from 34.1 g/m^2 to 229.9 g/m^2 with little variation between sites when compared with April of the previous year.

Ash free dry weights from trays of washed stone showed little temporal variation over the entire length of the study. Levels of AFDW rarely went above 50.0 g/m^2 over the twelve month period (see Table 37 and adjusted AFDW results in Table 38). This was with the exception of Sriff Bay (site S3) which recorded an AFDW level of 276.1 g/m^2 during the first exposure period, April 1997. Site S3, on the eastern shore of the lake, received considerable wind and wave action during this time (see Table 50, Appendix II). This high level of organic matter may be the result of wind blown debris and leaf litter accumulating in the trays.

Figures 24 and 25 do not clearly show the expected spring and autumn periphyton pulses. These peaks in the data are more visible from Table 37. AFDW levels during spring 1997 reached approximately 50.0 g/m^2 before falling to less than 15 g/m^2 in July. After the late autumnal bloom (biomass ranged from 11.0 g/m^2 to 46.4 g/m^2 during August) organic levels fell away to 10.0 g/m^2 during October as algal populations collapsed. Levels stayed constantly low until the advent of the spring growth and its associated diatom population in March 1998. It must be noted that data from trays of stones, like the data from *Littorella* plots, do not provide the same seasonal spread or range as seen with glass slides.

Over the entire project, the percentage organic matter in trays of washed stone was lower than any other artificial substrate used to monitor periphyton. Percentage organic matter rarely went above 25% (see Tables 39 and 40). Wind and wave action can disperse benthic materials into the waters of the littoral zone. The open tray placed on the bed of the littoral zone collected inorganic silt and sand suspended into the water column. During July 1997 and January 1998, when dry weight and AFDW levels were low, high percentage organic matter levels were recorded. Where other exposure periods may have seen a lot of inorganic silt and sand collected in the trays, these two periods may have been reactively free of this. Low wind speeds and calm weather patterns during these periods may have resulted in limited sediment re-suspension. In any event, the inorganic fraction from stone trays was considerably greater than that of glass slides or artificial *Littorella* plots. The trays primarily operated as sediment traps, overshadowing their function as an artificial substrate for the collection of periphyton.

5.3 Spatial variations in periphyton cover

Six sites were chosen around the shores of Lough Gill with the assumption that they would consistently indicate the temporal growth patterns of periphyton. However this was not the case, spatial differences in attached algal cover became very obvious. Each artificial substrate indicated varying growth patterns between the six sites. These differences have considerable consequences when identifying representative sampling locations in a periphyton monitoring programme.

While visiting the six sites over the course of the study periphyton populations in some locations were visually different to others. The presentation of data on a time scale axis (see Figures 7, 9, 13, 18, 20, 22 and 24) indicated similar growth patterns with noticeably different growth levels between sites. The large range in monthly data was particularly noticeable during spring and autumn growth pulses. The significance of these differences between sites and the factors influencing their variation were unknown.

In order to identify spatial variations a number of tests were applied to the data collected over the 15 month monitoring programme. The Wilcoxons' Rank Sum Test for Two Samples was initially used on paired sites (see Figure 45, Appendix III). This test did indicate a low level of significance between sites, however these results provided insufficient information about spatial patterns (results not presented). Subsequently Principal Component Analysis (PCA), a more powerful correlation tool, was used to isolate the number of influencing factors in each set of data (see Figure 46, Appendix III). From this a Cluster Analysis separated the sites depending on their degree of similarity and this was illustrated using dendrograms (or tuning-fork diagrams). PCA and cluster analysis was carried out on SPSS® Base 7.5 for Windows® (Statistics Package for Social Science) with all data analysis subsequently assessed by Mr. Paddy Greer of the Institute of Technology Dundalk.

From artificial substrate and phytoplankton data, PCA identified the number of factors influencing the variance within sample sites and allocated a percentage variability exerted by each factor at each site (see Tables 41, 42 and 43). Sites were then joined based on their similarity to one another (see Figures 29 and 30). Artificial substrate data indicated quite similar patterns from PCA with one principal factor extracted from all three and a second minor factor extracted from washed stone data. Cluster analysis was carried out on the dry weight data from glass slides and trays of washed stone. Communalities from dry weight data were very similar to AFDW data,

Sampling method	Table 41: Glass slides				Phytoplankton	
Data analysed	Dry weight	AFDW	Chlorophyll	Periphyton		
No. of factors extracted	1	1	1	1	2	
Communalities	%	%	%	%	1st %	2nd %
S1	88.9	86.3	63.1	92.3	87.0	7.5
S2	95.1	96.6	93.9	95.7	95.5	3.8
S3	66.8	64.4	86.7	80.4	5.3	74.5
S4	91.9	86.3	78.3	96.5	27.7	39.9
S5	85.1	89.4	59.1	86.7	3.1	72.6
S6	87.6	92.8	58.6	92.5	87.8	6.3

Sampling method	Table 42: Plots of plastic *Littorella*	
Data analysed	Dry weight	AFDW
No. of factors extracted	1	1
Communalities	%	%
S1	57.3	75.8
S2	82.8	79.0
S3	87.6	89.4
S4	93.9	76.3
S5	80.2	75.1
S6	65.8	68.1

Sampling method	Table 43: Trays of washed stone			
Data analysed	Dry weight		AFDW	
No. of factors extracted	2		2	
Communalities	1st %	2nd %	1st %	2nd %
S1	50.6	40.4	44.8	28.8
S2	57.3	32.5	33.2	48.7
S3	87.8	0.2	53.3	22.3
S4	68.1	>0.1	68.9	>0.1
S5	96.2	2.7	84.5	0.6
S6	74.6	20.3	69.9	18.6

Tables 41, 42 and 43: Principal Component Analysis applied to data obtained from the six sites in the lakes' littoral zone; the number of factors effecting variability and the percentage variance exerted by each factor at each site.

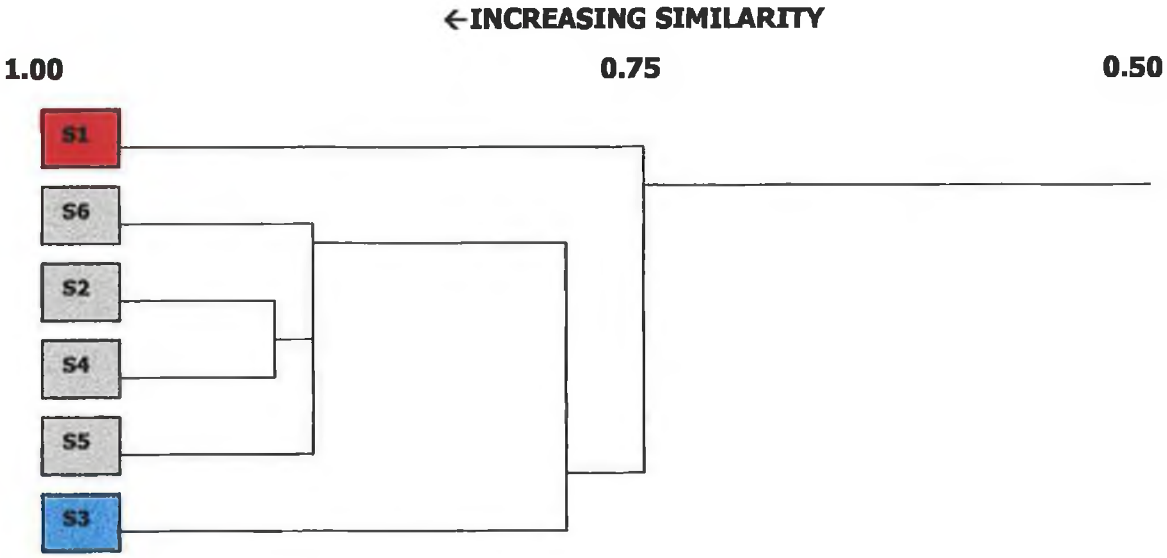


Figure 29: Dendrogram of the dry weight data from glass slides. A Hierarchical Cluster Analysis was used to join similar sites; sites joined closer to 1.0 have greater similarity. (Note: Like colors indicate similarity between sites)

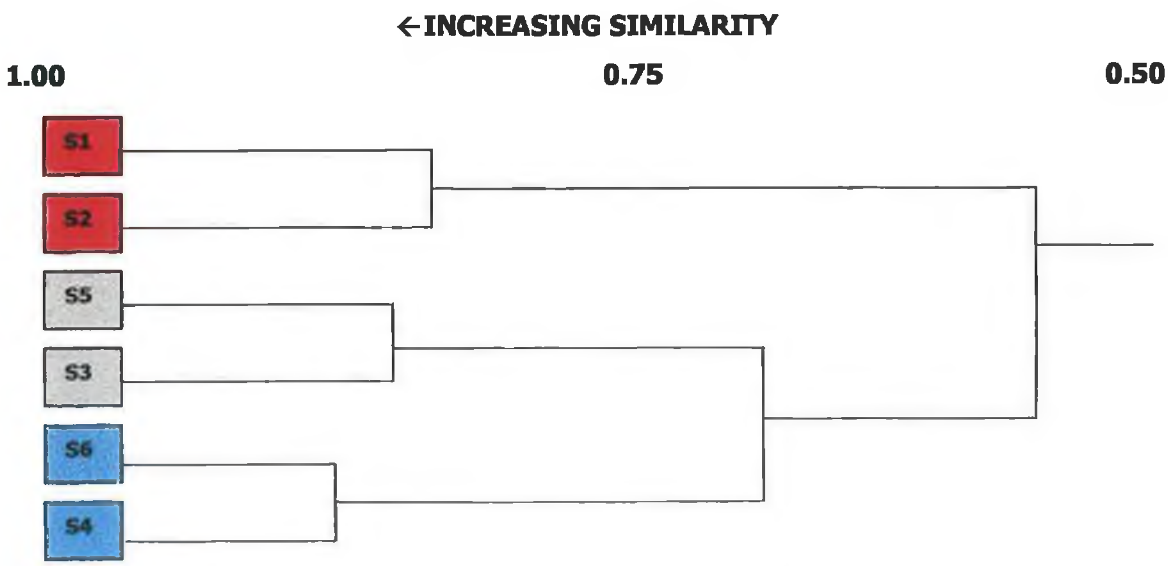


Figure 30: Dendrogram of the dry weight data from trays of washed stone. A Hierarchical Cluster Analysis was used to join similar sites; sites joined closer to 1.0 have greater similarity. (Note: Like colors indicate similarity between sites)

subsequently results from cluster analysis were also expected to be similar. A dendrogram of the dry weight data obtained from glass slides indicated that Half-moon Bay (site S1) and Sriff Bay (site S3) are quite different from the other sites and each other (see Figure 29). Cluster analysis carried out on dry weight data from trays of washed stones indicated a greater spatial pattern between sites with Half-moon Bay and Corwillick separated from Sriff Bay and Bunowen Bay and again from Whites' Bay and Tobernalt Bay (see Figure 30).

The principal factor extracted by PCA from artificial substrate data may be one of a number of possible elements. They may include one of the following:

- Grazer densities
- Underlying geology and substrate type
- Sunlight and water temperature
- Diffuse sources of nutrients from lands surrounding the lake
- Wind and weather patterns effecting water movement

Grazer densities on glass slides varied from site to site (see Table 14 and 15, Section 4). Molluscs were the most common grazers found on slides and may subsequently make the biggest impact on periphyton populations around the lake. Tobernalt Bay (site S6) appeared to have the highest density of snails on glass slides (see Table 103, Appendix IV.e) while considerable numbers of shells were observed along the shoreline. It may be assumed that algal densities are one factor in influencing grazer densities; the greater the algal growth the greater the number of grazers present. This was not the case in Lough Gill as Tobernalt Bay had average levels of periphyton biomass (see Figure 7 and Tables 2 and 4) which was reflected in its grouping with three other sites during cluster analysis. Grazer densities may exert some influence on periphyton growth patterns but it does not appear to be the principal factor causing spatial variability between sites.

Lough Gill lies along a north/south junction of two distinct rock types, Carboniferous limestone on the lakes' northern side and an older metamorphic rock type along its southern shores. The influence of site geology (as outlined in Section 3.2.2) on periphyton growth would split Whites' Bay and Bunowen Bay (sites S4 and S5) on metamorphic rock from the other four sites situated on limestone. PCA analysis does not appear to suggest such a split and again Figures 29 and 30 do not display these patterns. While substrate type (see Table 1, Section 3) varied from site to site artificial substrates were used to grow periphyton, therefor natural substrates would appear to exert only a minor impact on spatial growth patterns.

Site exposure to sunlight was not recorded but with the lake having an east-west orientation (see Plate 1) those areas along the northern shores may expect to get higher levels of light than sites along the shaded southern shores. Water temperature (see Figure 49, Appendix II), which one would expect to be related to the levels of sunshine, had a higher standard error (suggesting variation in the water temperature of the six sites) from late May 1997, when lake temperatures were rising, to mid August, when water temperatures peaked. The standard error between sites decreased from this point onwards as water temperatures dropped. This would suggest that sites receiving more sunshine might experience a more rapid rise in water temperature than other shaded sites. A north/south divide in sites may be expected, however this is not clear from Table 49 and spatial patterns in the data do not suggest this (see Figure 29 & 30).

Land use around the lake consists of mature forest predominating to the south and west, while farming covers the north and east of the lake from Corwillick to Manorhamilton (see Plate 1), private housing peppers the shores of the lake. These land uses may contribute to the lakes excessive periphyton growth yet their positive identification as factors effecting spatial growth are hard to estimate. Cluster analysis of data from artificial substrates does not appear to coincide with land use patterns.

The lakes' east/west orientation coincides with prevailing wind and weather patterns. As a result Sriff Bay (site S3) is quite exposed, receiving a long fetch at the eastern end of the lake, meanwhile Half-moon Bay (site S1) on the western shores is found to be quite sheltered. Cluster analysis found these sites differed from other sites, and each other (see Figure 29). This difference may indicate that periphyton growth patterns are associated with wind and its effect on water movement. The greater the flow of water around the mat the greater contact the material has with nutrients in the water column. Water currents would also stop the build up of oxygen during photosynthesis while attracting suspended and free floating inorganic and organic detritus.

Data from slides, plots of *Littorella* and washed stones had one principal factor extracted (see Tables 41, and 43), and it may be assumed that this was one and the same component. Trays of washed stones, on the other hand, had a second factor extracted (see Table 43). Trays of stones were positioned on the bed of the littoral zone and, as already noted, a large volume of inorganic material was collected at some sites (notably at Half-moon Bay and Corwillick; sites S1 and S2). From Figure 30, the similarity index groups these same two sites together. Sriff Bay and Bunowen Bay (sites S3 and S5) along with White's Bay and Tobernalt Bay (sites S4 and S6), are separated into two other groups. The substrate types within each group was quite similar (see Table 1, Section 3) with the more loose sediments in Half-moon Bay and Corwillick (S1 and S2) and more packed substrates in Whites' Bay and Tobernalt Bay (S4 and S6). Subsequently sediment re-suspension may possibly exert a second minor influence on the variance in data from washed stone.

Phytoplankton data also had two factors extracted and they may have differed from those identified in artificial substrates. Water temperature showed some variation on each sampling date with increased error between sites during the warmer summer months. From this, sunlight (which can influence water temperature) could appear to be the major factor effecting variance in phytoplankton numbers. Table 41 indicates that the second factor had a greater effect on the percentage variance in Sriff Bay and Bunowen Bay. Both of these sites were open to the predominant north westerly winds (see Figure 34) causing the dispersion of algal blooms within the water column. The second extracted factor may be a result of this exposure to prevailing wind and weather patterns; the more sheltered the site the greater the accumulation of algal cells within the littoral zone.

Spatial patterns in periphyton growth, and the factors effecting these patterns, have considerable implications for monitoring programs and the preliminary process of site selection. The scouting of potential locations to monitor periphyton growth may depend on the aims of the study. Site selection in long term studies of attached algae may not be as important with growth patterns being monitored over years. To observe short term monthly growth trends sites would need to be representative of natural occurring periphyton levels over the majority of the littoral zone. The number of sites could also play a role in achieving an accurate picture of periphyton growth patterns. Where one site could be hit or miss too many may not be feasible. The number of sites would depend on the study and its goals, however the influence of weather, land use, substrate type, littoral zone ecology along with easy access to potential sites should also be considered important factors in the selection process.

5.4 Comparison of periphyton growth between artificial substrates

It developing a lake monitoring protocol, sampling devices must be representative of naturally occurring processes. Using the three artificial substrates (glass slides, artificial plots of the macrophyte *Littorella uniflora* and trays of washed stone) to monitor periphyton biomass around the Lough Gill littoral zone allows a comparison of their efficiency, reliability and repeatability.

5.4.1 General trends

All three substrates, to varying degrees, indicated elevated dry weight levels from April to June 1997 (see Figures 7, 18 and 22). Levels dipped during the mid summer months before attached biomass increased again during August and September 1997. After this autumn bloom, algal populations dissipated with the onset of winter. The reduced amounts of daylight caused air and water temperatures to drop. Populations of periphyton diminished to a fraction of their former level. These stayed constantly low from the end of November 1997 through to early spring 1998.

Periphyton levels on glass slides increased through March before soaring during April 1998. Dry weight levels on slides were at their highest of the entire study during April 1998. *Littorella* plot trials were discontinued at the end of March 1998 and therefor could not concur with trends on glass slides. However in the previous month plastic *Littorella* plots showed a similar trend to glass slides with increased dry weight during March. Trays of washed stone do not reflect this. Collection of trays up on till the middle of May 1998 indicated trends in keeping with winter biomass levels rather than those of the previous spring (see Figure 22). Ash free dry weights from glass slides, *Littorella* plots and washed stone show comparable patterns.

Of the three substrates variations in seasonal growth patterns were less distinct in artificial *Littorella* plots and trays of washed stones. AFDW levels from washed stone did not coincide with trends in dry weight as a result of inorganic sediment masking periphyton growth. The differences between these substrates are of much concern when developing a monitoring programme and when comparing biomass between different studies and different artificial substrates.

5.4.2 Variations in the organic matter content of artificial substrates

Of immediate concern was the surprising degree of variation in biomass data between the three artificial substrates. All three substrates had dry weight and AFDW data converted to g/m^2 thereby allowing a direct comparison. Adjusted dry weight levels from glass slides during April 1997 (spring diatom peak) ranged from 3.2 g/m^2 to 19.0 g/m^2. During the same month artificial *Littorella* plots collected dry weights from 42.4 g/m^2 to 92.6 g/m^2, while biomass from trays of stone varied between 235.9 g/m^2 and 1,231.7 g/m^2. Dates of exposure are not identical however adjusted results are presented. Therefor the length of exposure period is comparable (30 days adjusted exposure). What is quite clear from these three sets of results is the large range in dry weight between the six sites and more significantly, the massive variation in dry weight between the three substrates used.

AFDW levels from the three materials were also significantly different. During the same month (April 1997) adjusted AFDW on glass slides ranged from 1.7 g/m^2 to 8.0 g/m^2 while *Littorella* plots went from 15.3 g/m^2 to 27.2 g/m^2. Trays of washed stone were again considerably higher, varying from 22.3 g/m^2 to 72.7 g/m^2 (site S3 in Sriff Bay had an AFDW peak of 306.8 g/m^2 during the same month, however this was exceptional and unrepresentative of true AFDW trends). Across the three substrates AFDW did not vary as much as dry weight. This is particularly true of washed stone; when dry weights were ten times greater than *Littorella* plots, AFDWs' were only twice as big. The organic content of glass slides ranged from 40% to 60% during spring through to the late summer of 1997 (see Figure 31). With the arrival of winter, the organic content increased to near 90%. These slides showed an exceptional variation over the course of the study with levels never dropping below 35%. Plots of artificial *Littorella* had an organic content that varied from 20% to 50%, with levels increasing during winter months (see Figure 32). The lowest organic content of the three substrates was found in trays of washed stone where highest levels were between 30% and 40% during the winter months with spring and summer rarely exceeded 25% (see Figure 33).

The position, orientation and size of the three artificial substrates may account for this large variation in biomass and organic content. Variability in dry weight and AFDW may be due to the entrapment of materials, not associated with periphyton growth, which are suspended in, or resuspended into, the water column. Such materials are considered to be part of the periphyton mat as defined by Wetzel (see Section 2.1.1). However this definition would consider such a fraction to be quite an insignificant part of the entire mat. The inorganic content of stone trays would go well beyond the scope of this definition.

Figure 31: Percentage organic matter from glass slides submerged at six sample sites around the littoral zone Lough Gill during 1997, 1998.

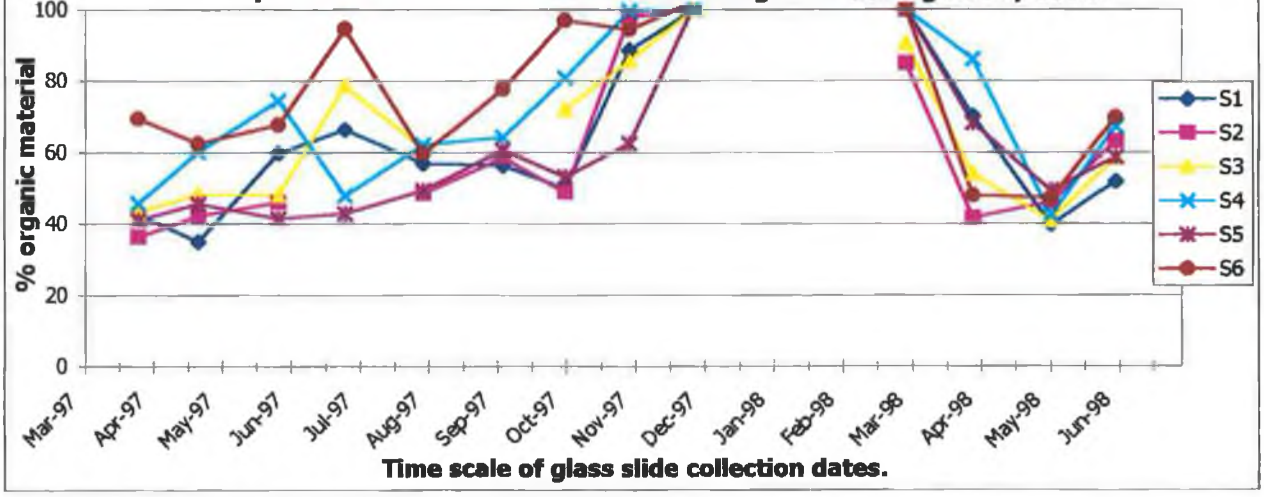


Figure 32: Percentage organic matter from plastic *Littorella* plots submerged at six sample sites around Lough Gill during 1997 and 1998.

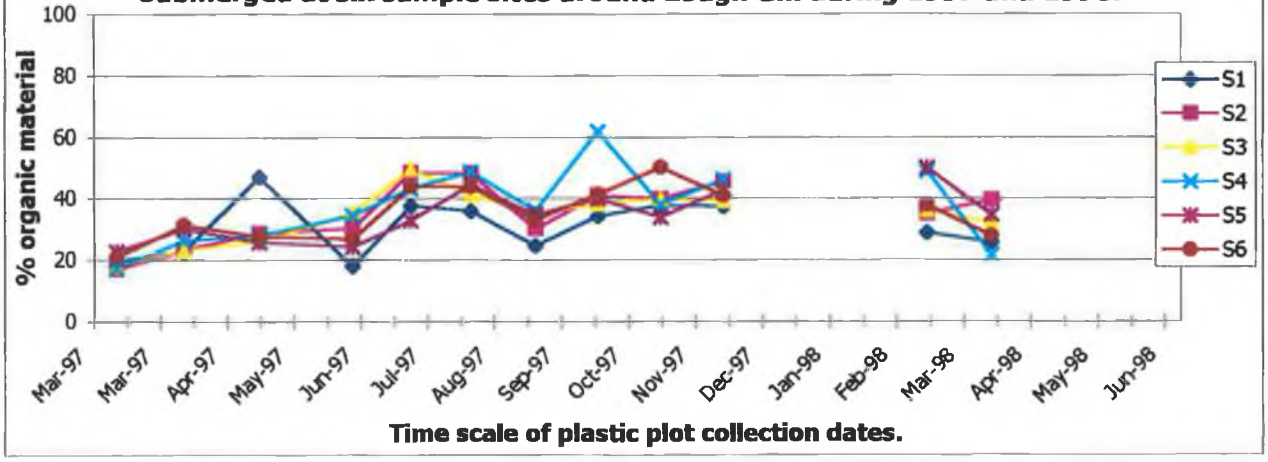
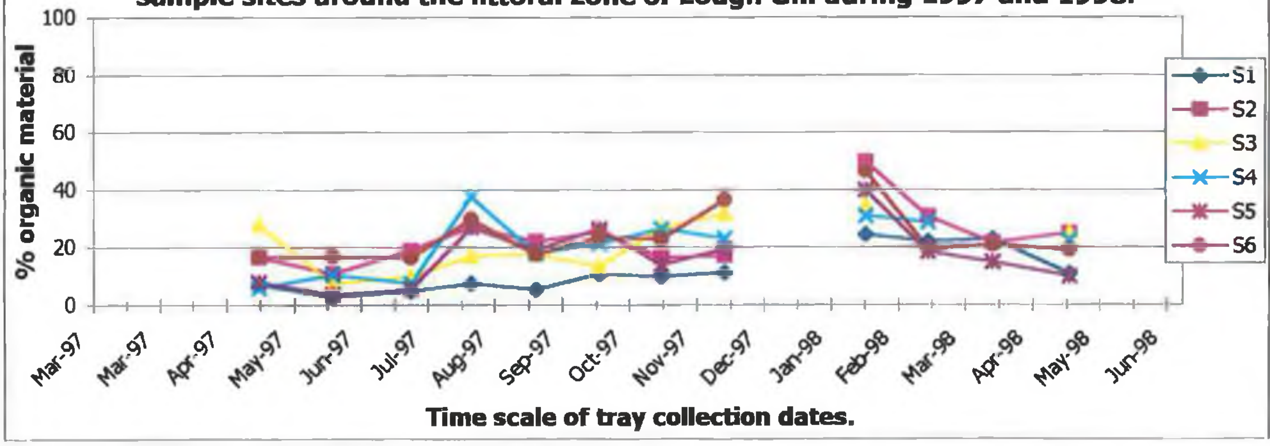


Figure 33: Percentage organic material collected in trays of stones at six sample sites around the littoral zone of Lough Gill during 1997 and 1998.



The nature and positioning of the artificial substrates may help to explain these variations. Trays of washed stone and *Littorella* plots were placed on the bed of the littoral zone. Glass slides were located in the water column. Glass slides also had the smallest surface area of the three substrates. In the analysis and calculation of biomass from artificial substrates, the smaller the surface area the greater the room for error. Of course the horizontal position of the trays, flat on the lake bed, would catch more materials sinking out of the water column above. Slides had a vertical orientation and would not have been as prone to this sedimentation. *Littorella* plots because of their shape and soft plastic structure did not collect as much suspended particles, however, their net-like nature made them more likely to trap sediments than glass slides.

The large area of the trays made them amenable to the collection of silts and sand. This was the one factor that made them primarily responsible for the large difference in biomass between stone trays and the other two substrates. Subsequently there was a massive variation in dry weight and AFDW. The vast majority of materials collected in plastic trays were inorganic in nature, the result of littoral sediments being resuspended in the water column, settling out within the tray. In effect the trays of washed stone became sediment traps. The percentage organic material reflects such an assumption.

The design of the trays was such that materials washed into them would be retained and analysed. This was above and beyond the actual periphytic growth upon the stones within the tray. The trays were very efficient in their placement and retrieval however their ability to represent periphyton trends is debatable. Within the literature the majority of periphyton work carried out on stone substrate involves the collection of a small portion of the material on a specific surface area and quite often sampling is done *in situ* (see Section 2.5.3). Thereby the materials collected consist primarily of the periphyton mat and not other non-associated inorganic sediment. Because of the spatial variation in the sediment and geology of the Lough Gill littoral zone, collection of replicate periphyton samples, from naturally occurring stone substrates, would be considerably difficult.

From these results, growth on glass slides would appear to reflect the lakes endemic periphyton population. Although surface texture and attachment mechanisms of the algal population have not been explored, the slides' performance would primarily be a result of their vertical position up in the water column. The simplicity and analytical properties of this artificial substrate, quite apart from its performance, make it by far the most suitable substrate used.

5.5 Divergence in results from attached and free floating algae around Lough Gill

Phytoplankton samples were collected at the six sites around the littoral zone of Lough Gill in conjunction with monthly glass slides between March 1997 and May 1998 (see Table 48, Appendix I). Phytoplanktonic genera were subsequently compared to attached periphyton. Also the influence of weather patterns and particularly wind dispersion of attached materials was investigated. With these results the effects of dispersed algae on littoral water could be better understood.

5.5.1 Variation in the genera of attached and free floating algae

A list of periphyton genera found on glass slides is presented in Table 12. The vast majority of algae found attached to slides are Bacillariophyta in origin. Even in the summer months of 1997, when green and blue/green genera were at their peak, they were still greatly out-numbered by diatom populations (see Figure 28 and Periphyton Genera Found on Glass Slides, Appendix IV.d). A percentage of the algae found on slides are assumed to be phytoplanktonic in origin, the gelatinous nature of the mat entrapping free-floating cells on and within it. Filamentous green algae, such as *Chaetophora* and *Cladophora*, along with the majority of the diatoms are associated with attached growth on submerged substrates. Blue/green algae are normally found dispersed in the water column and cells present on glass slides have most likely become entangled within the algal mat. From looking at the numbers of Cyanophyta found on slides (Appendix IV.d) it would appear that they have a marginal impact on attached populations. The impact of attached periphytic algae on free-floating phytoplankton may be more pronounced.

Algal genera in phytoplankton samples were more diverse than those attached to glass slides (see Tables 12 and 28). While green and blue/green algae made up a considerable proportion of the phytoplankton genera (see Phytoplankton Genera, Appendix IV.b) it is the diatoms, which are quite diverse with a high distribution year round, that are of most interest. The majority of diatoms found in littoral water samples were also noted in the periphyton mat (see Tables 12 and 28). Genera such as *Gomphonema*, *Navicula*, *Cymbella* and *Synedra* all employ attachment mechanisms that bind them to submerged substrates. Their presence in the water column would indicate detachment from substrates and subsequent dispersion in the water column of the littoral zone. The mechanism of detachment is assumed to be turbulence from wind and wave action.

5.5.2 Effects of climatic conditions on the periphyton mat

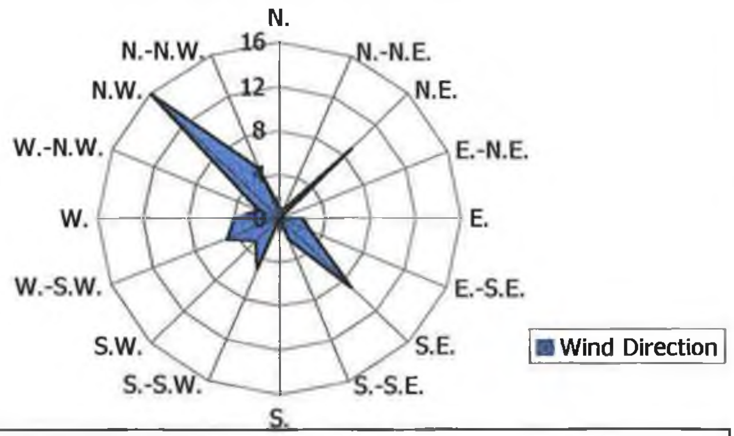
Prior to the projects initiation Dr. Don Cotton noted that a gelatinous mat, which covered most all submerged substrates of the littoral zone, could easily be re-suspended through agitation of the surface water (see Section 1.1). Its effect and implication on the waters of Lough Gill was unknown but was assumed to be deleterious. Wind speed and wind direction data was collected in conjunction with phytoplankton samples. This information may help to explain the impact of the periphyton population on the algae of the littoral zone water column. A north-westerly wind predominated over the seventy visits to sample stations around Lough Gill (see Figure 34). Wind speeds of force one to force two were common throughout (see Figure 35).

The first three phytoplankton samples, taken on the 5th March, 3rd April and 29th April 1997, were all collected during north westerly winds. This caused considerable wave-action in Bunowen Bay (site S5). Diatom diversity and density on all three sampling dates was found to be much higher at this site. The following month (2nd July 1997) sampling took place under a strong north easterly wind. Attached periphyton levels in Lough Gill peaked in Bunowen Bay (site S5). Around the shores of the lake blue/green algae eclipsed all other phyla of the phytoplankton nevertheless diatom numbers in the water column of Bunowen Bay over-shadowed similar populations in the other five sites (see Table 136, Appendix VI.b). On these sampling dates the diatom *Gomphonema* was one of the most common genera present in the phytoplankton. This alga along with similar pennate diatoms (notably *Cymbella*, *Nitzschia* and *Synedra*) is more commonly found in benthic systems (Jan Stevenson 1996). Their presence in phytoplankton samples would indicate detachment from submersed substrates which most likely is a result of wind and wave turbulence lifting cells into the water column of the littoral zone.

Wind and wave dispersion of periphyton was observed in Tobernalt Bay (site S6) on 11th May 1998. During this site visit the lake was under a moderate north easterly wind with a strength of force two on the Beaufort Scale (see Table 50, Appendix II). This wind direction channelled straight into Tobernalt Bay generating considerable wave action along its shore. Clots of detached algae were visibly present along the littoral zone out to a depth of 1.5 meters. This in turn caused the water column to become dark brown with transparency down to a couple of centimetres.

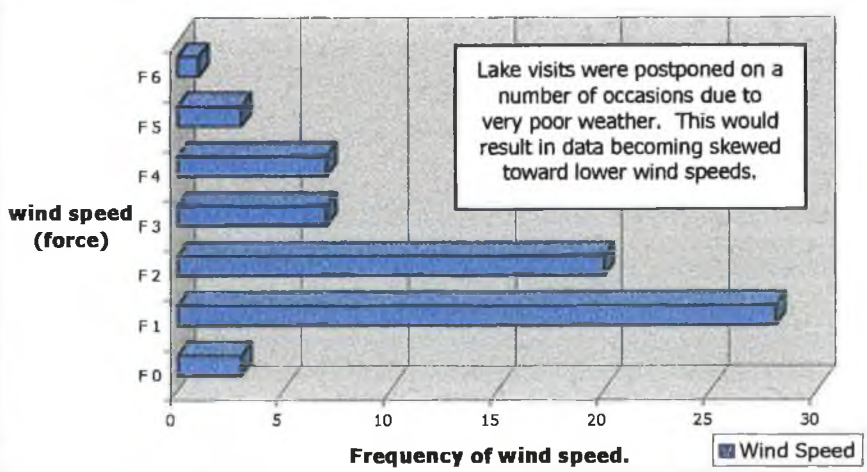
Periphyton populations exhibit extreme spatial and temporal differences in growth. Detachment of periphyton into the waters of the Lough Gill littoral zone predominantly occurs during the spring diatom bloom. With this in mind the greater the biomass of periphyton the easier the detachment of cells into the water column. The mat density, and the attachment mechanisms of algae within it, may also play a role in dictating levels of dispersion. Dispersed clouds of periphyton appear to have a localised effect on water clarity primarily dictated by wind and wave turbulence. These detached populations are of secondary importance when compared with the blue/green blooms that have occurred in the last number of years. Cyanophyta blooms, which are an indication of an enriched system, greatly over shadow all other phyla within the littoral zone during summer and autumn.

Figure 34: Frequency of wind direction observed over entire study period.



Wind direction was recorded over 70 visits to L. Gill. Figure represents 67 observations (3 visits were calm). All wind directions were recorded using a hand held compass.

Figure 35: Wind Speed frequency observed over 70 visits to sites on Lough Gill.



5.5.3 The influence of littoral zone algae on open water populations

When littoral populations are compared to phytoplankton of the open water (work carried out by the 'Lough Gill Environmental Management Project', See Section 1.3.3.1) the results are quite different. Although diatoms were observed to be dominant in the open-water samples collected during the spring of 1997 the genera involved were the free floating *Cyclotella*, *Stephanodiscus* and the colonial pennates *Asterionella* and *Fragilaria*. *Gomphonema*, *Cymbella* and *Synedra*, which were prominent within the littoral zone, are not noted. The mid-lake sampling stations found that diatoms gave way to green, and subsequently blue/green genera, during the summer and autumn months of 1997 (see Appendix VI.b). At the end of October 1997 blue/green species gave way and diatoms dominated once again. Samples from the month of the Bonet River indicated diatom prevalence throughout 1997. This was the influence of the algal population from the in-flowing river prior to mixing. Meanwhile diatoms overshadowed the algal population of the Lough Gill littoral zone from the 5th March to the 3rd June 1997 with blue/green algae becoming prevalent from the 2nd July right through to the 3rd November 1997, eclipsing the Chlorophyta population (see Appendix IV.d). Phytoplanktonic samples taken between the 1st December 1997 and the 4th February 1998 indicate diatom prevalence through the winter months.

During the summer months of 1997 when blue/green algae dominated the phytoplankton of the Lough Gill littoral zone diatom populations were still high. Diatom diversity was consistent throughout the summer with numbers considerably higher than green algae. The diatom genera *Cyclotella*, *Melosira* and *Fragilaria*, which were prominent in open water sites, were also found at the six sites around the shores of the lake. Here, however, their numbers were insignificant compared with the stalked diatoms *Gomphonema*, *Navicula* and *Nitzschia*. The periphyton populations significantly contributed to the phytoplankton of the littoral zone with a minimum effect on open waters.

Overall, samples taken at the six stations around the Lough Gill littoral zone appear to have a higher number of algal than those taken in open waters. This is particularly true of blue/green populations which dominated right through the summer and autumn of 1997. While dispersion of periphyton was an important factor influencing phytoplankton numbers, the overwhelming blue/green population was far more worrying. The importance of monitoring algal populations in the littoral zone should not be underestimated. As a result of nutrient enrichment, elevated algal numbers may manifest themselves in the littoral zone faster than the open waterbody.

Throughout the spring and summer of 1997 and 1998 mats of periphyton could be seen floating on the surface of Lough Gill. These detached mats, or metaphyton, came from substrates in the littoral zone of the lake. During photosynthesis oxygen and other gases build up within the mat. Gases reach such a volume that clumps of mat detach from its substrate floating on to the water surface. The mats must have some impact on the water quality of Lough Gill. Moreover, their very presence would indicate substantial periphyton biomass and may imply that the system is becoming over enriched.

After accumulation of metaphyton on the water surface during periods of calm weather prevailing winds may drive it towards shore. There it may agglomerate into a large raft before blanketing the shoreline of the littoral zone (see Plate 20, Appendix IX). The mats' decay could damage submerged macrophytes like *Littorella uniflora* which may already be stressed from periphyton cover. The mechanical agitation of the materials may also effect stalked macrophytes. Heavy mats of filamentous algae have been correlated with a reduction of the outermost reed stalks in macrophyte beds (Ostendorp 1992).

5.6 Effects of periphyton growth

5.6.1 Water quality

The implications of substantial periphyton growth may be two-fold. Primarily, the growth of the mat in large quantities could be an indication of elevated nutrient levels around the littoral zone of Lough Gill. The secondary implication, which would be a knock-on effect, involves the deterioration of the lakes water quality as result of mat dispersion in the water column.

Nutrient enrichment of a water body, although easy to identify through point sources, is considerably more problematic to asses from non-point sources. An estimation of the total phosphorus loading in the Lough Gill catchment shows that the majority is from diffuse sources with less than 10% from point source emissions (Thompson, Ryan and Cotton 1998). Land use around the lake comprises of forestry, housing and a small proportion of farmland scattered across the porous limestone hills on the northern shores. These may account for some diffuse nutrient enrichment into Lough Gill. As most Irish lakes have areas of intensive land use bordering their shores, non-point source enrichment from adjacent lands has become a considerable problem in the last fifteen years. As pointed out by Wetzel (see Section 2.2) the role of the lands bordering a waterbody is paramount in dictating the waters' state and quality. Identification, mitigation and legislative control of these nutrient sources are fraught with problems.

Another potential source of nutrients are the sediment loading emitted into Lough Gill as a result of the arterial drainage along the Bonet River. Work by Dr. Declan Murray on sediment cores indicated increased benthic productivity within the lake (see Section 1.3.4). This enrichment may also manifest itself in high levels of periphytic growth around the lakes' shoreline.

Using artificial substrates, a periphyton baseline pattern has been established. Because no similar work has been carried out on Lough Gill, long-term temporal trends within the lake can not be discussed. Results obtained from this survey may be used in the future to estimate changes in the nutrient status of the waterbody. Regardless, it is assumed that attached growth is above normal. With other lakes in County Sligo virtually devoid of periphyton, and growth levels on the western lakes a magnitude smaller, the state of Lough Gill is becoming more questionable. Ecological and chemical water quality parameters indicate a lake in a mesotrophic state (see Section 1.3.4). It would appear that periphyton monitoring and sediment core analyses tell a tale of a lake on the verge of over-enrichment, heading towards eutrophication. The lake system has always been considered quite productive and it may be in the sediments and the littoral zone where signs of nutrient enrichment first become apparent.

When applying the Autotrophic Index (AI) to monthly glass slide results (see Figure 43, Appendix III for calculations and Figure 15 for trends) most sites over the study period had a value around 100, which indicated normal water quality. During the spring pulses of 1997 and 1998 AI values increased considerably with levels from 250 upwards. This would point towards heterotrophic associations within the periphyton mat and indicate poor water quality. The AI results from Lough Gill must be considered in the context of high biomass figures associated with elevated nutrient levels around the littoral zone. It must be noted that the Autotrophic Index was developed for riverine systems and its application to a lentic waterbody may exhibit some problems. The higher the AI values the greater the ratio of AFDW to chlorophyll. The high AI ratio of periphyton during spring may be associated with the organisms of the periphyton mat, their chlorophyll production or the organic material trapped within it.

The physical features of the lake may help to account for periphyton productivity. The steep underwater contouring of the lake along with limited light penetration (as a result of humic acids) confines littoral development to a thin band close to shore (see Section 1.3.2). Consequently the lake has poor macrophyte development. It is in this band around the lake that the majority of nutrient recycling occurs with phosphate and nitrate uptake by phototrophs taking place in littoral sediments (see Section 2.2.1). Limited littoral development and poor macrophyte growth may result in a shift in the phototroph population elevating growth of the attached algal mat.

Increased levels of non-point source nutrients, associated with diffusion from lands adjacent to the lake, or, slow release phosphates from peat sediments deposited on the lake bed, may influence periphyton populations around Lough Gill. It may be here that the first signs of over enrichment becomes noticeable. While mid-lake sample sites on Lough Conn indicated insignificant nutrient levels, the littoral zone experienced increased macrophyte growth and intense algal blooms associated with a eutrophic waterbody (McGarrigle 1990, see Section 2.3.3). The lake in-effect became enriched in the littoral zone prior to deterioration of the whole system. A similar situation may be occurring within Lough Gill. Apart from substantial periphyton biomass, phytoplankton populations within the littoral zone are more dramatic than open water sites. Goldman (1981) found that it may be in the littoral zone that algal growth, associated with nutrient enrichment, is first perceived as an aesthetic, economic or ecological nuisance.

Artificial substrates indicate peak levels of periphyton during the growing season of *L. uniflora* from spring to early summer. Limiting the macrophytes available light during this period could seriously reduced photosynthesis, limit plant biomass and result in a decline in its distribution. The Lough Gill Environmental Management Programme undertook the mapping of macrophyte cover around the lake. Future changes in macrophyte growth as a result of periphyton pressures may be better understood from these maps. Nevertheless, continuous blanketing of *L. uniflora* during its growing season will undoubtedly limit growth and distribution patterns favouring a more emergent plant such as *Phragmites australis* Cav. (Common Reed) or *Phalaris arundinacea* L. (Reed Canary-grass).

5.6.3 Aquatic invertebrates

Macroinvertebrates found on glass slides were collected and identified (see Table 14). The majority of invertebrates found in the slides were gastropods (genera and density found on sets of glass slides can be seen in Table 15). Other macroinvertebrates found included Ephemeroptera and Trichoptera and *Chironomidae* larvae. Snail populations would appear to be the predominant macroinvertebrate benefiting from periphytic growth (see Table 103, Appendix IV.e).

While there is no evidence to suggest that periphyton has a negative impact on aquatic macroinvertebrates. The presence of a thick organic mat reducing water clarity during spring and early summer may alter stone, gravel or silt habitats of the macroinvertebrate. These areas may become more organic in nature. The long-term effect of dense periphyton cover could see a change in the macroinvertebrate community of the Lough Gill littoral zone. The elevated periphyton levels may shift the balance of the food web favouring periphyton grazers. This change may benefit some macroinvertebrates however it may 'squeeze' out others.

5.6.4 Aesthetic impact

The growth of this brown periphytic biomass during the spring and summer of 1997 and 1998 raised considerable interest. This may be a result of the authors' close involvement with the subject or the lakes' greater public attention through the Lough Gill Environmental Management Project. The gelatinous nature of the material growing close to the waters' edge (see Plate 2) makes it quite prominent to the public using the lake and its surrounding shores. Fishermen and people walking the lakes' shoreline have noted how dangerously slippery it can be. When re-suspended in the water column its brown clot-like appearance has been falsely associated with slurry or sewage. After the lake recedes during dry weather the dark material attached to all emerged surfaces dries to a light brown (see Plate 5). This algal crust can be most unsightly along the shores of the lake.

With the shoreline of Lough Gill receiving more recreational use than the main water body, it follows that the waters of the littoral zone are more closely scrutinised by the public. A blue/green bloom was dispersed in the open water of Lough Gill during August 1997. After calm conditions early in September a scum of concentrated algae formed along the shores of the littoral zone (see Plate 4). While previously under close scrutiny by Sligo and Leitrim County Councils, it was only at this point that it become of concern to the public. Periphyton because of its location in the littoral zone receives similar attention. This aesthetic problem can have a knock on effect upon public perception, tourism and the revenue tourism generates. A deteriorating image of Lough Gill, however false, may undermine the publics' confidence in the safety of Sligo towns' water supply.

5.6.5 Lough Gill compared with other lakes

Work by Dr. Rick Barbiero on the Western Lakes Project would appear to be the only other comprehensive periphyton study done in Ireland to date. A comparison of periphyton biomass and chlorophyll levels found Lough Gill to be at least a magnitude greater than those of Loughs Mask, Conn and Cullen during 1996 and 1997 (Dr. Kieran McCarthy pers. comm., data not published at time of printing). These comparatively high periphyton levels on Lough Gill are of great concern. This may indicate the early stages of enrichment and predict Lough Gills' future nutrient status and water quality. It would also confirm the seriousness of the growth around Lough Gill during spring and summer and would warrant its close examination in future years.

During the spring of 1998 periphyton blanketing submersed surfaces in Lough Gill was visually noted to be much greater than Lough Arrow, Glenade Lake and Glencar Lake, all within County Sligo. During the same period periphyton in the lakes of Killarney, which are considered to be quite enriched, appeared to have far less attached growth than Lough Gill. The comparative growth of attached algae around Lough Gill may indicate a system undergoing a process of enrichment not previously evident in other monitoring methods.

6.0 Conclusions and recommendations

6.1 Conclusions

6.1.1 Temporal trends in Periphyton

- The brown gelatinous material found in the littoral zone of Lough Gill particularly during spring and summer was identified as 'periphyton', a complex mat made up predominantly of algae but which can also contain bacteria, fungi and microscopic animals as well as trapped organic and inorganic detritus.

- Periphyton in Lough Gill exhibits two growth pulses over an annual cycle. Substantial growth occurs during spring, this is followed by a smaller pulse in August and September after which amounts drop to a background level throughout the winter.

- Diatom algae (Bacillariophyta), which dominated the periphyton mat over the entire year, accounted for the spring and autumn growth pulses. Green algae (Chlorophyta) and subsequently blue/green algae (Cyanophyta) became more prominent through the late summer and autumn, however, diatoms still make up over 70% of the mat during this period.

- The predominant diatom genera found on the slides include *Cocconeis*, *Cymbella*, *Fragilaria*, *Gomphonema*, *Nitzschia* and *Synedra*. Chlorophytes include *Chaetophora*, *Microspora*, *Stigeoclonium* and *Ulothrix*. The main Cyanophytes identified were *Anabaena*, *Aphanocapsa* and *Merismopedia*.

- From peoples observations over the last number of years periphyton levels in Lough Gill would appear to be increasing. Periphyton levels during April 1998 were considerably greater than anything previously recorded during 1997. A long-term continuation of this scenario would be most worrying pointing towards a continuing enrichment of the lake system.

6.1.2 Spatial trends in periphyton

- Over the course of the study a spatial difference in periphyton levels was observed at the six sites around the littoral zone of Lough Gill. Data from three artificial substrates indicated considerable spatial variation in materials collected.

- PCA identified one major factor which influenced the spatial variation in artificial substrate data collected from the six sites around the lakes' littoral zone. Half-moon Bay and Sriff Bay were found to be significantly different from other sites and at opposite ends of the spectrum from each other.

- Weather patterns and water movement may cause spatial differences in periphyton growth around the littoral zone of Lough Gill. Other influencing factors may include underlying geology and substrate type, sunlight and water temperature, grazer distributions and diffuse sources of nutrients from lands adjacent to the lakeshore.

- PCA found two factors accounted for the variance in data from trays of washed stones. While the major factor may be wind and water movement the position and design of this sampling device, sitting on the lake bed, may result in the substrate type of each site exerting a secondary minor influence on spatial variation patterns.

6.1.3 Periphyton and phytoplankton interactions

- Diatoms dominated open water phytoplankton during spring and early summer of 1997 however their numbers contribute significantly to the littoral water column throughout the year. The centric diatoms *Cyclotella* and *Stephanodiscus*, which were predominant in main waterbody, had a very low distribution around the littoral zone. The detached periphyton, *Cocconeis*, *Cymbella*, *Gomphonema*, *Nitzschia* and *Synedra*, made up a notable proportion of the littoral zone phytoplankton during this time.

- Littoral zone phytoplankton are greatly influenced by detached benthic algae. Storm conditions during the spring growth pulses can significantly reduce water clarity. Its impact on water quality is unknown. The appearance of brown algal clots is usually localised to the littoral zone. Reductions in water clarity are temporary with prevailing weather patterns dictating detachment and sedimentation rates.

- The appearance of the detached periphyton mat, metaphyton, on the surface of Lough Gill during the summer months is a result of trapped oxygen and other gases lifting the mat off its substrate into the water column. However unsightly, the mats impact on water quality is unknown. Its appearance in such high quantities would indicate substantial periphyton growth along the littoral zone of the waterbody.

- The phytoplankton populations of Lough Gill exert little influence upon the attached algae of the littoral zone. Very low number of planktonic cells settle out into the attached mat.

6.1.4 Periphyton as a monitoring method

- Periphyton would appear to be a good monitor of lake productivity because its phototrophic nature, fast growth rate and fixed position make it indicative of the nutrient status in a lakes' littoral zone. Nutrient enrichment may manifest itself in the littoral zone faster than the open waters therefor it could be a good indicator of future process within a lake system.

- Of the three artificial substrates glass slides were found to be indicative of naturally occurring periphyton populations on submerged substrates. Trays of washed stone and artificial Littorella plots, because of their position on the bed of the littoral zone, collected considerable amounts of inorganic material making them unrepresentative of natural occurring periphyton assemblages.

6.1.5 The impact of periphyton

- While the lake is quite productive the appearance of the periphyton mat in large quantities around the littoral zone would seem to be an indication of increased nutrient concentrations. This may be a result of land management practices around the shores of the lake or a legacy of the Bonet River drainage scheme. Regardless of the causes, periphyton growth around Lough Gill is considerably greater than other lakes studied in the west of Ireland and indicates enrichment patterns not evident in open water analysis.

- Considerable periphyton growth, which may be limited to only a thin band around the lake, could contribute to a large proportion of Lough Gills' primary production and may significantly influence the nutrient budget of the entire waterbody. This may imply that the lake is far more productive than its mesotrophic status would suggest.

- *Littorella uniflora* on the bed of the littoral zone is particularly vulnerable to blanketing from periphyton, which may result in reduced levels of plant biomass. This may lead to a shift in the macrophyte ecology of the lakeshore with emergent macrophytes dominating the littoral zone. Such ecological changes, if they were to occur, would be indicative of a system becoming eutrophic.

- Gastropods were the predominant macroinvertebrate found grazing the algae on glass slides. Elevated periphyton levels may benefit algal grazers resulting in a shift of the littoral zone food web putting pressure on other species. Periphyton blanketing the sediments and other habitats of aquatic macroinvertebrates may change the littoral ecology pushing out species that use stone and sand in favour of ones that prefer organically enriched silts and mud.

- Aesthetically, the coating of the littoral zone in periphyton during spring and summer is quite unsightly. The mats' dispersion during peak growth can appear quite disturbing and has been falsely mistaken for sewage or animal slurry. The material presents a minimal health risk but could damage the image of Lough Gill as a place of natural beauty influencing the lakes' recreational uses, having a knock-on financial effect on tourism.

- Detached periphyton entering water intakes may be costly in terms of water purification. However, it would appear unlikely that detached algae in the water column of Lough Gill would enter Sligo water supply inlet pipes. The location of the inlet at the mouth of the Garavogue River below the low water mark, is a sufficient distance from the lakes' littoral zone to limit abstraction of dispersed algal clots.

6.2 Recommendations

6.2.1 Using periphyton to monitor lake productivity

The following recommendations would be made for future studies using artificial substrates to monitor periphyton as an indicator of lake productivity.

- Periphyton are a good bio-monitor when estimating littoral zone productivity.
- Glass slides collect periphyton that is indicative of natural populations making them a suitable substrate when monitoring the productivity of a lakes' littoral zone.
- The number and location of sample sites can be vital in the success of a monitoring programme. Spatial differences in periphyton cover between sites could lead to an underestimation or an overestimation of growth levels.
- While algal identification and estimation of chlorophyll levels provide valuable information, biomass results are a quick and easy method of determining periphyton growth.
- The application of factorial analysis can provide a valuable insight into the elements effecting spatial growth patterns.

6.2.2 Lough Gill Littoral Zone:

Following the periphyton monitoring programme it would appear that processes are occurring in the Lough Gill littoral zone which are indicative of a system undergoing moderate stages of enrichment. For this reason close observation should be kept on this area. The following points are suggested:

- Implementation of areas within the Lough Gill Management Plan pertaining to the reduction of diffuse inputs of phosphorus. This would include the following; slurry spreading during proper weather conditions, maintenance of a nutrient buffer zone adjacent to the lake shores, adherence to Forestry Service guidelines on planting and harvesting trees and promotion of phosphorus-free detergents.
- Observation of periphyton growth from March to May with placement of glass slides for biomass analysis at two sites around the lake during April. Sites suggested are Sriff Bay and Bunowen Bay.
- Observation and monitoring of phytoplankton in the lakes' littoral zone during summer months.

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Appendices

I. Placement and retrieval dates of artificial substrates

Year	Sampling period	Sampling code	Placement date	Retrieval date	Exposure period (days)
1997	March	M1	05-Mar-97	03-Apr-97	29
	April	M2	03-Apr-97	29-Apr-97	26
	May	M3	29-Apr-97	03-Jun-97	35
	June	M4	03-Jun-97	02-Jul-97	29
	July	M5	02-Jul-97	05-Aug-97	34
	August	M6	05-Aug-97	09-Sep-97	35
	September	M7	09-Sep-97	06-Oct-97	27
	October	M8	06-Oct-97	03-Nov-97	28
	November	M9	03-Nov-97	01-Dec-97	28
	December	M10 (not obtained)*	01-Dec-97	07-Jan-98	37
1998	January	M11 (not obtained)*	07-Jan-98	04-Feb-98	28
	February	M12	04-Feb-98	03-Mar-98	27
	March	M13	03-Mar-98	01-Apr-98	29
	April	M14	01-Apr-98	05-May-98	34
	May	M15	05-May-98	02-Jun-98	28
Average exposure period of 1 month glass slides:					**30**

Table 44: Placement and Retrieval Dates of Monthly Glass Slides. (* = months not sampled in December 97 & January 98 due to poor weather conditions)

Sampling period	Sampling code	Placement date	Retrieval date	Exposure period (days)
1	W1	10-Apr-97	24-Apr-97	14
2	W2	24-Apr-97	08-May-97	14
3	W3	08-May-97	28-May-97	20
4	W4	28-May-97	12-Jun-97	15
Average exposure period of bi-weekly glass slides:				**16**

Table 45: Placement and retrieval dates of bi-weekly glass slides from sample sites around the littoral zone of Lough Gill.

Date	Sampling Period	Sampling Code	Placement Date	Retrieval Date	Exposure Period (days)
1997	February	Lt 1	30-Jan-97	11-Mar-97	40
	March	Lt 2	11-Mar-97	10-Apr-97	30
	April	Lt 3	10-Apr-97	14-May-97	34
	May	Lt 4	14-May-97	25-Jun-97	42
	June	Lt 5	25-Jun-97	21-Jul-97	26
	July	Lt 6	21-Jul-97	17-Aug-97	27
	August	Lt 7	17-Aug-97	15-Sep-97	29
	September	Lt 8	15-Sep-97	13-Oct-97	28
	October	Lt 9	13-Oct-97	10-Nov-97	28
	November	Lt 10	10-Nov-97	08-Dec-97	28
	December	Lt 11	08-Dec-97	13-Jan-98	36
1998	January	Lt 12	13-Jan-98	09-Feb-98	27
	February	Lt 13	09-Feb-98	09-Mar-98	28
	March	Lt 14	09-Mar-98	07-Apr-98	29
Average exposure period of 1 month plastic littorella plots:					**31**

Table 46: Placement and Retrieval Dates of Plastic Netting Plots from Littoral Sample Stations around the shoreline of Lough Gill.

Date	Sampling Period	Sampling Code	Placement Date	Retrieval Date	Exposure Period (days)
1997	April	St 1	17-Apr-97	14-May-97	27
	May	St 2	14-May-97	16-Jun-97	33
	June	St 3	16-Jun-97	21-Jul-97	35
	July	St 4	21-Jul-97	17-Aug-97	27
	August	St 5	17-Aug-97	15-Sep-97	29
	September	St 6	15-Sep-97	13-Oct-97	28
	October	St 7	13-Oct-97	10-Nov-97	28
	November	St 8	10-Nov-97	08-Dec-97	28
	December	St 9	08-Dec-97	13-Jan-98	36
1998	January	St 10	13-Jan-98	09-Feb-98	27
	February	St 11	09-Feb-98	09-Mar-98	28
	March	St 12	09-Mar-98	07-Apr-98	29
	April	St 13	07-Apr-98	11-May-98	34
Average exposure period of 1 month stone trays in the littoral zone around Lough Gill:					**30**

Table 47: Placement and retrieval dates of stone trays from littoral sample stations around the shoreline of Lough Gill.

Year	Periphyton			Phytoplankton	
	Sampling period of glass slides	Sampling code of glass slides	Retrieval date of glass slides	Sampling code of phytoplankton samples	Collection dates of phytoplankton samples
1997				P1	05-Mar-97
	March	M1	03-Apr-97	P2	03-Apr-97
	April	M2	29-Apr-97	P3	29-Apr-97
	May	M3	03-Jun-97	P4	03-Jun-97
	June	M4	02-Jul-97	P5	02-Jul-97
	July	M5	05-Aug-97	P6	05-Aug-97
	August	M6	09-Sep-97	P7	09-Sep-97
	September	M7	06-Oct-97	P8	06-Oct-97
	October	M8	03-Nov-97	P9	03-Nov-97
	November	M10 (not obtained)*	01-Dec-97	P10	01-Dec-97
1998	December	M11 (not obtained)*	07-Jan-98	P11	07-Jan-98
	January	M11	04-Feb-98	P12	04-Feb-98
	February	M12	03-Mar-98		
	March	M13	01-Apr-98		
	April	M14	05-May-98		
	May	M15	02-Jun-98		

Table 48: Retrieval dates of glass slides compared to collection dates of phytoplankton samples from 1997 and early 1998. Slides and phytoplankton samples taken from six sample sites in the littoral zone of Lough Gill. (* = periods not sampled due to poor weather conditions)

II. Weather and water temperature data

Sample site:	**TEMPERATURE (Deg.C)**							
	S1	S2	S3	S4	S5	S6	**Average site temperature**	Standard Error
1997								
09-Jan-97	No data collected*							
30-Jan-97	No data collected*							
04-Feb-97	No data collected*							
13-Feb-97	No data collected*							
20-Feb-97	No data collected*							
26-Feb-97	No data collected*							
05-Mar-97	No data collected*							
11-Mar-97	No data collected*							
18-Mar-97	No data collected*							
25-Mar-97	7.0	6.1	6.2	6.1	6.1	6.0	**6.3**	0.40
03-Apr-97	6.0	6.1	6.6	6.1	6.3	6.3	**6.2**	0.23
10-Apr-97	7.1	7.7	10.0	10.0	10.8	11.4	**9.5**	1.83
17-Apr-97	10.0	10.0	9.9	10.0	10.1	10.8	**10.1**	0.35
24-Apr-97	8.3	8.7	9.0	8.8	8.6	8.1	**8.6**	0.35
29-Apr-97	8.0	8.0	8.1	8.2	9.0	8.4	**8.3**	0.41
08-May-97	8.0	9.1	8.9	9.0	8.9	9.0	**8.8**	0.43
14-May-97	9.8	9.6	10.0	10.0	9.9	10.2	**9.9**	0.22
20-May-97	13.0	11.8	10.3	11.0	12.1	13.0	**11.9**	1.15
28-May-97	13.2	13.6	12.2	12.0	14.0	15.3	**13.4**	1.30
03-Jun-97	15.2	11.9	11.2	11.8	15.8	15.6	**13.6**	2.29
12-Jun-97	13.3	12.6	12.0	12.2	13.1	13.9	**12.9**	0.76
16-Jun-97	12.5	13.3	15.0	15.0	14.7	15.3	**14.3**	1.20
25-Jun-97	13.1	13.4	13.0	13.1	13.8	12.9	**13.2**	0.35
02-Jul-97	11.0	12.0	12.4	11.7	11.3	11.1	**11.6**	0.58
09-Jul-97	14.7	17.3	17.4	17.1	15.0	16.9	**16.4**	1.29
16-Jul-97	14.1	15.2	15.8	15.6	14.9	14.2	**15.0**	0.75
21-Jul-97	17.1	18.0	18.0	17.9	16.6	17.8	**17.6**	0.62
30-Jul-97	15.6	16.1	16.0	16.2	15.4	14.8	**15.7**	0.56
05-Aug-97	15.0	14.8	14.7	14.9	15.0	15.1	**14.9**	0.16
13-Aug-97	17.2	16.6	16.2	16.1	16.4	16.8	**16.6**	0.43
17-Aug-97	16.7	17.7	17.9	17.8	18.2	18.0	**17.7**	0.56
21-Aug-97	17.4	17.1	17.0	17.0	17.1	17.6	**17.2**	0.26
09-Sep-97	14.7	14.4	14.5	14.1	14.1	14.9	**14.5**	0.34
15-Sep-97	12.4	12.9	13.1	14.0	13.9	14.1	**13.4**	0.74
23-Sep-97	12.2	13.0	13.1	12.0	12.9	13.1	**12.7**	0.52
29-Sep-97	12.8	13.0	13.2	13.4	13.1	13.0	**13.1**	0.22
06-Oct-97	12.0	12.6	12.4	12.6	12.5	12.5	**12.4**	0.24
13-Oct-97	10.0	11.4	11.8	11.0	11.1	11.4	**11.1**	0.65
21-Oct-97	12.0	11.4	12.2	12.1	12.7	12.1	**12.1**	0.44
28-Oct-97	10.4	11.5	11.6	11.4	11.5	11.0	**11.2**	0.49

Table 49: Temperature levels from six sites around the littoral zone of Lough Gill on the specified dates. (* = indicates dates where water temperature was not noted)

Sample site:	TEMPERATURE (Deg.C)							
	S1	S2	S3	S4	S5	S6	**Average site temperature**	Standard Error
03-Nov-97	12.4	12.4	12.6	12.8	12.9	12.5	**12.6**	0.22
10-Nov-97	9.6	10.5	10.4	10.6	10.5	10.4	**10.3**	0.39
18-Nov-97	12.1	12.4	11.9	12.0	12.1	12.0	**12.1**	0.18
24-Nov-97	9.6	9.9	9.8	9.7	9.9	9.9	**9.8**	0.13
01-Dec-97	8.7	8.9	9.1	8.6	8.8	8.6	**8.8**	0.21
08-Dec-97	8.8	8.8	8.7	8.6	8.8	8.9	**8.8**	0.11
17-Dec-97	6.4	6.8	7.3	6.8	6.9	6.6	**6.8**	0.32
22-Dec-97	6.2	6.5	6.2	6.8	6.7	6.8	**6.5**	0.30
30-Dec-97	5.7	5.9	5.7	5.8	5.9	5.9	**5.8**	0.10
1998								
07-Jan-98	5.3	5.6	5.5	5.4	5.7	5.4	**5.5**	0.16
13-Jan-98	5.5	5.9	5.4	5.5	5.3	5.7	**5.6**	0.23
19-Jan-98	5.0	5.1	5.5	4.9	4.8	4.9	**5.0**	0.27
28-Jan-98	4.2	5.0	4.8	4.8	4.9	4.8	**4.8**	0.30
04-Feb-98	5.9	6.1	6.2	6.2	5.9	5.8	**6.0**	0.18
09-Feb-98	6.9	6.6	6.7	6.8	6.2	6.1	**6.5**	0.35
16-Feb-98	7.6	7.9	7.8	7.9	7.7	7.6	**7.8**	0.15
23-Feb-98	7.4	7.6	7.6	7.4	7.7	7.6	**7.6**	0.13
03-Mar-98	5.8	5.9	5.9	6.1	5.5	5.8	**5.8**	0.21
09-Mar-98	7.2	7.5	6.9	6.8	6.7	7.0	**7.0**	0.31
18-Mar-98	8.7	8.2	9.7	9.1	9.3	9.3	**9.1**	0.56
23-Mar-98	8.2	8.1	8.2	7.8	7.7	7.8	**8.0**	0.24
01-Apr-98	8.6	8.6	8.2	8.3	7.9	8.8	**8.4**	0.35
07-Apr-98	9.0	9.0	9.1	9.2	9.3	9.0	**9.1**	0.13
15-Apr-98	7.7	8.0	8.0	7.8	8.1	8.0	**7.9**	0.16
20-Apr-98	8.9	9.0	8.0	7.9	8.6	8.7	**8.5**	0.49
27-Apr-98	9.1	9.9	10.1	9.9	9.6	9.1	**9.6**	0.46
05-May-98	9.9	10.9	11.0	11.2	10.4	9.6	**10.5**	0.68
11-May-98	11.9	10.9	10.5	10.7	10.3	11.6	**11.0**	0.67
19-May-98	14.7	17.3	17.5	16.3	15.6	15.9	**16.2**	1.12
25-May-98	17.0	16.9	16.4	16.1	14.8	12.9	**15.7**	1.67
02-Jun-98	13.9	12.5	12.9	13.4	13.7	14.2	**13.4**	0.68
Range:								
Maximum	17.4	18.0	18.0	17.9	18.2	18.0	**17.7**	2.29
Minimum	4.2	5.0	4.8	4.8	4.8	4.8	**4.8**	0.10
Range	13.2	13.0	13.2	13.1	13.4	13.2	**12.9**	2.2

Table 49 (continued): Temperature levels from six sites around the littoral zone of Lough Gill on the specified dates. (* = indicates dates where water temperature was not noted)

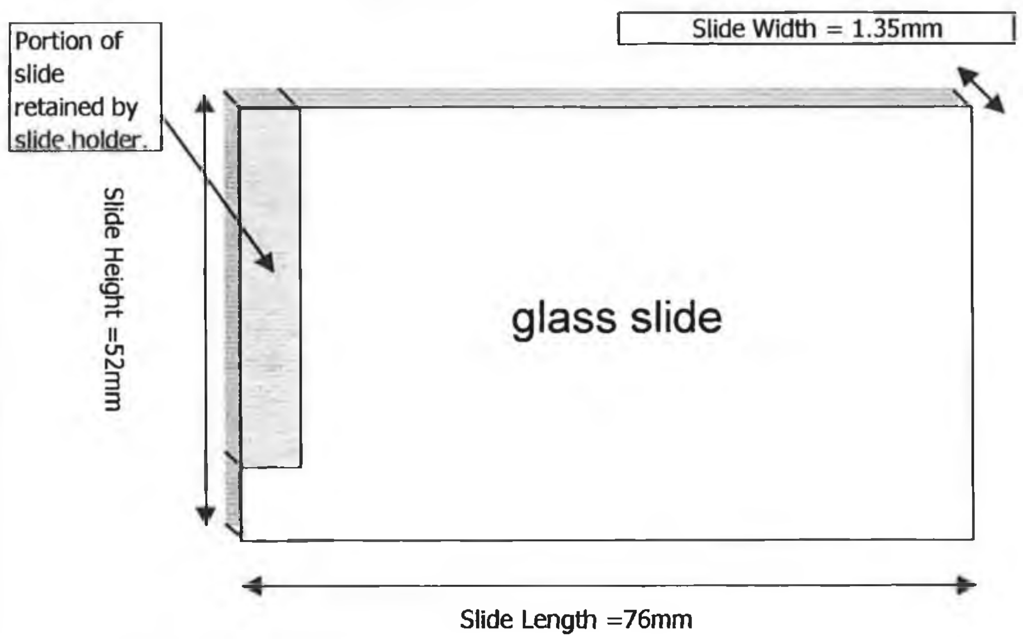
Date of Observation	Lake Height (meters)	Weather (On & Before the Specified Date)				
		Rain-fall (observed)	Wind Direct.	Wind Speed (force)	Air Temp. (^{0}C)	Visibility (observed)
1997						
9-Jan	0.70m	None	E.-S.E.	F 1-2	2~5	Moderate
30-Jan	0.70m					
04-Feb	1.00m	Scattered	E.-S.E.	F 1-2	3~5	Moderate
13-Feb	1.50m	Extensive	N.W.	F 5-6	1~3	Poor
20-Feb	1.60m	Extensive	N.W.	F 4-5	3~5	Poor
26-Feb	1.60m	Extensive	N.-N.W.	F 6	5~7	Moderate
05-Mar	1.20m	Light	N.W.	F 1-2	5~8	Good
11-Mar	1.10m	None	E.-S.E.	F 1	10~15	Moderate
18-Mar	1.00m	Scattered	W.-N.W.	F 5-6	10~14	V. Good
25-Mar	1.00m	Extensive	S.-S.E.	F 2-3	12~16	Moderate
03-Apr	0.90m	Scattered	N.W.	F 4-5	12~16	Good
10-Apr	0.80m	None	N.W.	F 1	16~20	V. Good
17-Apr	0.75m	None	W.	F 0	14~18	Moderate
24-Apr	0.65m	None	N.W.	F 2	14~18	Moderate
29-Apr	0.91m	Extensive	N.W.	F 3	12~14	Moderate
08-May	0.95m	Scattered	N.W.	F 1	10~12	Moderate
14-May	1.09m	Scattered	S.-S.W.	F 1	14~18	Good
20-May	0.95m	Scattered	Calm	F 0	16~19	Poor
28-May	0.85m	Light	N.E.	F 1	16~21	V. Good
03-Jun	0.74m	None	E.	F 2	20~22	V. Good
12-Jun	0.72m	None	N.-N.W.	F 1	16~20	Poor
16-Jun	0.69m	None	W.-S.W.	F 0-1	17~21	V. Good
25-Jun	0.76m	Extensive	N.E.	F 2-3	12~16	Moderate
02-Jul	0.78m	Scattered	N.-N.E.	F 4-5	11~15	Poor
09-Jul	0.72m	Light	S.E.	F 0-1	18~21	V. Good
16-Jul	0.78m	Scattered	W.	F 1-2	18~21	Moderate
21-Jul	0.81m	None	W.-N.W.	F 1-0	19~24	Good
30-Jul	1.01m	Extensive	S.W.	F 4	18~20	Good
05-Aug	1.10m	Extensive	N.E.	F 2	17~20	Moderate
13-Aug	0.85m	Light	S.E.	F 2	19~22	V. Good
17-Aug	0.80m	Light	N.W.	F 0-1	20~22	V. Good
21-Aug	0.75m	None	Calm	F 0	19~22	V. Good
9-Sep	1.04m	Scattered	N.W.	F 2	15~18	Good
15-Sep	0.99m	Extensive	W.-S.W.	F 4	16~19	Good
23-Sep	0.99m	Scattered	S.E.	F 0-1	18~20	Good
29-Sep	0.80m	None	S.-S.W.	F 0-1	16~19	Good

Table 50: Lake height and weather patterns observed on the specified sampling dates. Information on air temperature obtained from daily newspapers.

Date of Observation	Lake Height (meters)	Weather (On & Before the Specified Date)				
		Rain-fall (observed)	Wind Direct.	Wind Speed (force)	Air Temp. (^{0}C)	Visibility (observed)
06-Oct	0.74m	Little	S.-S.W.	F 2	15~18	Good
13-Oct	1.20m	V. Extensive	N.-N.W.	F 2	12~16	Moderate
21-Oct	1.29m	V. Extensive	N.E.	F 2-3	10~12	V. Good
28-Oct	0.95m	None	S.E	F 4-5	8~10	V. Good
03-Nov	0.83m	Scattered	S.E.	F 0-1	12~14	Poor
10-Nov	0.95m	Extensive	N.-N.W.	F 2-3	9~11	Moderate
18-Nov	1.55m	V. Extensive	S.W.	F 3	12~15	Poor
24-Nov	1.26m	Extensive	S.-S.E.	F 3	9~12	Moderate
01-Dec	1.09m	Scattered	N.-N.W.	F 1-2	7~10	Moderate
08-Dec	1.25m	V. Extensive	W.-S.W.	F 5-6	8~12	Poor
17-Dec	1.20m	Scattered	S.E.	F 1-2	4~7	Moderate
22-Dec	0.99m	Extensive	N.E.	F 4-5	6~9	Poor
30-Dec	1.35m	Extensive	S.-S.W.	F 2-3	6~9	Poor
1998						
7-Jan	1.61m	Scattered	S.E.	F 2-3	3~6	Good
13-Jan	1.56m	Extensive	Calm	F 0-1	6~8	Moderate
19-Jan	1.65m	V. Extensive	N.E.	F 1	1~3	V. Good
28-Jan	1.21m	None	E.	F 0-1	1~3	Moderate
04-Feb	0.92m	Scattered	N.W.	F 2	4~6	Moderate
09-Feb	0.98m	Light	N.W.	F 2-3	8~10	Poor
16-Feb	1.05m	Light	N.W.	F 3	12~14	Moderate
23-Feb	1.03m	Light	W.-S.W.	F 3	9~12	Good
03-Mar	1.24m	Extensive	N.W.	F 1	6~9	Moderate
09-Mar	1.39m	Extensive	W.	F 0-1	5~8	Good
18-Mar	1.03m	None	N.W.	F 1	10~14	V. Good
23-Mar	0.98m	Light	S.-S.W.	F 1	8~12	Moderate
01-Apr	0.98m	Light	S.E.	F 2	10~14	Good
07-Apr	1.04m	Scattered	N.E.	F 2	8~10	Moderate
15-Apr	0.94m	Scattered	N.	F 2-3	6~8	Good
20-Apr	0.89m	Extensive	S.W.	F 1	8~12	Good
27-Apr	1.04m	Light	S.E.	F 0	14~14	Good
05-May	0.92m	Light	W.	F 3	12~15	Moderate
11-May	1.21m	Extensive	N.E.	F 2	16~18	Moderate
19-May	0.93m	None	N.W.	F 0	19~24	V. Good
25-May	0.77m	None	W.-S.W.	F 2	12~16	Moderate
2-Jun	0.73m	None	N.E.	F 3	11~15	Moderate

Table 50 (continued): Lake height and weather patterns observed on the specified sampling dates. Information on air temperature obtained from daily newspapers.

III. Calculations and statistics



Slide dimensions:

Slide Length:	76.0mm
Slide Height:	52.0mm
Slide Width:	1.35mm

Total surface area of Glass slide: $0.00825m^2$

Slide dimensions retained in slide holder:

Slide Length:	40.0mm
Slide Height:	4.0mm
Slide Width:	1.35mm

Total surface area of slide retained in slide holder: $0.000379m^2$

Total surface area of exposed glass slide: $0.00787m^2$

Figure 36: Surface area of glass slides used in attached algal monitoring around Lough Gill.

To calculate the mean Dry Weight and Ash-Free Dry Weight from a glass slide (dimensions 76mm x 52mm x 1.35mm) by gravametric determination and report biomass per square meter of submerged surface area:

Weight of algae on one filter paper = Weight of algae from one glass slide

$$\frac{\text{grams of algae per slide}}{0.00787\text{m}^2}$$

= weight of algae (g/m^2).

(g/m^2 = g/slide(avg.) / $0.00787m^2$)

Three glass slides were used at each sample site each month during the study. A mean result was obtained from the three replicate slides.

Figure 37: Dry weight and AFDW calculations from glass slides.

To calculate the mean chlorophyll content from glass slides (dimensions 76mm x 52mm x 1.35mm), by hot methanol extraction and colourametric determination, reporting as Total Pigment content (uncorrected for presence of phaeophytins) per square meter of submerged surface area:

Absorbance figures obtained correspond to chlorophyll content per slide.

Chlorophyll (mg/slide) = 13.9 x (O.D.sample - O.D. blank) x vol. methanol (l)

13.9 = constant
O.D. = Optical Density (abs at 665nm - abs at 750nm)
vol. of methanol = 0.015 liters

$$\frac{\text{mg Chlorophyll per slide}}{0.00787\text{m}^2}$$

= Chlorophyll (mg/m^2)

Three glass slides were used at each sample site each month during the study. A mean result was obtained from the three replicate slides.

Figure 38: Chlorophyll calculations from glass slides.

To calculate the number of algal cells present, per square millimeter of submerged surface area, using glass slides as an artificial substrate.

One submerged slide per sample site was used during each exposure period of the study.
After suitable dilutions a field count was carried out using a Sedgwick-Rafter cell. This was done in triplicate.
Calculations were carried out per Sedgwick-Rafter count.

Average number of attached algae (per mm^2) was obtained from the three sets of field counts.

$$\textbf{Organisms / mm}^2 = \frac{N \times A_t \times V_t}{A_c \times V_s \times A_s}$$

N = Average Number of Organisms per Field (S-R slide)

At = Area of Sedgwick-Rafter Chamber Bottom (1000 mm2)

Vt = Volume of Original Algal Suspension (mls)

Ac = Area Counted (mm2)

Vs = Sample Volume used in Chamber (1 ml)

As = Surface Area of Glass Sampling Slide (7870mm2)

That is......

$$\textbf{Organisms / mm}^2 = \frac{N \times 1000mm^2 \times V_t}{A_c \times 1\ ml \times 7870\ mm^2}$$

For Example.....

N = 79 Algae per field

V_t = 25.5 mls of Original Algal Suspension

A_c = Average area counted $1mm^2$

$$\textbf{Organisms / mm}^2 = \frac{79\ Algae/field \times 1000mm^2 \times 25.5\ mls}{1mm^2 \times 1\ ml \times 7870\ mm^2}$$

$\Longrightarrow$ **256 Algae / mm^2**

Figure 39: Attached algal enumeration from glass slides and the calculation of cells per surface area of substrate.

To calculate the number of phytoplankton cells (cells/ml) found in water samples taken from six sites around the littoral zone of Lough Gill.
Samples were collected in conjunction with glass slides exposed for one month periods during 1997 and early 1998.

2 liters of water was collected and preserved at each site.
Samples were left to stand in the dark for 3 weeks after which approximately 1700mls was siphoned slowly of the top. The remaining volume and concentrated algae at the bottom of the container were retained for enumeration and identification.

I = Initial volume of sample (mls)
R = Volume remaining after siphoning (mls)

Strip counts were carried out on the majority of samples using a Sedgwick-Rafter slide.
Enumeration was by total cell count reporting to cells/ml.

Strip Count:

$$\frac{C \times 1000\text{mm}^3}{L \times D \times W \times S}$$

= cells/ml (concentrated volume)

C = number of organisms counted
L = Length of each strip (50mm)
D = Depth of each strip (1mm)
W = Width of each strip (1mm)
S = Number of strips counted

One strip was counted per Sedgwick-Rafter slide.
Three Sedgwick-Rafter slides were used per sample.

$$\frac{\text{cells/ml (concentrated volume)} \times I\ (2000\text{mls})}{R\ (\text{mls})}$$

= cells/ml (original sample)

Numbers were reported to mils of original volume, reflecting the figures present in the water column of the littoral zone on the day of sampling.

Figure 40: Phytoplankton enumeration from water samples taken in conjunction with the collection of monthly glass slides.

To calculate the dry weight and ash free dry weight of attached materials and periphyton from cut portions of plastic netting submerged around the littoral zone of Lough Gill:

Littorella plots assumed to have 100 cm^2 ($0.01m^2$) submerged surface area of *Littorella* growth.

V = Volume of washings collected from a *Littorella* plot in the laboratory (mls.)
F = Volume of washings passed through a 11.0cm Whatman GFC filter paper (mls.)

A = Weight of pre-washed, dry filter paper (grams)
B = Weight of filter paper and solids from **F** after drying at 103° C (grams)
C = Weight of filter paper and solids from **F** sfter ashing at 500° C (grams)

Dry weight:

$$\frac{(B - A) \times V}{F}$$

= dry weight of material on a *Littorella* plot ($g/0.01m^2$)

Dry weight of plot ($g/0.01m^2$) x 100

= Dry weight (g/m^2)

Ash free dry weight:

$$\frac{(B - C) \times V}{F}$$

= Ash free dry weight of material on *Littorella* plot ($g/0.01m^2$)

Ash free dry weight ($g/0.01m^2$) x 100

= Ash free dry weight (g/m^2)

Initially three plastic plots per site were positioned per exposure period, this was increased to five plots per site (to reduce standard error between plots). A mean result was reported for the number of plots collected per site.

Figure 41: Dry weight and ash free dry weight calculations for Plastic *Littorella* plots.

To calculate the dry weight and ash free dry weight of attached materials and periphyton from trays of washed stones submerged around the littoral zone of Lough Gill:

Trays had internal dimensions 221mm by 261mm.
Trays assumed to have an internal surface area of $0.05768m^2$.
Measurments relate to $0.05768m^2$ submerged area of littoral zone.

V = Volume of washings collected from a tray in the laboratory (mis.)
F = Volume of washings passed through a 11.0cm Whatman GFC filter paper (mls.)

A = Weight of pre-washed, dry filter paper (grams)
B = Weight of filter paper and solids from **F** after drying at 103^o C (grams)
C = Weight of filter paper and solids from **F** sfter ashing at 500^o C (grams)

Dry weight:

$$\frac{(B - A) \times V}{F}$$

= dry weight of material in a tray ($g/0.05768m^2$)

$$\frac{\textbf{Dry weight of tray } (g/0.05768m^2)}{0.05768m^2}$$

= Dry weight (g/m^2)

Ash free dry weight:

$$\frac{(B - C) \times V}{F}$$

= Ash free dry weight of material in a tray ($g/0.05768m^2$)

$$\frac{\textbf{Ash free dry weight } (g/0.05768m2)}{0.05768m^2}$$

= Ash free dry weight (g/m^2)

Initially three trays per site were positioned per exposure period, this was increased to five plots per site (to reduce standard error between plots). A mean result was reported for the number of trays collected per site.

Figure 42: Dry weight and ash free dry weight calculations for trays of washed stones.

Figure 43: Calculation of the Autotrophic Index (AI) from ash free dry weights and chlorophyll content of periphyton communities

The Autotrophic Index (AI) is a means of determining the trophic nature of the periphyton community. 'Standard Methods' (A.P.H.A. 1985) noted that AI is an approximate means of describing changes in periphyton communities between sampling locations.

It is calculated as follows:

$$AI = \frac{\text{Biomass (ash-free dry weight of organic matter) mg/m}^2}{\text{Chlorophyll } a \text{ (mg/m}^2\text{)}}$$

50 to 200 = Normal AI value range

>200 = Indicates poor water quality (heterotrophic associations)

This index was applied to results glass slides exposed for one month periods at six sites situated around the littoral zone of the lake. For example at site S1 the AI value for March 1997 was 95. This was calculated as follows.

AFDW = 4000.0 mg/m^2

Chlorophyll *a* = 42.0 mg/m^2

$$AI = \frac{4000.0 \text{ mg/m}^2}{42.0 \text{ mg/m}^2} = 95$$

It should be noted that this is more applicable to lotic waters. Also organic material trapped in the periphyton community may effect the index. Nonliving organic material may inflate the numerator and produce disproportionately high AI values. The location of the glass slides in the water column during turbulent weather conditions may be congenial to the collection of such material. However it must be assumed that this occurs at all sites, and although it may limit comparisons with other lentic systems, sites within Lough Gill may be quite analogous.

Figure 44: Estimation of Standard Error from analysis of replicate artificial substrates and other samples taken from Lough Gill

Two areas of the project required analysis of standard error:

1. The error between replicate artificial substrates submerged at sample sites.
   For each exposure period glass slides had a maximum of three replicates per site, trays of stones and plastic *Littorella* plots also had three replicates. After three months of sampling stones and *Littorella* replicates were increased to five each in order to reduce variation and standard error.
2. The error between replicate algal counts using a Sedgwick-Rafter slide.
   In carrying out field counts for periphyton five fields were randomly selected in each Sedgwick-Rafter slide. Three slides were used per sample. The standard error between the three slides was calculated.
   Phytoplankton numbers were estimated by strip counts. Three slides were used and one strip per slide was counted. Again the standard error between the three slides was calculated.

From replicate samples taken at each site the mean (μ) and population standard deviation (s) was estimated:

$$\mu = \frac{\sum X}{n}$$

A population standard deviation is chosen however n is small (n <30) and a normal distribution will not apply.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

To achieve the standard error of a sample for a small population *Bessel's correction* must be applied. The population standard deviation is biased and underestimates the population variance.

$$\hat{\sigma} = s * \sqrt{\frac{n}{n-1}} = \frac{s}{\sqrt{n-1}}$$

What is obvious from both areas requiring analysis was the small sample population ($n = / < 5$).

These small sample sizes will introduce further sampling errors in the estimation of standard error.

In order to find a correct interval estimate the sample standard deviation must be multiplied its *t* distribution.

$$\hat{\sigma} = \frac{s}{\sqrt{n-1}} * t$$

From standard statistical tables the 95% interval estimate (*t*) was obtained. Thereby the mean, +/- standard error, was as follows:

$$\mu +/- \hat{\sigma} \; * t$$

For Example:

From washed stone sample St 6 exposed during September 1997, site S6 at Tobernalt Bay had the following results from five trays of stones exposed for 28 days.

Tray number	Dry Weight (g/m^2)
1	17.6
2	15.7
3	20.8
4	16.7
5	15.2
μ	17.2

Standard error with 95% confidence levels was calculated as follows:

Sample standard deviation $$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n}} = 1.98$$

To this *Bessel's correction* must be applied.

$$\hat{\sigma} = \frac{s}{\sqrt{n-1}} = \frac{1.98}{\sqrt{5-1}} = 2.21$$

In determining 95% confidence limits with a two tailed *t*-test *t* values were obtained from Lindley and Scott (1984).

$n = 5$

$v = 4$

$t = 2.8$ (at 0.9756 confidence)

Therefor the standard error was... $\hat{\sigma} * t$ = 2.21*2.8 = 6.19

Dry weight at S6 = 17.2g/m^2 +/- 6.19

Figure 45: Wilcoxons' rank sum test for two samples

During the course of the study spatial differences between the six sites became visually evident. The significance of the variation between the sites, as well as factors influencing this variability, was unknown. Data collected from the three artificial substrates as well as phytoplankton samples taken at these six sites around Lough Gill were non-normal. For this reason non-parametric tests were applied in determining spatial variation between sites. The Wilcoxon's Rank Sum Test for Two Samples is the non-parametric analogue for the two-sample *t* test (applied to normal data) (Bailey 1985).

Like the *t* test, Wilcoxon's rank sum tests the null hypothesis that two independent samples come from the same population. The test is based on ranks issued to the combined observations from both samples put in order of ascending magnitude. Each samples' ranks are summed independently (*T* value). The normal variable *d*, with zero mean and unit standard deviation is obtained.

$$d = \frac{T - \frac{1}{2}n(n+m+1)}{\sqrt{v}}$$

n = number of data points in sample one. m = number of data points in sample two.

v is the variance of the numerator. Where there are no ties the following formula is used.

$$v = \frac{1}{12}nm(n+m+1)$$

Where ties do occur a modified formula for v is applied.

$$v = \frac{nm(N^3 - N - R)}{12N(N-1)} \qquad \text{where} \quad N = n + m$$

The reduction term R is found by adding together all the quantities $t^3 - t$ arising from each group of t tied values.

The value d can then be compared with values in the normal distribution function table.

The Normal Distribution

P	0.20	0.15	0.10	0.05	0.025
d	0.84	1.04	1.29	1.65	1.96

If the *d* value falls within the normal distribution (i.e. +/-1.96 at 95% confidence) than there is no significant difference between sites at that level of confidence. It is significant if it falls out side this band.

Figure 46: Principal Component Analysis

Principal Component Analysis (PCA) helps to unravel and understand the structure of a correlation matrix. From this it can study the correlations among interrelated quantitative variables by grouping the variables into a few components or factors. After grouping, the variables within each factor are more highly correlated with variables in that factor than with variables in other factors. In other words the analysis can identify the number of factors influencing the collection of material on artificial substrates at the six sites around the lake. It can subsequently allocate the percentage variance allocated to each factor at each site and determine if any site is varying independently. This analysis, while quite involved if carried out long hand, is a rudimentary operation for the computer package SPSS® Base 7.5 for Windows®. An example of Principal Component Analysis through SPSS® is presented in the following pages. In explaining the presentation of PCA, table headings are visible in bold.

While carrying out **Descriptive Statistics**, the package also provides a **Correlation Matrix** from which the slope of the two sample sites is identified from the particular set of data. The closer the figure to 1.0 the better the slope and the better the correlation between the two sites. From this **Communalities** is presented. For each variable the communality is the proportion of the variance of that variable that can be explained by the common factor (in other words, the squared multiple correlation of the variable with the factors). All initial components in PCA are 1, which is the total proportion of variance account for by the common factors. The estimates of communalities in the next column report the proportion of variance explained by the number of components extracted from the six sites. Where there is one component extracted its proportion of the variance is presented, where there is two their combined proportion is presented.

Tables of **Total Variance Explained** show the statistics of each factor before and after the components are extracted. For the principle component the initial and extraction statistics are always the same. In the column labelled *Total*, the eigenvalues for the multivariate space of the original variables are ordered by size. Each value is the total variance explained by a factor (the total variance of the diagonal elements of a correlation matrix). By default SPSS® extracts and computes as many components as there are eigenvalues greater than 1. These are presented on the right hand side of the table. In the following **Component Matrix** table coefficients (or loadings) that relate the variables to the components are presented. In the case where there are two components it indicates the correlation between the sets of data (sample sites S1 to S6) and each of the extracted components.

To recap, the following information can be gained from Principal Component Analysis:

Descriptive Statistics Information related to the mean and standard deviation of each data set. This was of little interest to the project because of the temporal nature of the data sets.

Correlation Matrix Provides an insight into the relationship of sites to one another with greater correlation between sites the closer the score is to 1.

Communalities This indicates the sum of percentage variance from the extracted components (be it one or more) for each sample site.

Total Variance Explained Provides the percentage variance of each component and the number of extracted components (those with an eigenvalue greater than 1).

Component Matrix This indicates the coefficient of each extracted component for each sample site. The percentage variance of each component (shown in the table of Communalities) can be obtained by squaring the presented coefficient.

In the following example dry weight data from trays of washed stone are analysed using Principal Component Analysis on the SPSS® computer package. In the 'communalities' table the principal components accounted for 88.0% to 96.3% of the variance among the six sites. The table of 'total variance explained' indicated that 2 components or factors were the source of variance between the sites. The first accounted for 72.4% of the total variance among the six sites, while the other accounted for 20.2% of what remained. In the component matrix it can be seen that the first component caused the bulk of the variation, the second had a moderate effect. Sites S3 and S5, which had very low coefficients (or loadings), were insignificantly effected by this secondary factor.

When using trays of washed stones as a monitoring method, it can be concluded that the variation in biomass between the six sites is a result of two factors. The variation is significantly caused by one factor. Sites S1, S2, S4 and S6 are effected by a secondary factor. This secondary factor exerts insignificant variance at sites S3 and S5.

Dry weight data analysis from trays of washed stones

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
S1	291.415	465.151	13
S2	125.546	126.068	13
S3	214.292	129.802	13
S4	101.169	129.802	13
S5	262.708	348.727	13
S6	64.854	66.301	13

Correlation Matrix

Correlation	S1	S2	S3	S4	S5	S6
S1	1.000	0.817	0.606	0.250	0.695	0.352
S2	0.817	1.000	0.669	0.342	0.723	0.388
S3	0.606	0.669	1.000	0.745	0.888	0.824
S4	0.250	0.342	0.745	1.000	0.842	0.827
S5	0.695	0.723	0.888	0.842	1.000	0.827
S6	0.352	0.388	0.824	0.925	0.827	1.000

Communalities

	Initial	Extraction
S1	1.000	0.910
S2	1.000	0.899
S3	1.000	0.880
S4	1.000	0.958
S5	1.000	0.963
S6	1.000	0.948

Extraction Method: Principal Component Analysis

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.346	72.434	72.434	4.346	72.434	72.434
2	1.212	20.201	92.635	1.212	20.201	92.635
3	0.188	3.139	95.774			
4	0.166	2.767	98.541			
5	7.64E-02	1.2767	99.815			
6	1.11E-02	0.185	100.00			

Extraction Method: Principal Component Analysis

Component Matrix[a]

	Component	
	1	2
1	0.711	0.636
2	0.757	0.570
3	0.937	-4.817E-02
4	0.825	-0.527
5	0.981	-1.653E-0.2
6	0.864	-0.450

Extraction Method: Principal Component Analysis

a. 2 components extracted

IV. Monthly glass slides

a. Dry weight, ash free dry weight and organic matter data from glass slides

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M1	March-97	29 days	1	8.8		20.2		19.0		8.0		10.6		2.0	
				2	9.0		19.8		17.7		8.2		10.2		1.6	
				3	11.1		17.0		16.9		8.2		11.1		2.2	
	Monthly Site Average (g/m^2) +/- Std. Error				**9.6**	3.2	**19.0**	4.3	**17.9**	2.6	**8.1**	0.3	**10.6**	1.1	**1.9**	0.8

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M1	March-97	29 days	1	3.9		7.3		8.8		3.5		3.6		1.3	
				2	3.7		7.2		5.7		3.3		4.5		1.1	
				3	4.3		5.5		7.9		4.0		4.6		1.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**4.0**	0.8	**6.7**	2.5	**7.5**	4.0	**3.6**	0.9	**4.2**	1.4	**1.3**	0.5

Percentage Organic Matter (%)	**41.2**	**35.1**	**41.8**	**44.3**	**39.8**	**67.2**

Table 51: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of March 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M2	April-97	26 days	1	7.5		7.9		18.9		2.8		11.5		2.7	
				2	6.2		6.2		16.5		3.5		14.9		2.7	
				3	7.4		7.2		14.2		2.9		15.1		3.1	
	Monthly Site Average (g/m^2) +/- Std. Error				**7.0**	1.8	**7.1**	2.1	**16.5**	5.8	**3.1**	0.9	**13.8**	5.0	**2.8**	0.6

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M2	April-97	26 days	1	2.0		2.9		8.1		1.4		4.7		1.6	
				2	1.7		2.4		6.9		1.9		5.5		1.5	
				3	2.7		2.5		5.8		1.5		6.2		1.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**2.1**	1.3	**2.6**	0.7	**6.9**	2.9	**1.6**	0.7	**5.5**	1.9	**1.5**	0.1

Percentage Organic Matter (%)	**30.3**	**36.6**	**41.9**	**52.2**	**39.5**	**54.1**

Table 52: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of April 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M3	May-97	35 days	1	1.4		8.1		25.7		17.0		8.3		4.8	
				2	2.0		9.9		25.2		15.5		11.3		5.0	
				3	1.9		12.4		23.0		11.3		9.6		5.4	
	Monthly Site Average (g/m^2) +/- Std. Error				**1.8**	0.8	**10.1**	5.4	**24.6**	3.6	**14.6**	7.3	**9.7**	3.7	**5.1**	0.8

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M3	May-97	35 days	1	1.0		4.5		14.9		14.6		3.6		3.7	
				2	1.4		5.2		14.3		13.7		5.5		4.1	
				3	1.3		6.6		12.2		9.8		5.0		4.2	
	Monthly Site Average (g/m^2) +/- Std. Error				**1.2**	0.5	**5.4**	2.7	**13.8**	3.5	**12.7**	6.3	**4.7**	2.4	**4.0**	0.7

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**69.8**	**53.6**	**56.0**	**87.0**	**48.3**	**78.9**

Table 53: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of May 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
M4	June-97	29 days	1	1.8		Slide lost *		4.9		13.6		14.2		1.9	
			2	1.7		Slide lost *		5.6		12.5		17.0		2.3	
			3	1.8		Slide lost *		4.5		9.3		14.6		1.6	
Monthly Site Average (g/m^2) +/- Std. Error				**1.8**	0.1			**5.0**	1.4	**11.8**	5.5	**15.3**	3.8	**1.9**	0.9

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
M4	June-97	29 days	1	1.2		Slide lost *		4.0		5.4		5.9		1.8	
			2	1.1		Slide lost *		4.2		6.4		6.7		2.1	
			3	1.1		Slide lost *		3.2		4.6		6.4		1.4	
Monthly Site Average (g/m^2) +/- Std. Error				**1.1**	0.1			**3.8**	1.3	**5.5**	2.2	**6.3**	1.0	**1.8**	0.9

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**64.2**		**76.0**	**46.3**	**41.5**	**91.4**

Table 54: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of June 1997. (* = slides vandalised)

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
M5	July-97	34 days	1	1.5		5.2		1.7		2.1		1.9		2.2	
			2	1.7		4.4		1.5		2.3		3.2		2.9	
			3	1.6		4.6		2.0		2.0		3.3		1.7	
Monthly Site Average (g/m^2) +/- Std. Error				**1.6**	0.2	**4.7**	1.0	**1.7**	0.6	**2.1**	0.4	**2.8**	1.9	**2.3**	1.5

(Sample site: S1–S6)

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
M5	July-97	34 days	1	1.0		2.6		1.2		1.6		1.4		1.3	
			2	1.1		2.5		1.0		1.6		1.8		1.9	
			3	1.0		2.7		1.4		1.3		1.5		1.4	
Monthly Site Average (g/m^2) +/- Std. Error				**1.0**	0.1	**2.6**	0.2	**1.2**	0.5	**1.5**	0.4	**1.6**	0.5	**1.5**	0.8

(Sample site: S1–S6)

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**64.6**	**54.9**	**69.2**	**70.3**	**56.0**	**67.6**

Table 55: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of July 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site: S1		S2		S3		S4		S5		S6	
M6	August-97	35 days	1	2.1		2.1		Slide lost *		0.8		2.0		1.1	
			2	2.8		2.0		Slide lost *		0.9		1.6		1.1	
			3	2.7		2.2		Slide lost *		0.7		1.9		1.0	
Monthly Site Average (g/m^2) +/- Std. Error				**2.5**	0.9	**2.1**	0.2			**0.8**	0.2	**1.8**	0.5	**1.1**	0.1

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site: S1		S2		S3		S4		S5		S6	
M6	August-97	35 days	1	1.5		1.3		Slide lost *		0.6		1.5		1.0	
			2	2.0		1.4		Slide lost *		0.7		1.2		1.0	
			3	1.5		1.6		Slide lost *		0.5		1.2		0.9	
Monthly Site Average (g/m^2) +/- Std. Error				**1.7**	0.7	**1.4**	0.4			**0.6**	0.2	**1.3**	0.4	**1.0**	0.1

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**65.8**	**68.3**		**75.0**	**70.9**	**90.6**

Table 56: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of August 1997. (*=slides vandalised)

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
M7	Sep-97	27 days	1	4.4		2.6		2.9		1.8		4.0		2.0	
			2	4.7		2.7		4.5		2.0		3.3		2.8	
			3	6.9		3.8		3.1		2.1		4.2		2.3	
Monthly Site Average (g/m^2) +/- Std. Error				**5.3**	3.4	**3.0**	1.7	**3.5**	2.2	**2.0**	0.4	**3.8**	1.2	**2.4**	1.0

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
M7	Sep-97	27 days	1	2.1		0.9		2.1		1.4		1.9		1.8	
			2	2.2		1.4		2.7		1.5		1.7		2.5	
			3	2.9		1.7		2.0		1.4		1.9		1.9	
Monthly Site Average (g/m^2) +/- Std. Error				**2.4**	1.1	**1.3**	1.0	**2.3**	0.9	**1.4**	0.1	**1.8**	0.3	**2.1**	0.9

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**45.0**	**44.0**	**64.8**	**72.9**	**47.8**	**87.3**

Table 57: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of September 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
M8	October-97	28 days	1	1.2		0.8		0.2		1.3		2.5		0.8	
			2	0.9		0.7		0.4		0.8		3.6		1.5	
			3	0.8		0.8		0.4		1.1		2.3		1.1	
Monthly Site Average (g/m^2) +/- Std. Error				**1.0**	0.5	**0.8**	0.1	**0.3**	0.3	**1.1**	0.6	**2.8**	1.7	**1.1**	0.9

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
M8	October-97	28 days	1	0.9		0.6		0.2		1.3		1.4		0.8	
			2	0.8		0.7		0.4		0.8		2.2		1.3	
			3	0.7		0.8		0.2		0.9		1.3		0.9	
Monthly Site Average (g/m^2) +/- Std. Error				**0.8**	0.2	**0.7**	0.2	**0.3**	0.3	**1.0**	0.7	**1.6**	1.2	**1.0**	0.7

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**82.8**	**91.3**	**80.0**	**93.8**	**58.3**	**88.2**

Table 58: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of October 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M9	Nov-97	28 days	1	0.3		0.1		0.2		0.5		0.6		0.7	
				2	0.3		0.2		0.3		0.3		0.5		0.9	
				3	0.4		Slide lost		0.3		0.5		0.6		0.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**0.3**	0.1	**0.2**	0.7	**0.3**	0.1	**0.4**	0.3	**0.6**	0.1	**0.7**	0.5

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M9	Nov-97	28 days	1	0.3		0.1		0.2		0.5		0.5		0.6	
				2	0.3		0.2		0.3		0.3		0.5		0.8	
				3	0.4		Slide lost		0.3		0.4		0.6		0.6	
	Monthly Site Average (g/m^2) +/- Std. Error				**0.3**	0.1	**0.2**	0.7	**0.3**	0.1	**0.4**	0.2	**0.5**	0.1	**0.7**	0.3

Percentage Organic Matter (%)	**100.0**	**100.0**	**100.0**	**92.3**	**94.1**	**95.2**

Table 59: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of November 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M12	Feb-98	27 days	1	0.2		1.1		0.8		0.3		0.1		0.1	
				2	0.3		1.3		0.9		0.1		0.1		0.1	
				3	0.3		1.0		1.0		0.2		0.1		0.1	
	Monthly Site Average (g/m²) +/- Std. Error				**0.3**	0.1	**1.1**	0.4	**0.9**	0.2	**0.2**	0.2	**0.1**	0.0	**0.1**	0.0

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M12	Feb-98	27 days	1	0.2		0.7		0.7		0.3		0.1		0.1	
				2	0.3		1.0		0.6		0.1		0.1		0.1	
				3	0.3		0.9		0.9		0.2		0.1		0.1	
	Monthly Site Average (g/m²) +/- Std. Error				**0.3**	0.1	**0.9**	0.4	**0.7**	0.4	**0.2**	0.2	**0.1**	0.0	**0.1**	0.0

Percentage Organic Matter (%)	**100.0**	**76.5**	**81.5**	**100.0**	**100.0**	**100.0**

Table 60: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of February 1998.

	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
Dry Weights at 103°C	M13	March-98	29 days	1	2.0		10.8		13.1		1.6		6.1		3.5	
				2	1.1		7.5		11.6		0.9		4.5		5.0	
				3	2.2		7.8		10.1		1.7		3.8		2.7	
	Monthly Site Average (g/m^2) +/- Std. Error				**1.8**	1.5	**8.7**	4.5	**11.6**	3.7	**1.4**	1.1	**4.8**	2.9	**3.7**	2.9

	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
Ash Free Dry Weights at 500°C	M13	March-98	29 days	1	1.3		3.8		6.9		1.3		4.9		0.4	
				2	0.9		3.3		6.0		0.9		2.5		2.9	
				3	1.4		3.4		5.2		1.3		2.1		1.9	
	Monthly Site Average (g/m^2) +/- Std. Error				**1.2**	0.7	**3.5**	0.7	**6.0**	2.1	**1.2**	0.6	**3.2**	3.8	**1.7**	3.1

Percentage Organic Matter (%)	**67.9**	**40.2**	**52.0**	**83.3**	**66.0**	**46.4**

Table 61: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of March 1998.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M14	April-98	34 days	1	29.9		37.7		24.0		32.7		28.7		35.9	
				2	23.0		30.1		22.8		33.6		25.0		19.0	
				3	30.5		40.3		23.9		32.7		25.9		Slide lost	
	Monthly Site Average (g/m^2) +/- Std. Error				**27.8**	10.3	**36.0**	13.2	**23.6**	1.7	**33.0**	1.3	**26.5**	4.8	**27.5**	109.9

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	M14	April-98	34 days	1	13.8		15.6		11.2		15.9		15.9		19.1	
				2	10.7		14.1		10.3		16.2		14.3		10.3	
				3	13.1		26.7		11.2		15.7		14.3		Slide lost	
	Monthly Site Average (g/m^2) +/- Std. Error				**12.5**	4.0	**18.8**	17.1	**10.9**	1.3	**15.9**	0.6	**14.8**	2.3	**14.7**	57.2

Percentage Organic Matter (%)	**45.1**	**52.2**	**46.3**	**48.3**	**55.9**	**53.6**

Table 62: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of April 1998.

	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
Dry Weights at 103°C	M15	May-98	28 days	1	8.3		14.3		25.0		11.3		7.3		9.9	
				2	12.2		15.5		24.3		10.3		7.7		10.0	
				3	12.4		14.7		20.3		13.7		9.7		6.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**11.0**	7.1	**14.8**	1.8	**23.2**	7.8	**11.8**	5.3	**8.2**	3.8	**8.8**	6.1

	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
Ash free Dry Weights at 500°C	M15	May-98	28 days	1	4.0		10.0		13.5		7.0		4.3		6.3	
				2	6.4		8.2		13.0		6.9		4.4		6.5	
				3	5.6		8.0		11.5		8.3		4.8		4.4	
	Monthly Site Average (g/m^2) +/- Std. Error				**5.3**	3.8	**8.7**	3.3	**12.7**	3.2	**7.4**	2.3	**4.5**	0.7	**5.7**	3.7

Percentage Organic Matter (%)	**48.5**	**58.8**	**54.6**	**62.8**	**54.8**	**65.1**

Table 63: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed at six sampling sites around the littoral zone of Lough Gill for the month of May 1998.

IV. Monthly glass slides

b. Chlorophyll data from glass slides

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M1	March-97	29 days	1	36.8		58.7		75.8		41.0		46.7		4.4	
			2	53.1		73.0		73.5		40.6		50.5		5.0	
			3	36.1		72.1		76.3		44.6		46.6		7.1	
Monthly Site Average (mg/m^2) +/- Std. Error				**42.0**	23.9	**67.9**	19.9	**75.2**	3.7	**42.1**	5.5	**47.9**	5.5	**5.5**	3.5

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M2	April-97	26 days	1	29.6		58.1		73.4		14.0		66.5		25.6	
			2	24.7		46.9		81.1		14.5		67.6		26.9	
			3	27.5		53.3		68.6		15.7		70.2		30.0	
Monthly Site Average (mg/m^2) +/- Std. Error				**27.3**	6.1	**52.8**	13.9	**74.4**	15.7	**14.7**	2.2	**68.1**	4.7	**27.5**	5.6

Table 64 and 65: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of March and April 1997.

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M3	May-97	35 days	1	1.5		41.0		47.6		17.0		41.2		33.6	
			2	2.3		48.7		38.7		10.4		53.8		31.3	
			3	2.3		41.8		39.9		56.6		55.6		24.0	
Monthly Site Average (mg/m²) +/- Std. Error				**2.0**	1.1	**43.8**	10.5	**42.1**	12.0	**28.0**	62.0	**50.2**	19.5	**29.6**	12.4

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M4	June-97	29 days	1	7.0		Slide lost *		33.0		50.5		92.3		4.6	
			2	6.2		Slide lost *		30.1		49.1		84.1		4.8	
			3	8.1		Slide lost *		31.8		40.6		Slide lost *		5.6	
Monthly Site Average (mg/m²) +/- Std. Error				**7.1**	2.4			**31.6**	3.6	**46.7**	13.3	**88.2**	53.3	**5.0**	1.3

Table 66 and 67: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of May and June 1997. (* = slides vandalised)

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M5	July-97	34 days	1	6.9		27.1		19.8		20.9		12.4		13.5	
			2	8.9		32.2		18.7		17.1		13.4		14.7	
			3	8.1		27.5		13.2		19.0		7.7		18.6	
Monthly Site Average (mg/m^2) +/- Std. Error				**8.0**	2.5	**28.9**	7.0	**17.2**	8.8	**19.0**	4.7	**11.2**	7.6	**15.6**	6.6

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M6	August-97	35 days	1	67.0		9.5		Slide lost *		2.9		8.3		3.9	
			2	21.3		19.7		Slide lost *		2.9		9.3		5.0	
			3	9.9		Slide lost *		Slide lost *		2.9		8.9		5.4	
Monthly Site Average (mg/m^2) +/- Std. Error				**32.7**	75.0	**14.6**	66.3			**2.9**	0.0	**8.8**	1.2	**4.8**	1.9

Table 68 and 69: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of July and August 1997. (* = slides vandalised)

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M7	Sep-97	27 days	1	24.0		21.5		25.1		26.8		20.1		25.3	
			2	19.2		20.5		24.7		30.7		23.1		21.8	
			3	23.2		23.8		21.4		25.3		20.7		22.7	
Monthly Site Average (mg/m^2) +/- Std. Error				**22.1**	6.4	**21.9**	4.2	**23.7**	5.0	**27.6**	6.9	**21.3**	3.9	**23.3**	4.5

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M8	Oct-97	28 days	1	6.8		8.1		1.3		7.4		28.4		9.5	
			2	7.2		8.3		0.9		5.7		23.7		6.8	
			3	Slide lost *		7.1		0.9		8.3		28.5		8.5	
Monthly Site Average (mg/m^2) +/- Std. Error				**7.0**	2.6	**7.8**	1.6	**1.0**	0.6	**7.1**	3.3	**26.9**	6.8	**8.3**	3.4

Table 70 and 71: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of September and October 1997. (* = slide broken)

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M9	Nov-97	28 days	1	3.6		0.7		1.5		1.5		8.4		5.5	
			2	1.8		0.9		1.5		2.8		8.3		6.1	
			3	2.9		0.8		1.0		2.5		8.0		7.5	
Monthly Site Average (mg/m^2) +/- Std. Error				**2.8**	2.3	**0.8**	0.2	**1.3**	0.7	**2.3**	1.7	**8.2**	0.5	**6.4**	2.5

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M12	Feb-98	27 days	1	2.7		6.3		6.1		2.3		0.5		1.0	
			2	2.4		7.2		7.3		1.4		0.9		0.9	
			3	2.6		9.3		4.5		2.6		0.4		1.1	
Monthly Site Average (mg/m^2) +/- Std. Error				**2.6**	0.4	**7.6**	3.8	**6.0**	3.5	**2.1**	1.6	**0.6**	0.7	**1.0**	0.2

Table 72 and 73: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of November 1997 and February 1998.

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M13	March-98	29 days	1	16.2		75.8		20.8		24.0		54.0		57.2	
			2	29.7		65.4		45.7		15.8		47.4		62.2	
			3	17.5		56.0		39.7		23.2		58.8		52.4	
Monthly Site Average (mg/m^2) +/- Std. Error				**21.1**	18.5	**65.7**	24.6	**35.4**	32.3	**21.0**	11.2	**53.4**	14.2	**57.3**	12.2

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M14	April-98	34 days	1	29.3		75.9		71.8		48.6		33.0		21.2	
			2	57.8		74.0		76.8		64.1		54.8		52.9	
			3	22.5		58.9		76.7		53.5		36.0		Slide lost	
Monthly Site Average (mg/m^2) +/- Std. Error				**36.5**	46.5	**69.6**	23.1	**75.1**	7.1	**55.4**	19.7	**41.3**	29.3	**37.1**	206.1

Table 74 and 75: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during the months of March and April 1998. (* = slide broken)

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
M15	May-98	28 days	1	65.2		66.7		74.8		58.9		58.9		68.5	
			2	68.3		71.3		64.1		59.0		49.5		55.5	
			3	66.4		73.9		64.8		63.4		48.5		55.5	
Monthly Site Average (mg/m^2) +/- Std. Error				**66.6**	3.8	**70.6**	9.1	**67.9**	14.8	**60.4**	6.4	**52.3**	14.2	**59.8**	18.6

Table 76: Chlorophyll data from glass slides submerged at six sample sites around the littoral zone of Lough Gill during May 1998.

IV. Monthly glass slides

c. Periphyton numbers from glass slides

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M1	March-97	29 days	1	1631		6181		10896		5379		4832		1024	
			2	1879		10302		7907		6545		5179		1109	
			3	1577		7973		10367		5508		7980		1006	
Periphyton numbers (cells/mm^2) +/- Std. Error				**1696**	400	**8152**	5130	**9723**	3960	**5811**	1587	**5997**	4285	**1046**	137

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M2	April-97	26 days	1	2137		3699		9591		1631		5775		2094	
			2	2728		4975		8036		1771		6086		2750	
			3	3344		4350		9947		2247		6242		2676	
Periphyton numbers (cells/mm^2) +/- Std. Error				**2736**	1498	**4341**	1584	**9191**	2523	**1883**	802	**6034**	590	**2507**	892

Table 77 and 78: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton grown collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during March and April 1997.

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M3	May-97	35 days	1	5711		13123		18541		34691		10720		13151	
			2	5377		14323		15095		37543		13467		9149	
			3	5389		14209		14943		21748		12452		6375	
Periphyton numbers (cells/mm^2) +/- Std. Error				**5492**	470	**13885**	1644	**16193**	5052	**31327**	20898	**12213**	3448	**9558**	8457

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M4	June-97	29 days	1	2580		Slide lost *		6671		12896		10801		1445	
			2	2389		Slide lost *		7322		7071		17186		2049	
			3	1977		Slide lost *		6734		9361		14835		1493	
Periphyton numbers (cells/mm^2) +/- Std. Error				**2315**	765			**6909**	891	**9776**	7285	**14274**	8017	**1662**	833

Table 79 and 80: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during May and June 1997. (* = slides vandalised)

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M5	July-97	34 days	1	1281		5116		4001		3673		2754		4849	
			2	1784		5423		4324		3231		2539		5832	
			3	1529		5577		4126		3375		3340		4551	
Periphyton numbers (cells/mm^2) +/- Std. Error				**1531**	624	**5372**	583	**4150**	404	**3426**	560	**2878**	1029	**5077**	1664

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M6	August-97	35 days	1	1094		1998		1503		610		2591		1721	
			2	1459		2301		1322		488		3178		818	
			3	1868		3899		2290		594		3036		1152	
Periphyton numbers (cells/mm^2) +/- Std. Error				**1474**	961	**2733**	2536	**1705**	1278	**564**	165	**2935**	760	**1230**	1133

Table 81 and 82: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during July and August 1997.

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M7	Sep-97	27 days	1	3947		3131		5693		3772		3488		5713	
			2	3790		2535		4544		4067		4546		4219	
			3	4768		2410		5642		3762		4870		4036	
Periphyton numbers (cells/mm^2) +/- Std. Error				**4168**	1304	**2692**	957	**5293**	1612	**3867**	430	**4301**	1794	**4656**	2284

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M8	Oct-97	28 days	1	956		920		321		691		4478		1110	
			2	1258		985		366		819		3807		1065	
			3	1185		808		325		835		4259		1053	
Periphyton numbers (cells/mm^2) +/- Std. Error				**1133**	391	**904**	222	**337**	62	**782**	196	**4181**	849	**1076**	75

Table 83 and 84: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during September and October 1997.

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M9	Nov-97	28 days	1	616		177		223		393		950		480	
			2	494		114		140		252		838		416	
			3	317		80		134		229		736		539	
Periphyton numbers (cells/mm^2) +/- Std. Error				**476**	373	**124**	122	**166**	123	**291**	220	**841**	266	**478**	153

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M12	Feb-98	27 days	1	148		879		921		455		73		40	
			2	592		946		953		363		76		107	
			3	246		786		966		442		80		39	
Periphyton numbers (cells/mm^2) +/- Std. Error				**329**	579	**870**	199	**947**	57	**420**	124	**76**	9	**62**	97

Table 85 and 86: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the shore of Lough Gill during November 1997 and February 1998.

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M13	March-98	29 days	1	2965		6861		7543		4262		7311		6347	
			2	3023		6709		6933		4097		8770		5241	
			3	3089		6766		7644		4543		7703		4956	
Periphyton numbers (cells/mm^2) +/- Std. Error				**3026**	154	**6779**	191	**7373**	955	**4301**	560	**7928**	1875	**5515**	1824

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M14	April-98	34 days	1	24478		26773		15907		43050		28361		31868	
			2	29860		22839		19029		39527		27274		31812	
			3	28576		27920		21656		42602		29962		31868	
Periphyton numbers (cells/mm^2) +/- Std. Error				**27638**	6978	**25844**	6616	**18864**	7145	**41726**	4761	**28532**	3357	**31849**	80

Table 87 and 88: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during March and April 1998.

Sample Code	Placement Date	Retrieval Date	Sedgwick-Rafter slide no.	Sample site											
				S1		S2		S3		S4		S5		S6	
M15	May-98	28 days	1	13431		18051		13499		22266		5832		10911	
			2	13358		15661		12361		20630		6728		8705	
			3	13081		13753		11426		17695		7090		7898	
Periphyton numbers (cells/mm^2) +/- Std. Error				**13290**	458	**15822**	5346	**12429**	2577	**20197**	5750	**6550**	1608	**9171**	3872

Table 89: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton growth collected upon glass slides submerged at six sites around the littoral zone of Lough Gill during May 1998.

IV. Monthly glass slides

d. Periphyton genera found on glass slides

March-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta							
Chlorophyta	*Ankistrodesmus*	202					
	Chaetophora						154
	Microspora	137	60		22	33	
	Oocystis	86					
Bacillariophyta	*Cocconeis*		10		54	25	21
	Cymbella	140	2906	498	594	2040	15
	Diatoma				22	8	8
	Fragilaria	61	129	602	378	273	
	Gomphonema	994	3205	5303	3974	1966	835
	Gyrosigma		20				
	Meridion	29	1264	1183	432	107	4
	Navicula		129	405	119	149	2
	Nitzschia	29	368	1608	108	339	4
	Pinnularia	7		21	22	17	4
	Rhoicosphenia			52	32	8	
	Surirella					8	
	Synedra	11	60	52	54	25	
Total number of cells per mm^2:		**1696**	**8152**	**9723**	**5810**	**4997**	**1046**

Table 90: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during March 1997.

April-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Oscillatoria*	16		130			
Chlorophyta	*Ankistrodesmus*		26				
	Chaetophora				583		549
	Microspora	575	52				
	Stigeoclonium			400			25
Bacillariophyta	*Cocconeis*	36	43	65	29	88	37
	Cymbella	209	972	1685	58	2174	107
	Diatoma			22		5	8
	Fragilaria	443	790	864	72	130	8
	Gomphonema	1251	1693	3921	1008	2013	1516
	Gyrosigma		9				
	Melosira			454	14	467	29
	Meridion	36	182	184		10	
	Navicula	24	130	205	7	99	4
	Nitzschia	101	122	886	104	975	215
	Pinnularia			11			
	Rhoicosphenia	4	26	43	4	21	
	Synedra	40	295	302	4	52	8
	Tabellaria			22			
Total number of cells per mm^2:		**2736**	**4341**	**9191**	**1883**	**6034**	**2507**

Table 91: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during April 1997.

May-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Oscillatoria*					309	
Chlorophyta	*Chaetophora*	471	1163	1616	3299	119	3688
	Stigeoclonium				21944	567	191
Bacillariophyta	*Cocconeis*	37	19	91	9	30	29
	Cymbella	21	515	2186	112	557	334
	Diatoma	12	48	173	47	199	
	Fragilaria	25	86	3690	3541	3663	886
	Gomphonema	665	1639	2328	1510	2449	2058
	Gyrosigma			10			
	Melosira	17	19	142		309	48
	Meridion		57				
	Navicula	12	19	112		30	29
	Nitzschia	4220	10206	5144	745	3802	2278
	Pinnularia			41			
	Rhoicosphenia	12	57			60	19
	Surirella			152		30	
	Synedra		57	508	93	50	
	Zygnema					40	
	Unknown A				28		
Total number of cells per mm^2:		**5493**	**13885**	**16193**	**31327**	**12213**	**9559**

Table 92: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during May 1997.

June-97							
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Anabaena*			48		85	
	Aphanocapsa			95			
	Gomphosphaeria	88					
	Merismopedia	24			191		
Chlorophyta	*Chaetophora*	62		1022	2424	794	1096
Bacillariophyta	*Cocconeis*	695		16	101	53	58
	Cymbella	40		2197	1145	1324	48
	Diatoma				90	1842	
	Fragilaria	8		725	1437	8291	
	Gomphonema	1370		2621	3738	508	365
	Melosira			21		371	
	Navicula			11	34	53	5
	Nitzschia	12		127	617	657	90
	Rhoicosphenia	18				74	
	Surirella					53	
	Synedra			26		169	
Total number of cells per mm^2:		**2316**	**Slide lost**	**6909**	**9776**	**14274**	**1662**

Table 93: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during June 1997.

July-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²
Cyanophyta	*Anabaena*		340	347	52	7	
	Aphanocapsa	371		23	58	20	198
	Chroococcus						15
	Gomphosphaeria				68		442
	Merismopedia	28	19	50	4		19
Chlorophyta	*Chaetophora*	8	489	386	131	9	191
Bacillariophyta	*Achnanthes*				909	350	1872
	Cocconeis	459	33	54	56	218	164
	Cymbella	43	1808	1203	64	537	46
	Gomphonema	596	1482	1247	1889	1374	1856
	Gyrosigma			2			
	Navicula	1	23	3	6		11
	Nitzschia	19	1151	834	183	325	244
	Rhoicosphenia	6	28	2	6	38	19
Total number of cells per mm²:		**1532**	**5372**	**4151**	**3427**	**2878**	**5078**

Table 94: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during July 1997.

August-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²
Cyanophyta	*Anabaena*		72		15		
	Aphanocapsa	261	68		100	92	8
	Aphanothece				11		
	Gomphosphaeria						296
	Merismopedia		25	52		17	
	Microcystis					143	45
	Oscillatoria	24					
Chlorophyta	*Chaetophora*		436	346	58	690	55
	Cladophora	6					
Bacillariophyta	*Achnanthes*	62	554	657	188	1127	393
	Cocconeis	732	864	63	30	179	154
	Cyclotella		18				
	Cymbella	62	40	156	4	31	8
	Diatoma	6	4	3			
	Fragilaria	27	43	26			
	Gomphonema	234	464	302	117	618	263
	Navicula		4	6		3	2
	Nitzschia	42	90	86	41	28	6
	Pinnularia	6					
	Rhoicosphenia	3	11	6		8	
	Tabellaria	9	40	3			
Total number of cells per mm²:		**1474**	**2733**	**1706**	**564**	**2935**	**1230**

Table 95: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during August 1997.

September-97							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Anabaena*			95		254	
	Aphanocapsa	406	116	315	450		434
	Gomphosphaeria		181			121	
	Merismopedia	97			33	143	
	Oscillatoria			41			
Chlorophyta	*Chaetophora*	994		44	377	35	78
	Cladophora		77				
	Ulothrix		270				68
Bacillariophyta	*Achnanthes*	1006	240	2951	1132	1973	2633
	Cocconeis	551	649	125	870	1719	1169
	Cymbella	109	80	122	23	10	34
	Diatoma		62		3		
	Fragilaria		83				
	Gomphonema	986	356	1108	857	32	37
	Navicula	4	39		3	3	30
	Nitzschia	16	400	471	89	13	119
	Rhoicosphenia		59	20	30		20
	Synedra		80				34
Total number of cells per mm^2:		**4169**	**2693**	**5293**	**3867**	**4301**	**4656**

Table 96: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during September 1997.

October-97							
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Aphanocapsa*	74	64	27	7	42	30
	Aphanothece		176	10	18		
	Merismopedia	7		2		25	
Chlorophyta	*Chaetophora*	7			19		27
Bacillariophyta	*Achnanthes*	130	103	115	186	1715	343
	Cocconeis	531	242	54	249	590	206
	Cymbella	6	7	0	4	47	22
	Fragilaria					63	
	Gomphonema	341	243	84	255	803	344
	Navicula	7	17	3	4	59	9
	Nitzschia	20	48	42	36	595	52
	Rhoicosphenia	11	4	1		137	27
	Synedra				3	105	16
Total number of cells per mm^2:		**1133**	**904**	**338**	**782**	**4181**	**1076**

Table 97: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during October 1997.

November-97							
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²
Cyanophyta	*Achnanthes*						
	Aphanocapsa						57
	Gomphosphaeria	58	27	12	41		
	Merismopedia			12			20
Chlorophyta	*Chaetophora*	55					
Bacillariophyta	*Achnanthes*	54	27	30	40	50	32
	Cocconeis	126	46	6	78	155	62
	Cymbella	13	8	13	17	57	30
	Diatoma					7	
	Gomphonema	133	9	73	98	477	258
	Melosira	3				16	
	Navicula	2	1	2		2	
	Nitzschia	26	6	18	18	64	18
	Rhoicosphenia	5		1		12	2
	Tabellaria					2	
Total number of cells per mm²:		**476**	**123**	**166**	**291**	**841**	**479**

Table 98: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during November 1997.

February-98							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²	cells/mm²
Cyanophyta							
Chlorophyta							
Bacillariophyta	*Amphora*			1	3	3	
	Cocconeis	108	139	40	47	22	13
	Cymbella		74	15	23	3	2
	Fragilaria	3	18				
	Gomphonema	75	579	857	317	38	17
	Navicula	2	15	6	9	3	2
	Nitzschia	4	40	20	17	6	4
	Rhoicosphenia	2	6		5		
	Synedra			7		2	
	Unknown B	136					24
Total number of cells per mm²:		**329**	**870**	**947**	**420**	**77**	**62**

Table 99: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during February 1998.

March-98							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta							
Chlorophyta							
Bacillariophyta	*Achnanthes*	77	254	129	975	1714	1144
	Amphipleura						13
	Amphora	50	25	61		119	38
	Cocconeis	165	140	54	11	107	89
	Cymbella	251	845	1050	94	765	203
	Diatoma				6		
	Fragilaria				22		19
	Gomphonema	2409	5235	5354	2984	4483	3780
	Melosira			163			
	Navicula		13		28		13
	Nitzschia	14	197	495	176	735	184
	Pinnularia			7			32
	Rhoicosphenia	52	70	54			
	Surirella	8		7			
	Synedra					6	
	Unknown C				5		
Total number of cells per mm^2:		**3026**	**6779**	**7373**	**4300**	**7928**	**5515**

Table 100: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during March 1998.

April-98							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Oscillatoria*			512			
Chlorophyta	*Ankistrodesmus*		18				
	Scenedesmus				149	76	373
	Tetrastrum						75
Bacillariophyta	*Achnanthes*	838		297	335	1449	1845
	Amphipleura	18					
	Amphora	127	474	297	354	38	149
	Cocconeis	273	146	83	56	400	
	Craticula	18		17			
	Cyclotella				19		
	Cymbella	2705	8451	3618	9691	11550	2385
	Diatoma	27			19	38	
	Fragilaria	382		1668	3187	1315	1137
	Gomphonema	8961	7595	5517	11368	9034	14741
	Gyrosigma		18				19
	Melosira	10709	3296	2197	1715	820	7529
	Navicula	118	73	132	447	362	56
	Nitzschia	3296	5391	3964	13530	3011	3205
	Rhoicosphenia			66			75
	Surirella		73				
	Synedra	164	310	496	857	438	261
Total number of cells per mm^2:		**27638**	**25844**	**18864**	**41726**	**28532**	**31849**

Table 101: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during April 1998.

May-98							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	Anabaena	1756	2097				
	Oscillatoria						223
Chlorophyta	*Chaetophora*		489		426		565
	Scenedesmus	37					26
	Stigeoclonium				1873	349	1792
Bacillariophyta	*Achnanthes*	3028	3117	2318	4535	2243	945
	Amphora					273	33
	Cocconeis	55	7	190		13	46
	Cymbella	418	503	989	231	1023	401
	Diatoma	86	601	54	112		144
	Fragilaria	1112	1565	1328	6478	381	1641
	Gomphonema	2211	1922	2426	3760	750	2508
	Melosira	2678	3473	3267	636	521	
	Navicula	12	7				
	Nitzschia	1701	1796	1789	1999	775	709
	Rhoicosphenia	6	28	14			13
	Synedra	190	189	54	147	222	125
	Tabellaria		28				
Total number of cells per mm^2:		**13290**	**15822**	**12429**	**20197**	**6550**	**9171**

Table 102: The distribution of attached algal genera found upon glass slides submerged at six sampling sites around the littoral zone of Lough Gill during May 1998.

IV. Monthly glass slides

e. Grazer data from glass slides

Date	Slides collected	Grazer species	Sample site						Total species number found on slide collection dates	Total number of snails found on slide collection dates:
			S1	S2	S3	S4	S5	S6		
03-Apr-97	M1	*Bithynia tentaculata*	0	0	1	2	0	12	15	23
		Lymnaea peregra	0	0	1	3	1	2	7	
		Physa fontinalis	0	0	0	1	0	0	1	
10-Apr-97		*Bithynia tentaculata*	1	0	2	7	1	9	20	21
		Lymnaea peregra	0	0	1	0	0	0	1	
24-Apr-97	W1	*Bithynia tentaculata*	0	0	0	4	2	6	12	15
		Lymnaea peregra	0	1	0	0	2	0	3	
29-Apr-97	M2	*Theodoxus fluviatilis*	0	0	0	0	0	3	3	11
		Bithynia tentaculata	2	1	1	1	0	2	7	
		Lymnaea peregra	0	0	0	0	1	0	1	
08-May-97	W2	*Bithynia tentaculata*	3	0	1	1	0	19	24	27
		Lymnaea peregra	0	0	0	0	0	2	2	
		Physa fontinalis	1	0	0	0	0	0	1	
28-May-97	W3	*Theodoxus fluviatilis*	0	1	2	0	0	0	3	29
		Bithynia tentaculata	0	1	0	12	0	9	22	
		Lymnaea peregra	2	0	1	0	0	1	4	
03-Jun-97	M3	*Theodoxus fluviatilis*	2	0	1	0	0	0	3	28
		Potamopyrgus jenkinsi	10	0	0	0	0	0	10	
		Bithynia tentaculata	0	2	3	0	0	4	9	
		Lymnaea stagnalis	1	0	0	0	0	0	1	
		Lymnaea peregra	2	0	2	0	0	1	5	
12-Jun-97	W4	*Theodoxus fluviatilis*	2			2	0	0	4	31
		Bithynia tentaculata	4	Slides	Slides	2	0	18	24	
		Lymnaea stagnalis	1	lost	lost	0	0	1	2	
		Lymnaea peregra	1			0	0	0	1	
02-Jul-97	M4	*Potamopyrgus jenkinsi*	71	Slides	Slides	0	0	0	71	86
		Bithynia tentaculata	1	lost	lost	3	2	9	15	
05-Aug-97	M5	*Theodoxus fluviatilis*	0	0	0	2	0	1	3	31
		Bithynia tentaculata	2	2	6	6	1	6	23	
		Lymnaea stagnalis	2	0	0	0	0	0	2	
		Lymnaea peregra	1	1	0	0	1	0	3	
09-Sep-97	M6	*Theodoxus fluviatilis*	0	2	0	0	1	0	3	50
		Potamopyrgus jenkinsi	3	0	0	2	2	0	7	
		Bithynia tentaculata	3	3	1	4	1	3	15	
		Lymnaea peregra	5	2	2	2	4	4	19	
		Physa fontinalis	1	0	0	0	0	0	1	
		Planorbis carinatus	5	0	0	0	0	0	5	
06-Oct-97	M7	*Theodoxus fluviatilis*	0	2	3	0	0	3	8	44
		Bithynia tentaculata	0	0	8	5	3	6	22	
		Lymnaea peregra	2	1	6	1	1	3	14	
03-Nov-97	M8	*Theodoxus fluviatilis*	0	0	11	0	0	1	12	23
		Lymnaea peregra	3	2	1	0	1	1	8	
		Planorbis carinatus	0	2	0	0	0	0	2	
		Acroloxus lacustris	0	0	1	0	0	0	1	
01-Dec-97	M9	*Theodoxus fluviatilis*	0	4	2	3	0	2	11	25
		Potamopyrgus jenkinsi	1	1	0	1	0	1	4	
		Bithynia tentaculata	1	0	0	0	0	0	1	
		Lymnaea peregra	5	1	2	1	0	0	9	
03-Mar-98	M12	*Lymnaea stagnalis*	0	0	0	0	1	0	1	4
		Lymnaea peregra	0	0	0	0	0	2	2	
		Physa fontinalis	0	0	0	0	1	0	1	
01-Apr-98	M13	*Theodoxus fluviatilis*	0	1	0	0	0	0	1	11
		Bithynia tentaculata	2	0	1	3	0	1	7	
		Lymnaea peregra	1	0	0	1	1	0	3	
05-May-98	M14	*Theodoxus fluviatilis*	3	0	0	0	0	0	3	32
		Bithynia tentaculata	7	3	4	0	3	0	17	
		Lymnaea peregra	1	2	3	1	2	3	12	
02-Jun-98	M15	*Theodoxus fluviatilis*	0	2	2	4	0	5	13	50
		Potamopyrgus jenkinsi	3	0	4	0	4	0	11	
		Bithynia tentaculata	2	0	5	10	5	3	25	
		Lymnaea stagnalis	1	0	0	0	0	0	1	

Table 103: Mollusca species and their distribution upon glass slides from six sample sites submerged around the littoral zone of Lough Gill.

V. Biweekly glass slide data

	Sample code	Exposure period		Length of exposure (days)	Replicate no.	Sample site											
		Placment	Collection			S1		S2		S3		S4		S5		S6	
Dry Weights at 103°C	W1	10-Apr-97	24-Apr-97	14	1	5.3		4.5		3.0		0.7		5.9		1.9	
					2	3.2		3.7		4.2		1.3		5.5		3.3	
					3	3.0		4.2		4.5		0.9		5.2		2.1	
	Monthly Site Average (g/m^2) +/- Std. Error					**3.8**	3.2	**4.1**	1.0	**3.9**	1.9	**1.0**	0.7	**5.5**	1.0	**2.5**	1.9

	Sample code	Exposure period		Length of exposure (days)	Replicate no.	Sample site											
		Placment	Collection			S1		S2		S3		S4		S5		S6	
Ash Free Dry Weights at 500°C	W1	10-Apr-97	24-Apr-97	14	1	2.3		1.5		1.5		0.7		2.6		0.9	
					2	1.3		1.6		1.8		0.9		1.7		1.4	
					3	1.2		1.5		2.1		0.7		2.2		1.1	
	Monthly Site Average (g/m^2) +/- Std. Error					**1.6**	1.4	**1.5**	0.2	**1.8**	0.8	**0.7**	0.4	**2.2**	1.0	**1.1**	0.7

Percentage Organic Matter (%)	**41.6**	**36.5**	**45.4**	**78.0**	**39.0**	**46.5**

Table 104: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed for a two week period at six sites around the littoral zone of Lough Gill during April 1997.

Dry Weights at 103°C

Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
W2	24-Apr-97	8-May-97	14	1	2.0		14.6		8.0		3.1		7.4		1.9	
				2	2.0		16.4		8.1		3.9		8.3		1.9	
				3	3.4		17.0		6.5		3.6		7.2		1.0	
Monthly Site Average (g/m^2) +/- Std. Error					**2.5**	2.1	**16.0**	3.1	**7.5**	2.2	**3.5**	1.0	**7.6**	1.5	**1.6**	1.3

Ash Free Dry Weights at 500°C

Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
W2	24-Apr-97	8-May-97	14	1	1.0		5.3		3.5		1.4		3.1		1.1	
				2	1.0		6.7		3.5		1.6		3.5		1.2	
				3	1.9		7.0		2.9		1.5		3.0		0.7	
Monthly Site Average (g/m^2) +/- Std. Error					**1.3**	1.3	**6.3**	2.3	**3.3**	0.9	**1.5**	0.2	**3.2**	0.7	**1.0**	0.7

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**52.3**	**39.6**	**43.8**	**42.5**	**41.9**	**62.5**

Table 105: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed for a two week period at six sites around the littoral zone of Lough Gill during April and early May 1997.

Dry Weights at 103°C

Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site: S1		S2		S3		S4		S5		S6	
W3	8-May-97	28-May-97	20	1	2.2		7.3		6.7		3.3		5.6		3.1	
				2	2.2		4.6		7.4		2.6		5.5		2.2	
				3	2.1		5.4		8.1		4.4		6.9		5.0	
Monthly Site Average (g/m²) +/- Std. Error					**2.2**	0.2	**5.8**	3.3	**7.4**	1.8	**3.4**	2.2	**6.0**	1.9	**3.5**	3.5

Ash Free Dry Weights at 500°C

Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site: S1		S2		S3		S4		S5		S6	
W3	8-May-97	28-May-97	20	1	1.2		3.5		3.8		2.7		3.2		1.8	
				2	1.2		2.4		3.2		2.3		3.2		1.6	
				3	1.2		2.7		4.4		3.2		3.8		2.7	
Monthly Site Average (g/m²) +/- Std. Error					**1.2**	0.0	**2.9**	1.4	**3.8**	1.5	**2.7**	1.1	**3.4**	0.8	**2.0**	1.5

Percentage Organic Matter (%)	**56.1**	**49.8**	**51.4**	**79.9**	**56.4**	**58.1**

Table 106: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged glass slides) exposed for a two week period at six sites around the littoral zone of Lough Gill during May 1997.

Dry Weights at 103°C	Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site: S1	S2	S3	S4	S5	S6
	W4	28-May-97	12-Jun-97	15	1	0.5	Slide lost *	Slide lost *	1.3	3.1	2.4
					2	0.7	Slide lost *	Slide lost *	1.2	3.2	1.8
					3	1.9	Slide lost *	Slide lost *	1.3	Slide lost *	1.4
	Monthly Site Average (g/m^2) +/- Std. Error					**1.0** 1.9			**1.2** 0.2	**3.2** 0.5	**1.9** 1.3

Ash Free Dry Weights at 500°C	Sample code	Exposure period: Placment	Exposure period: Collection	Length of exposure (days)	Replicate no.	Sample site: S1	S2	S3	S4	S5	S6
	W4	28-May-97	12-Jun-97	15	1	0.1	Slide lost *	Slide lost *	0.7	1.7	2.3
					2	0.3	Slide lost *	Slide lost *	1.1	1.5	1.8
					3	0.8	Slide lost *	Slide lost *	1.2	Slide lost *	1.4
	Monthly Site Average (g/m^2) +/- Std. Error					**0.4** 0.9			**1.0** 0.7	**1.6** 1.1	**1.8** 1.2

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**40.6**			**82.4**	**50.6**	**97.7**

Table 107: Dry weight, AFDW and organic matter data from replicate artificial substrates (glass slides) exposed for a two week period at six sites around the littoral zone of Lough Gill during late May and early June 1997. (* = slides vandalised)

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
W1	10-Apr	24-Apr	1	21.1		17.8		23.7		3.1		27.0		2.4	
			2	12.4		24.0		34.6		2.3		22.3		9.1	
			3	23.8		13.2		36.1		2.5		25.2		9.2	
Monthly Site Average (mg/m^2) +/- Std. Error				**19.1**	14.8	**18.3**	13.5	**31.5**	16.8	**2.6**	1.0	**24.8**	5.9	**6.9**	9.7

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
W2	24-Apr	08-May	1	22.9		181.5		47.2		17.5		32.2		12.3	
			2	15.5		162.2		42.5		22.7		41.0		13.2	
			3	16.5		160.5		46.4		21.8		38.1		Slide lost	
Monthly Site Average (mg/m^2) +/- Std. Error				**18.3**	10.0	**168.1**	29.0	**45.4**	6.2	**20.7**	6.9	**37.1**	11.1	**12.8**	5.8

Tables 108 and 109: Chlorophyll data from glass slides submerged for two week peiods at six sites around the littoral zone of Lough Gill during April and early May 1997.

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
W3	08-May	28-May	1	3.9		26.9		48.7		11.4		30.2		18.3	
			2	4.3		28.8		37.9		11.0		34.0		14.7	
			3	15.5		44.3		39.5		16.8		22.3		14.2	
Monthly Site Average (mg/m^2) +/- Std. Error				**7.9**	16.3	**33.3**	23.7	**42.0**	14.5	**13.1**	8.0	**28.8**	14.8	**15.7**	5.6

Sample Code	Placement Date	Retrieval Date	Replicate No.	Sample site											
				S1		S2		S3		S4		S5		S6	
W4	28-May	12-Jun	1	2.4		Slide lost *		Slide lost *		8.6		24.2		10.7	
			2	2.4		Slide lost *		Slide lost *		7.7		21.9		8.8	
			3	4.3		Slide lost *		Slide lost *		10.0		Slide lost *		9.4	
Monthly Site Average (mg/m^2) +/- Std. Error				**3.0**	2.7					**8.8**	2.9	**23.1**	15.0	**9.6**	2.4

Tables 110 and 111: Chlorophyll data from glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during May and early June 1997. (* = slides vandalised)

Sample code	Exposure period		Length of exposure period (days)	Sedgwick-Rafter slide no.	Sample site											
	Placement	Retrieval			S1		S2		S3		S4		S5		S6	
W1	10-Apr-97	24-Apr-97	14	1	1511		2292		3282		425		4014		1152	
				2	979		2151		3259		444		3854		1053	
				3	1226		1916		3236		377		4048		1239	
Monthly Site Average (cells/mm^2) +/- Std. Error					**1239**	661	**2120**	472	**3259**	57	**415**	86	**3972**	257	**1148**	231

Sample code	Exposure period		Length of exposure period (days)	Sedgwick-Rafter slide no.	Sample site											
	Placement	Retrieval			S1		S2		S3		S4		S5		S6	
W2	24-Apr-97	8-May-97	14	1	1827		9588		8168		5898		5199		1487	
				2	1724		8094		7103		5144		5689		1525	
				3	1710		9713		8906		5619		5745		1677	
Monthly Site Average (cells/mm^2) +/- Std. Error					**1754**	159	**9132**	2236	**8059**	2250	**5554**	946	**5544**	746	**1563**	250

Tables 112 and 113: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton collected upon glass slides submerged for two week exposure periods at six sites around the littoral zone of Lough Gill during April and May 1997.

Sample code	Exposure period		Length of exposure period (days)	Sedgwick-Rafter slide no.	Sample site											
	Placement	Retrieval			S1		S2		S3		S4		S5		S6	
W3	8-May-97	28-May-97	20	1	2791		3920		5285		6196		5644		7943	
				2	2353		3674		3971		4734		5017		5435	
				3	2382		3565		4210		3302		4837		4419	
Monthly Site Average (cells/mm²) +/- Std. Error					**2509**	608	**3720**	451	**4489**	1738	**4744**	3592	**5166**	1052	**5932**	4503

Sample code	Exposure period		Length of exposure period (days)	Sedgwick-Rafter slide no.	Sample site											
	Placement	Retrieval			S1		S2		S3		S4		S5		S6	
W4	28-May-97	12-Jun-97	15	1	658		Slide lost *		Slide lost *		3355		6290		2010	
				2	658		Slide lost *		Slide lost *		4333		8219		1376	
				3	764		Slide lost *		Slide lost *		3103		4780		1449	
Monthly Site Average (cells/mm²) +/- Std. Error					**693**	152					**3597**	1613	**6430**	4279	**1612**	861

Tables 114 and 115: Periphyton counts obtained from Sedgwick-Rafter slides. Periphyton collected on glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during May and June 1997. (*=slides vandalised)

10 April to 24 April 1997 (W1)

Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta							
Chlorophyta							
Bacillariophyta	*Amphora*	8	145	141		103	25
	Cocconeis		12	4	8		8
	Craticula					4	
	Cyclotella				1		
	Cymbella	153	466	888	32	1700	413
	Diatoma			7	2		25
	Gomphonema	145	529	591	298	838	491
	Melosira	454	39	103		351	74
	Navicula	33	8				
	Nitzschia	372	752	1296	60	789	87
	Pinnularia						25
	Rhoicosphenia				3		
	Synedra	74	169	229	11	187	
Total number of cells/mm^2 per site:		**1239**	**2120**	**3259**	**415**	**3972**	**1148**

Table 116: The distribution of attached algal genera found upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during April 1997.

24 April to 8 May 1997 (W2)							
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta							
Chlorophyta	*Ankistrodesmus*			9	14		
	Scenedesmus						17
Bacillariophyta	*Achnanthes*	34			112		
	Amphora		249	729	75	210	
	Cocconeis			18		5	17
	Cyclotella					5	
	Cymbella	234	3207	2204	610	2166	64
	Diatoma			46	19		59
	Fragilaria	302	1577	164	159	284	
	Gomphonema	404	249	1402	1943	1463	1054
	Melosira	263	571	36	45	182	42
	Navicula	15		27	9	37	
	Nitzschia	414	2304	3306	2563	1048	297
	Rhoicosphenia						13
	Surirella				5		
	Synedra	88	975	118		144	
Total number of cells/mm^2 per site:		**1754**	**9132**	**8059**	**5554**	**5544**	**1563**

Table 117: The distribution of attached algal genera found upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during April and May 1997.

8 May to 28 May 1997 (W3)							
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Aphanocapsa*						418
	Oscillatoria					139	
Chlorophyta	*Closterium*					10	
	Stigeoclonium		64				896
Bacillariophyta	*Achnanthes*	1305	1471			109	
	Amphora			119	39	20	
	Cocconeis		32		10	40	
	Cymbella	54	314	1573	107	697	438
	Diatoma	5	9	279	29		
	Fragilaria			169	1578	508	527
	Gomphonema	492	1038	1085	2036	2060	2847
	Gyrosigma						
	Melosira			80		129	
	Nitzschia	653	774	856	633	1364	796
	Pinnularia						
	Rhoicosphenia		9	60	20	10	10
	Surirella			169			
	Synedra		9	99		80	
Unknown	Unknown C				292		
Total number of cells/mm^2 per site:		**2509**	**3720**	**4489**	**4744**	**5166**	**5932**

Table 118: The distribution of attached algal genera found upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during May 1997.

28 May to 12 June 1997 (W4)

Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2	cells/mm^2
Cyanophyta	*Aphanocapsa*	63					
	Oscillatoria					662	
Chlorophyta	*Stigeoclonium*				792		115
Bacillariophyta	*Achnanthes*	74			652	1752	223
	Amphora						
	Cocconeis	4			131	28	18
	Cymbella	20			131	103	72
	Diatoma					18	
	Fragilaria	7				2069	66
	Gomphonema	474			1621	1360	966
	Nitzschia	51			270	270	145
	Synedra					19	6
	Tabellaria					149	
Total number of cells/mm^2 per site:		**693**	**Slide lost**	**Slide lost**	**3597**	**6430**	**1611**

Table 119: The distribution of attached algal genera found upon glass slides submerged for two week periods at six sites around the littoral zone of Lough Gill during May and June 1997.

VI. Phytoplankton data

a. Phytoplankton numbers

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P1	5-Mar-97	1	2022		6974		4130		6797		15312		1837	
		2	2135		7237		2950		8889		13769		2544	
		3	3483		5000		5664		4967		13650		2686	
Phytoplankton numbers (cells/ml) +/- Std. Error			**2547**	2018	**6404**	3035	**4248**	3378	**6885**	4872	**14243**	2301	**2356**	1129

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P2	3-Apr-97	1	1079		50000		64783		55025		54725		27709	
		2	2806		36304		38478		55838		50769		22346	
		3	863		53261		38913		54416		64615		18101	
Phytoplankton numbers (cells/ml) +/- Std. Error			**1583**	2644	**46522**	22338	**47391**	37396	**55093**	1771	**56703**	17705	**22719**	11953

Table 120 and 121: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly glass slides from six sites around Lough Gill on the 5th March (P1) and 3rd April (P2) 1997.

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P3	29-Apr-97	1	21209		14888		75915		28416		83091		56390	
		2	19535		7534		74383		44887		99091		67122	
		3	24372		12735		63830		30045		78182		17561	
Phytoplankton numbers (cells/ml) +/- Std. Error			**21705**	6098	**11719**	9386	**71376**	16335	**34449**	22532	**86788**	27144	**47024**	64732

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P4	3-Jun-97	1	19820		87358		160457		16986		159429		300550	
		2	15856		59623		184686		24110		70857		241468	
		3	45766		45660		179657		14795		109524		171376	
Phytoplankton numbers (cells/ml) +/- Std. Error			**27147**	40331	**64214**	52692	**174933**	31744	**18630**	12091	**113270**	110239	**237798**	160538

Table 122 and 123: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly slides from six sites around Lough Gill on the 29th April (P3) and 3rd June (P4) 1997.

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P5	2-Jul-97	1	32077		44461		111276		99850		73485		69231	
		2	28986		67361		115720		121053		73182		49615	
		3	76522		62305		109300		110827		65606		72692	
Phytoplankton numbers (cells/ml) +/- Std. Error			**45862**	66031	**58042**	29867	**112099**	8163	**110576**	26324	**70758**	11082	**63846**	30897

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P6	5-Aug-97	1	80000		43265		12549		36327		13737		73864	
		2	59632		31224		19216		18980		11313		46591	
		3	130552		22449		4510		21633		10505		45909	
Phytoplankton numbers (cells/ml) +/- Std. Error			**90061**	90652	**32313**	25945	**12092**	18281	**25646**	23198	**11852**	4176	**55455**	39589

Table 124 and 125: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly slides from six sites around Lough Gill on the 2nd July (P5) and 5th August (P6) 1997.

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P7	9-Sep-97	1	48298		143232		197937		232077		121340		122476	
		2	32553		112929		118254		175459		64115		80190	
		3	26809		191111		143175		194396		113684		112762	
Phytoplankton numbers (cells/ml) +/- Std. Error			**35887**	27621	**149091**	97862	**153122**	101196	**200644**	71552	**99713**	77123	**105143**	54987

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P8	6-Oct-97	1	145352		164681		197978		115467		38222		120237	
		2	155493		171277		159326		84000		40178		85444	
		3	152113		147447		201798		62400		58133		97988	
Phytoplankton numbers (cells/ml) +/- Std. Error			**150986**	12819	**161135**	30547	**186367**	58332	**87289**	66251	**45511**	27246	**101223**	43745

Table 126 and 127: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly slides from six sites around Lough Gill on the 9th September (P7) 6th October (P8) 1997.

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P9	3-Nov-97	1	406425		653333		34568		97178		33469		1242083	
		2	436684		898571		47901		71656		43810		1182083	
		3	312953		688095		37531		117301		49796		1249583	
Phytoplankton numbers (cells/ml) +/- Std. Error			**385354**	160130	**746667**	329434	**40000**	17381	**95378**	56791	**42358**	20506	**1224583**	91848

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P10	1-Dec-97	1	117705		57368		44211		34118		117931		21858	
		2	69836		172368		26466		90000		78621		52678	
		3	79672		70789		35489		37647		70690		36503	
Phytoplankton numbers (cells/ml) +/- Std. Error			**89071**	62762	**100175**	156106	**35388**	22027	**53922**	77692	**89080**	62804	**37013**	38273

Table 128 and 129: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly glass slides from around Lough Gill on the 3rd November (P9) and 1st December (P10) 1997.

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P11	7-Jan-98	1	7883		14286		12778		6452		25313		5185	
		2	51387		8052		17778		7742		23750		6173	
		3	13431		24416		23333		4129		10313		4444	
Phytoplankton numbers (cells/ml) +/- Std. Error			**24234**	58784	**15585**	20504	**17963**	13108	**6108**	4546	**19792**	20472	**5267**	2154

Sample Code	Sampling Date	Sedgwick-Rafter slide no.	Sample site											
			S1		S2		S3		S4		S5		S6	
P12	4-Feb-98	1	3938		7188		4651		4091		12800		4148	
		2	8290		7188		22636		2500		5867		16000	
		3	3316		10938		11783		5227		8533		4444	
Phytoplankton numbers (cells/ml) +/- Std. Error			**5181**	6728	**8438**	5375	**13023**	22484	**3939**	3401	**9067**	8682	**8198**	16780

Table 130 and 131: Phytoplankton counts obtained from Sedgwick-Rafter slides. Phytoplankton collected in conjunction with monthly glass slides from around Lough Gill on the 7th January (P11) and 4th February (P12) 1998.

VI. Phytoplankton data

b. Phytoplankton genera

Sampling date:	5-Mar-97			Code:	P1		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Gomphosphaeria*		219				
		487	307				
	Spirulina					40	
Chlorophyta	*Actinastrum*				131	752	
	Ankistrodesmus	150	351	39	261	158	94
	Chlamydomonas		132			40	
	Haematococcus						189
	Stigeoclonium					514	
	Volvox	112	263	39	261	395	94
Euglenophyta:	*Euglena*		175				
Bacillariophyta	*Cocconeis*	112	44	79	131	633	141
	Craticula					158	
	Cymbella	187	351	157	87	673	94
	Diatoma						94
	Fragilaria			79			
	Gomphonema	375	1623	2557	3748	5737	613
	Melosira	862	1360	865	1612	2493	754
	Navicula	112	921	118	349	1345	142
	Nitzschia	112	395	197	218	475	47
	Pinnularia			118		39	
	Rhoicosphenia	38	44		87	395	47
	Surirella		219			277	
	Synedra					119	47
Total number of cells per ml:		**2547**	**6404**	**4248**	**6885**	**14243**	**2356**

Table 132: The distribution of phytoplanktonic algae found in the water column of six sites in the Lough Gill littoral zone on the 5th March 1997.

Sampling date:	3-Apr-97			Code:	P2		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*			2029			
	Chroococcus		652	870	406	513	149
	Oscillatoria		7101	1739	745	2271	2160
Chlorophyta	*Actinastrum*			580			
	Ankistrodesmus	144	435	362	406	293	819
	Ceratium		73				75
	Chlamydomonas			5870	3452		447
	Haematococcus			870	745	293	1192
	Scenedesmus			72			149
	Volvox	24				147	
Euglenophyta:	*Euglena*		145	72	68		
Bacillariophyta	*Cocconeis*	24	145		406	1392	298
	Craticula				203	220	
	Cyclotella	192	507	580	744	513	1117
	Cymbella	24	4348	1449	5482	4322	298
	Diatoma		290		68		
	Fragilaria				677		
	Gomphonema	288	21015	21667	28494	34872	2011
	Gyrosigma		145				
	Melosira	623	5507	5435	7174	5128	13259
	Navicula	168	3333	1304	2504	2637	298
	Nitzschia	48	2246	3043	2436	2637	149
	Rhoicosphenia		507	942	677	1172	
	Surirella		73			73	149
	Synedra	48		507	406	220	149
Total number of cells per ml:		**1583**	**46522**	**47391**	**55093**	**56703**	**22719**

Table 133: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 3rd April 1997.

Sampling date:	29-Apr-97			Code:	P3		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*						2146
	Chroococcus	310	120	284			65
	Merismopedia			227			
	Nostoc		538				
	Oscillatoria		897	5163	4525	11818	22894
Chlorophyta	*Actinastrum*					485	
	Ankistrodesmus	806	359	738	302	364	585
	Ceratium				121		
	Chlamydomonas	1674				182	
	Cryptomonas		1734	794	1327	4363	1951
	Gonium						65
	Haematococcus	2047	658	567	422	121	325
	Scenedesmus		538	454	1025	242	260
Bacillariophyta	*Achnanthes*			227			
	Asterionella	682	239	284		303	1236
	Cocconeis			397	362	364	
	Cyclotella	2419	1315	1248	1569	1394	2602
	Cymbella	186	538	7773	1750	15576	586
	Diatoma				362	61	65
	Epithemia					2000	
	Fragilaria	124	179		362	9273	
	Gomphonema	1364	538	31149	14842	22606	4293
	Melosira	9985	1614	9872	1810	6061	8585
	Navicula	496	837	1816	1689	4667	455
	Nitzschia	1364	837	7546	2473	4363	586
	Rhoicosphenia	62	120	2326	362	1091	260
	Surirella	124		57	362	121	
	Synedra	62	419	454	784	1333	65
	Tabellaria		239				
Total number of cells per ml:		**21705**	**11719**	**71376**	**34449**	**86788**	**47024**

Table 134: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 29th April 1997.

Sampling date:	3-Jun-97			Code:	P4		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	8589	24339	7010	2009	36825	88318
	Aphanocapsa	12372	21572	457	1096	48952	143733
	Aphanothece		4528				
	Chroococcus		440	305	122	381	
	Cyanothece		818	76			
	Gomphosphaeria			12114			
	Merismopedia	240					
	Microcystis		1761		1157		
	Oscillatoria	601	2893	1676		5016	4037
Chlorophyta	*Actinastrum*			457			
	Ankistrodesmus	481	440	381	365		
	Ceratium		126			64	122
	Chaetophora			1676			
	Coelastrum		1006	305			
	Cryptomonas		566		61		122
	Haematococcus	481	314	305		254	122
	Micrasterias			76			
	Spirogyra			305			
	Volvox			610	122	191	
Euglenophyta:	*Euglena*		189	76			
Bacillariophyta	*Cocconeis*		126			318	
	Craticula			305			
	Cyclotella	60	63		122	127	
	Cymbella	180	755	4648	3409	1651	122
	Diatoma	180	63	2057		2921	
	Fragilaria	1141		117333	1096	5460	
	Gomphonema	721	2579	4800	4323	2349	856
	Gyrosigma					63	
	Melosira	420	503	7009	1583	4254	
	Navicula	240	126	2209	791	889	122
	Nitzschia	1261	755	7467	1948	2794	122
	Rhoicosphenia	120		838		317	122
	Surirella			457	304	63	
	Synedra	60	252	1981	122	381	
Total number of cells per ml:		**27147**	**64214**	**174933**	**18630**	**113270**	**237798**

Table 135: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 3rd June 1997.

Sampling date:	2-Jul-97			Code:	P5		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	20419	48624	94431	92080	42929	52308
	Aphanocapsa	644	149	1591	1554	808	1667
	Chroococcus	64	50		200		
	Gomphosphaeria	13913					
	Oscillatoria	3027	1933	6145	7519	7424	4359
Chlorophyta	*Ankistrodesmus*	322	496	439	301	202	
	Ceratium			110	150	50	
	Coelastrum			549			
	Cryptomonas		297	274			833
	Gloeocystis	644					
	Haematococcus	580	198	329	150	202	449
	Mougeotia	387					
	Scenedesmus	515	198	219			513
	Volvox	258			50		64
Bacillariophyta	*Amphora*	64		165		455	
	Cocconeis		50	165		152	
	Cyclotella					101	128
	Cymbella	129	595	494	702	1111	1346
	Diatoma		248	2359	601	13434	64
	Fragilaria		396	933	2757	152	
	Gomphonema	709	2726	1636	2306	1162	1282
	Gyrosigma			55			64
	Melosira	3478	1288				
	Navicula	129	248	1043	351	303	64
	Nitzschia	387	496	1097	1504	859	641
	Rhoicosphenia	129	50		50		
	Surirella	64					
	Synedra			165	301	1414	64
Total number of cells per ml:		**45862**	**58042**	**112199**	**110576**	**70758**	**63846**

Table 136: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 2nd July 1997.

Sampling date:	5-Aug-97			Code:	P6		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	24703	3401	588	10680	2088	23636
	Aphanocapsa	5890	3401		4014		12652
	Merismopedia	327	272				
	Microcystis				4354		
	Oscillatoria	10634	2381	5621	1769	1145	6667
Chlorophyta	*Ankistrodesmus*	3354	1293	719	1701	741	2045
	Characium		136	66			
	Closteriopsis	245	68		272	202	227
	Closterium		204		136		
	Cryptomonas	3681	1429	66	748	875	2348
	Haematococcus			196	68	67	
	Mougeotia	1309			204		303
	Oedogonium	29693					
	Scenedesmus	4090	544	261			606
	Staurastrum					67	
	Volvox	245	136	66			
Bacillariophyta	*Amphora*			66		67	
	Cocconeis	736	204	66	136	270	833
	Craticula						227
	Cyclotella	245		66	68		76
	Cymbella	491	1973	1111	272	539	530
	Diatoma		68			471	
	Fragilaria		2177	784	340	1077	
	Gomphonema	1718	12245	1764	68	1684	2273
	Melosira		340			1077	152
	Navicula	654	953	261	340	135	758
	Nitzschia	573	544	130	408	875	1970
	Rhoicosphenia	409	544	261		270	76
	Synedra	164			68	202	76
	Unknown D	900					
Total number of cells per ml:		**90061**	**32313**	**12092**	**25646**	**11852**	**55455**

Table 137: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 5th August1997.

Sampling date:	9-Sep-97			Code:	P7		
Phylum	**Algae genera**	**Sample Site**					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	567	21212	50370	36586	7911	16063
	Aphanocapsa	4113	12862				444
	Cyanothece		2424				
	Gomphosphaeria		18788	4286	17327	13525	3873
	Microcystis	16524	51515	13545	72979	28772	27683
	Oscillatoria	9007	33401	82857	68921	29920	52825
Chlorophyta	*Actinastrum*				258		
	Ankistrodesmus	780	606		838		254
	Ceratium		202		64		
	Closteriopsis	284	270	159	129	255	317
	Cryptomonas		135	476	387		
	Haematococcus	284					
	Micrasterias					127	
	Oedogonium					9059	
	Scenedesmus		1347	423	258	510	508
	Volvox			53			
Euglenophyta:	*Euglena*			53		64	
Bacillariophyta	*Cocconeis*	213			64	383	
	Craticula			106			
	Cyclotella	213	404		64	64	
	Cymbella	71	673	159	64	702	254
	Diatoma	284	404	53			64
	Fragilaria	213			1675	1722	
	Gomphonema		2896	211	193	1786	254
	Gyrosigma		67		64		
	Melosira	2979				1914	2159
	Navicula		404	53	258	702	64
	Nitzschia	284	404	159	451	1212	254
	Rhoicosphenia		673	106		510	
	Surirella					128	
	Synedra	71	404	53	64	447	127
Total number of cells per ml:		**35887**	**149091**	**153122**	**200644**	**99713**	**105143**

Table 138: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 9th September 1997.

Sampling date:	**6-Oct-97**		**Code:**	**P8**		
Phylum	**Algae genera**	**Sample Site**				
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	14742	35957	31685	3022	1304	5917
	Aphanocapsa						1105
	Gomphosphaeria		6028	7940			22248
	Merismopedia	939					
	Microcystis	22441	31348	23820	11911		3235
	Oscillatoria	93427	83546	111311	57511	30993	49704
Chlorophyta	*Ankistrodesmus*	751	284				552
	Asterococcus			899		830	
	Closteriopsis	1596	425	974	1600	296	2051
	Coelastrum						79
	Crucigenia			300			
	Scenedesmus	751	284		1245	711	
	Staurastrum						79
	Tetrastrum				89	59	158
Bacillariophyta	*Amphora*	94					
	Asterionella	751					
	Cocconeis	282				178	
	Craticula						79
	Cyclotella	376	142		178	119	158
	Cymbella	469		150			
	Diatoma	94	71		89		
	Fragilaria	563	709			1422	
	Gomphonema	845	213	300	89	355	158
	Gyrosigma					59	
	Melosira	11831	1560	8764	11111	7704	15542
	Navicula	376	213			592	
	Nitzschia	188	213	224	444	415	158
	Rhoicosphenia	376				237	
	Surirella	94	71				
	Synedra		71			237	
Total number of cells per ml:		**150986**	**161135**	**186367**	**87289**	**45511**	**101223**

Table 139: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 6th October 1997.

Sampling date:	3-Nov-97		Code:	P9		
Phylum	**Algae genera**	**Sample Site**				
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	69361	61111		2945		262083
	Aphanocapsa		100794	576			
	Aphanothece						2083
	Gomphosphaeria	66114	317460				192639
	Microcystis	5872	115873				
	Nostoc						238750
	Oscillatoria	241244	147619	18025	84499	16054	520277
Chlorophyta	*Ankistrodesmus*			1646	82	907	
	Asterococcus	484					3333
	Closteriopsis	1934	159	412	1963	2268	4167
	Cryptomonas				2045		
	Pediastrum						139
	Scenedesmus			329			
	Tetrastrum					91	
Bacillariophyta	*Amphora*					91	
	Asterionella				654		
	Cocconeis					91	
	Craticula			82			
	Cyclotella			329		181	278
	Cymbella					272	417
	Diatoma			82			
	Gomphonema	69	2540		245	181	
	Gyrosigma	69					
	Melosira			16708	2863	21769	
	Navicula	69	1111	494		181	417
	Nitzschia	69			82		
	Rhoicosphenia			165			
	Surirella	69					
	Synedra			576		272	
	Unknown E			576			
Total number of cells per ml:		**385354**	**746667**	**40000**	**95378**	**42358**	**1224583**

Table 140: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 3rd November 1997.

Sampling date:	1-Dec-97			Code:	P10		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Anabaena*	9727	4912			4828	583
	Gomphosphaeria	7541	13158			31034	6557
	Oscillatoria	43060	34737	23358	22157	16781	13188
Chlorophyta	*Actinastrum*			301			
	Ankistrodesmus	219					
	Closteriopsis	3825	1579	2305	2059	4023	947
	Coelastrum	109					
	Cryptomonas	765					
	Scenedesmus	437	351			919	291
Chrysophyta:	*Uroglena*		29562		9805		5100
Bacillariophyta	*Amphora*	109	88				
	Cocconeis	219					
	Craticula			100			
	Cyclotella	109	175	100	294	230	146
	Cymbella		351		98	115	291
	Diatoma					230	
	Fragilaria		1140		196		146
	Frustulia				98		
	Gomphonema	1093	175	201	588	805	219
	Gyrosigma		88				
	Melosira	21530	12544	8221	17549	28046	8670
	Navicula	328	614	301	588	919	291
	Nitzschia		263				219
	Rhoicosphenia		263	100	98	805	146
	Surirella				98		
	Synedra		175	401	294	345	219
Total number of cells per ml:		**89071**	**100175**	**35388**	**53922**	**89080**	**37013**

Table 141: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 1st December 1997.

Sampling date:	7-Jan-98			Code:	P11		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Gomphosphaeria*						
	Oscillatoria	13626	7792	9260		1979	
Chlorophyta	*Closteriopsis*	487	866	1852	172	1876	658
	Scenedesmus				344	417	
	Tetrastrum			370			
Bacillariophyta	*Achnanthes*			370			329
	Amphora	97				104	
	Asterionella				172		
	Cocconeis		86			104	
	Cyclotella	97			86	208	
	Cymbella			185		208	82
	Diatoma					104	
	Gomphonema		346	185	172	938	247
	Melosira	8175	6494	5185	4904	13646	3704
	Navicula	195		556	258	104	
	Nitzschia	97					82
	Rhoicosphenia					104	
	Synedra						165
	Unknown F	1460					
Total number of cells per ml:		**24234**	**15584**	**17963**	**6108**	**19792**	**5267**

Table 142: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 7th January 1998.

Sampling date:	4-Feb-98			Code:	P12		
Phylum	Algae genera	Sample Site					
		S1	S2	S3	S4	S5	S6
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Cyanophyta	*Oscillatoria*						2370
	Spirulina				76		
Chlorophyta	*Actinastrum*	276	418				
	Closteriopsis	276	1250	1034	152	711	691
	Tetrastrum		104	103			
Chrysophyta:	*Uroglena*			4651			
Bacillariophyta	*Amphora*				76		99
	Cocconeis				227	356	198
	Cyclotella	207	104		76	178	296
	Cymbella					178	296
	Gomphonema		208	207	530	533	1580
	Melosira	4353	5833	5581	2348	6577	2569
	Navicula		208	724	227	356	99
	Rhoicosphenia			413	227	178	
	Surirella			103			
	Synedra	69	313	207			
Total number of cells per ml:		**5181**	**8438**	**13023**	**3939**	**9067**	**8198**

Table 143: The distribution of phytoplanktonic algae found in the water column of six sites within the Lough Gill littoral zone on the 4th February 1998.

VII. Artificial *Littorella* data

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L1	Feb-97	40	1	49.0		36.7		42.3		34.1		22.3		31.3	
				2	57.3		27.3		46.2		24.9		45.3		32.7	
				3	57.4		19.9		37.4		34.1		23.3		34.4	
	Monthly Site Average (g/m^2) +/- Std. Error				**54.6**	12.0	**28.0**	20.9	**42.0**	10.9	**31.0**	13.2	**30.3**	32.3	**32.8**	3.9

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L1	Feb-97	40	1	13.0		5.6		10.7		8.3		5.8		8.6	
				2	15.9		7.4		11.9		5.8		14.0		10.1	
				3	13.9		5.9		7.6		7.3		7.7		8.7	
	Monthly Site Average (g/m^2) +/- Std. Error				**14.3**	3.7	**6.3**	2.4	**10.1**	5.5	**7.1**	3.1	**9.2**	10.7	**9.1**	2.1

Percentage Organic Matter (%)	**26.1**	**22.5**	**24.0**	**23.0**	**30.3**	**27.8**

Table 144: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during February 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
L2	March-97	30	1	77.2		93.0		85.1		47.9		52.0		43.2	
			2	48.6		103.9		68.8		54.5		46.2		34.5	
			3	73.9		86.1		80.2		50.6		74.3		29.8	
Monthly Site Average (g/m^2) +/- Std. Error				**66.6**	38.8	**94.3**	22.3	**78.0**	20.8	**51.0**	8.2	**57.5**	36.8	**35.8**	16.9

Ash free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
L2	March-97	30	1	18.7		21.5		20.7		12.5		16.6		12.2	
			2	13.2		28.0		15.9		15.6		12.6		10.0	
			3	13.5		15.8		17.8		12.2		22.5		11.6	
Monthly Site Average (g/m^2) +/- Std. Error				**15.1**	7.7	**21.8**	15.2	**18.1**	6.0	**13.4**	4.7	**17.2**	12.4	**11.3**	2.8

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**22.7**	**23.1**	**23.2**	**26.3**	**30.0**	**31.4**

Table 145: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during March 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
L3	April-97	34	1	53.2		70.8		103.5		53.7		71.0		74.2	
			2	42.9		79.6		110.4		56.5		53.0		39.3	
			3	Plot lost *		74.5		101.2		54.6		81.0		81.9	
Monthly Site Average (g/m^2) +/- Std. Error				**48.1**	67.0	**75.0**	11.0	**105.0**	11.9	**54.9**	3.5	**68.3**	35.2	**65.1**	56.4

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
L3	April-97	34	1	26.3		21.7		29.5		18.7		20.2		14.2	
			2	24.8		26.5		33.7		16.1		16.7		15.2	
			3	Plot lost *		24.6		29.1		17.0		22.9		31.6	
Monthly Site Average (g/m^2) +/- Std. Error				**25.6**	9.8	**24.3**	6.0	**30.8**	6.3	**17.3**	3.3	**19.9**	7.7	**20.3**	24.3

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**53.2**	**32.4**	**29.3**	**31.4**	**29.2**	**31.2**

Table 146: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during April 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L4	May-97	42	1	50.0		21.6		30.1		25.8		42.5		51.4	
				2	31.8		30.0		31.3		32.1		62.4		39.7	
				3	30.5		21.7		23.5		25.1		34.6		60.8	
				4	47.8		25.9		32.9		39.1		38.7		42.6	
				5	43.2		28.3		29.2		29.8		32.5		34.7	
	Monthly Site Average (g/m^2) +/- Std. Error				**40.7**	11.3	**25.5**	4.8	**29.4**	4.5	**30.4**	7.1	**42.1**	15.0	**45.8**	12.9

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L4	May-97	42	1	12.0		9.6		14.1		13.2		16.8		17.6	
				2	9.8		11.3		15.6		15.0		13.3		15.7	
				3	8.9		8.8		13.2		12.8		13.9		20.8	
				4	10.0		11.6		15.5		18.4		15.7		16.7	
				5	10.3		12.7		13.6		13.8		11.7		15.2	
	Monthly Site Average (g/m^2) +/- Std. Error				**10.2**	1.4	**10.8**	2.0	**14.4**	1.4	**14.6**	2.8	**14.3**	2.5	**17.2**	2.8

Percentage Organic Matter (%)	**25.1**	**42.4**	**49.0**	**48.2**	**33.9**	**37.5**

Table 147: Dry weight, ash free dry weight and percentage organic matter obtained from submerged poits of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during May 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L5	June-97	26	1	17.6		31.9		18.1		29.6		37.3		47.7	
				2	24.7		28.1		21.4		25.2		161.9		53.1	
				3	26.4		31.4		21.9		33.4		49.6		41.0	
				4	42.9		31.2		Plot lost		24.9		44.1		54.0	
				5	38.5		27.5		Plot lost		32.0		38.2		46.4	
	Monthly Site Average (g/m^2) +/- Std. Error				**30.0**	13.0	**30.0**	2.6	**20.5**	5.1	**29.0**	4.8	**66.2**	67.3	**48.4**	6.6

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L5	June-97	26	1	7.2		13.2		8.1		11.8		12.6		18.3	
				2	9.1		12.1		7.8		10.9		40.2		19.4	
				3	10.0		12.4		10.4		11.2		15.9		16.9	
				4	11.5		13.3		Plot lost		9.0		14.4		18.2	
				5	11.0		12.1		Plot lost		11.3		10.9		19.3	
	Monthly Site Average (g/m^2) +/- Std. Error				**9.8**	2.1	**12.6**	0.7	**8.8**	3.5	**10.8**	1.4	**18.8**	15.2	**18.4**	1.3

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**32.5**	**42.0**	**42.8**	**37.4**	**28.4**	**38.0**

Table 148: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during June 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L6	July-97	27	1	66.0		29.2		34.9		25.6		31.2		43.0	
				2	38.9		33.5		24.5		26.3		27.4		44.1	
				3	57.7		33.3		41.4		22.1		30.6		38.0	
				4	44.7		29.1		36.4		18.2		29.5		40.2	
				5	51.0		29.9		23.0		17.5		31.5		28.4	
	Monthly Site Average (g/m^2) +/- Std. Error				**51.7**	13.3	**31.0**	2.8	**32.0**	10.0	**21.9**	5.1	**30.0**	2.1	**38.7**	7.8

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L6	July-97	27	1	20.5		11.6		13.9		10.2		12.6		16.9	
				2	13.3		14.7		8.9		12.0		13.2		16.9	
				3	18.4		15.8		15.5		8.4		11.6		14.7	
				4	14.1		13.6		12.0		9.2		10.1		15.8	
				5	17.2		11.6		9.2		8.1		12.7		12.0	
	Monthly Site Average (g/m^2) +/- Std. Error				**16.7**	3.8	**13.5**	2.3	**11.9**	3.6	**9.6**	2.0	**12.0**	1.5	**15.3**	2.6

Percentage Organic Matter (%)	**32.3**	**43.4**	**37.1**	**43.7**	**40.1**	**39.4**

Table 149: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during July 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L7	August-97	29	1	65.7		55.7		35.4		34.9		33.0		29.3	
				2	61.3		46.8		37.1		32.2		45.4		27.6	
				3	58.8		41.4		37.2		20.5		Plot lost		30.5	
				4	66.2		56.6		Plot lost		33.1		Plot lost		36.6	
				5	Plot lost		44.4		Plot lost		26.4		Plot lost		Plot lost	
	Monthly Site Average (g/m^2) +/- Std. Error				**63.0**	5.7	**49.0**	8.5	**36.6**	2.5	**29.4**	7.4	**39.2**	80.6	**31.0**	6.3

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L7	August-97	29	1	17.0		15.8		12.7		11.7		11.6		7.9	
				2	15.1		14.3		12.9		12.1		14.7		9.4	
				3	14.5		12.6		11.7		7.8		Plot lost		10.5	
				4	13.6		14.7		Plot lost		10.2		Plot lost		11.8	
				5	Plot lost		13.7		Plot lost		9.5		Plot lost		Plot lost	
	Monthly Site Average (g/m^2) +/- Std. Error				**15.1**	2.3	**14.2**	1.5	**12.4**	1.6	**10.3**	2.2	**13.2**	20.2	**9.9**	2.6

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**23.9**	**29.0**	**34.0**	**34.9**	**33.5**	**31.9**

Table 150: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during August 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L8	Sep-97	28	1	53.9		36.9		38.1		24.6		23.8		34.6	
				2	50.0		37.9		34.5		19.6		20.1		34.7	
				3	54.9		41.0		33.4		33.1		32.7		33.3	
				4	39.0		42.2		46.3		18.4		25.7		35.2	
				5	Plot lost		45.3		Plot lost		Plot lost		24.1		49.0	
	Monthly Site Average (g/m^2) +/- Std. Error				**49.5**	11.6	**40.7**	4.2	**38.1**	9.3	**23.9**	10.7	**25.3**	5.8	**37.4**	8.2

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	L8	Sep-97	28	1	15.4		16.7		12.1		12.3		8.9		13.1	
				2	15.3		17.5		9.6		8.2		9.6		14.9	
				3	15.8		16.0		10.3		24.8		12.4		14.7	
				4	16.6		17.0		22.1		9.9		8.3		13.8	
				5	Plot lost		10.4		Plot lost		Plot lost		7.8		15.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**15.8**	0.9	**15.5**	3.6	**13.5**	9.3	**13.8**	12.0	**9.4**	2.3	**14.4**	1.2

Percentage Organic Matter (%)	**31.9**	**38.2**	**35.5**	**57.7**	**37.2**	**38.5**

Table 151: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sites around the littoral zone of Lough Gill during September 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
	L9	Oct-97	28	1	22.1		24.2		23.2		20.3		17.6		24.8	
				2	19.0		22.3		15.0		19.7		22.8		24.9	
				3	19.1		27.0		14.2		22.7		16.5		30.9	
				4	20.6		24.1		Plot lost		21.0		19.9		15.4	
				5	Plot lost		26.9		Plot lost		Plot lost		Plot lost		25.1	
	Monthly Site Average (g/m^2) +/- Std. Error				**20.2**	2.3	**24.9**	2.5	**17.5**	12.4	**20.9**	2.1	**19.2**	4.5	**24.2**	7.0

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
	L9	Oct-97	28	1	10.1		10.2		9.5		9.0		6.7		5.5	
				2	5.5		8.5		3.3		6.5		7.5		8.9	
				3	7.0		8.1		6.7		5.9		4.0		21.5	
				4	5.9		10.5		Plot lost		8.3		6.0		11.1	
				5	Plot lost		9.0		Plot lost		Plot lost		Plot lost		9.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**7.1**	3.3	**9.3**	1.3	**6.5**	7.7	**7.4**	2.3	**6.1**	2.4	**11.3**	7.6

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**35.3**	**37.2**	**37.2**	**35.5**	**31.5**	**46.7**

Table 152: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during October 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
L10	Nov-97	28	1	19.0		16.5		15.5		17.1		11.5		16.1	
			2	14.9		20.5		14.1		14.9		13.6		20.4	
			3	17.6		19.5		13.0		15.2		16.0		29.5	
			4	22.3		26.0		14.6		Plot lost		16.5		16.5	
			5	14.2		Plot lost		Plot lost		Plot lost		Plot lost		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**17.6**	4.1	**20.6**	6.3	**14.3**	1.7	**15.7**	3.0	**14.4**	3.7	**20.6**	10.0

Sample site spans columns S1–S6.

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
L10	Nov-97	28	1	7.6		7.7		6.1		7.1		5.3		6.7	
			2	5.7		10.1		4.7		6.6		5.4		8.3	
			3	6.0		4.5		4.0		6.6		5.6		10.1	
			4	5.5		12.7		6.1		Plot lost		6.7		6.3	
			5	5.8		Plot lost		Plot lost		Plot lost		Plot lost		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**6.1**	1.1	**8.8**	5.6	**5.2**	1.7	**6.8**	0.7	**5.8**	1.0	**7.9**	2.8

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**34.8**	**42.4**	**36.5**	**43.0**	**39.9**	**38.1**

Table 153: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sites around the littoral zone of Lough Gill during November 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
L13	Feb-98	28	1	23.7		20.4		20.6		12.2		12.7		28.1	
			2	26.2		29.3		30.5		22.2		31.5		26.0	
			3	27.4		23.3		16.4		23.0		27.0		Plot lost	
			4	Plot lost		24.9		Plot lost		15.1		Plot lost		Plot lost	
			5	Plot lost		28.4		Plot lost		Plot lost		Plot lost		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**25.8**	4.7	**25.3**	4.6	**22.5**	18.0	**18.1**	8.5	**23.7**	24.4	**27.1**	13.7

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
L13	Feb-98	28	1	5.7		6.6		7.2		5.5		11.3		10.9	
			2	8.1		9.5		9.2		8.9		11.4		8.2	
			3	6.9		7.7		6.3		7.1		10.4		Plot lost	
			4	Plot lost		8.1		Plot lost		11.5		Plot lost		Plot lost	
			5	Plot lost		9.3		Plot lost		Plot lost		Plot lost		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**6.9**	3.0	**8.2**	1.5	**7.6**	3.7	**8.3**	4.1	**11.0**	1.4	**9.6**	17.6

Percentage Organic Matter (%)	**26.8**	**32.6**	**33.6**	**45.5**	**46.5**	**35.3**

Table 154: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sites around the littoral zone of Lough Gill during February 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
L14	March-98	29	1	51.0		42.7		47.8		31.8		37.9		50.3	
			2	47.1		65.2		49.5		33.3		44.8		50.6	
			3	45.5		47.1		50.6		37.1		44.4		51.7	
			4	50.0		Plot lost		50.4		32.5		49.5		Plot lost	
			5	52.3		Plot lost		50.8		Plot lost		44.7		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**49.2**	3.5	**51.7**	29.6	**49.8**	1.5	**33.7**	3.8	**44.3**	5.2	**50.9**	1.8

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
L14	March-98	29	1	9.1		8.2		9.9		5.8		15.3		15.6	
			2	11.8		34.6		20.4		7.3		12.0		12.9	
			3	10.5		16.3		14.5		8.9		19.3		12.5	
			4	13.8		Plot lost		14.7		6.2		14.5		Plot lost	
			5	16.1		Plot lost		17.5		Plot lost		13.2		Plot lost	
Monthly Site Average (g/m^2) +/- Std. Error				**12.3**	3.5	**19.7**	33.6	**15.4**	4.9	**7.1**	2.2	**14.9**	3.5	**13.7**	4.2

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**24.9**	**38.1**	**30.9**	**20.9**	**33.6**	**26.9**

Table 155: Dry weight, ash free dry weight and percentage organic matter obtained from submerged plots of plastic *Littorella* at six sample sites around the littoral zone of Lough Gill during March 1997.

VIII. Washed stone data

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 1	April-97	27	1	295.6		193.8		1109.6		185.1		543.5		250.9	
			2	388.6		277.2		1107.4		758.3		785.5		256.9	
			3	288.8		166.0		Tray lost		324.3		1467.7		218.8	
Monthly Site Average (g/m^2) +/- Std. Error				**324.3**	138.4	**212.3**	143.7	**1108.5**	14.3	**422.6**	742.2	**932.2**	1189.8	**242.2**	50.9

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 1	April-97	27	1	16.1		25.0		254.0		18.6		51.5		38.3	
			2	18.7		36.9		298.2		26.6		82.5		35.5	
			3	25.4		31.2		Tray lost		20.5		62.3		34.3	
Monthly Site Average (g/m^2) +/- Std. Error				**20.1**	11.9	**31.0**	14.8	**276.1**	287.3	**21.9**	10.4	**65.4**	39.1	**36.0**	5.1

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**6.2**	**14.6**	**24.9**	**5.2**	**7.0**	**14.9**

Table 156: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of April 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	St 2	May-97	33	1	1292.1		407.5		758.4		88.2		577.1		105.3	
				2	1677.8		436.3		346.1		56.9		988.6		121.9	
				3	2181.9		528.9		1416.7		248.7		1204.5		65.7	
	Monthly Site Average (g/m^2) +/- Std. Error				**1717.3**	1107.8	**457.6**	157.5	**840.4**	1340.6	**131.3**	255.5	**923.4**	791.3	**97.6**	71.7

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	St 2	May-97	33	1	41.8		50.1		54.9		13.6		27.9		18.8	
				2	47.3		59.9		35.1		10.1		42.6		23.2	
				3	60.8		52.1		109.1		21.3		39.2		11.6	
	Monthly Site Average (g/m^2) +/- Std. Error				**50.0**	24.3	**54.0**	12.9	**66.4**	95.1	**15.0**	14.2	**36.6**	19.1	**17.9**	14.5

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**2.9**	**11.8**	**7.9**	**11.4**	**4.0**	**18.3**

Table 157: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of May 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 3	June-97	35	1	341.0		94.3		176.9		321.5		636.7		103.1	
			2	380.1		72.1		258.1		307.0		548.8		165.2	
			3	320.3		75.9		Tray lost		367.5		887.4		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**347.1**	75.4	**80.8**	29.5	**217.5**	527.8	**332.0**	78.4	**691.0**	436.2	**134.2**	403.7

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 3	June-97	35	1	17.2		19.6		16.6		31.6		48.6		24.9	
			2	20.1		15.5		31.9		28.5		41.1		25.9	
			3	18.6		18.3		Tray lost		26.4		38.1		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**18.6**	3.6	**17.8**	5.2	**24.3**	99.5	**28.8**	6.5	**42.6**	13.4	**25.4**	6.5

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**5.4**	**22.0**	**11.1**	**8.7**	**6.2**	**18.9**

Table 158: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of June 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 4	July-97	27	1	432.6		37.2		166.0		37.2		33.6		73.7	
			2	113.8		31.9		44.4		47.4		26.7		125.4	
			3	176.3		30.7		105.6		39.5		29.2		139.2	
			4	298.1		18.1		43.7		52.3		25.8		69.3	
			5	Tray lost		46.6		123.5		Tray lost		30.8		86.5	
Monthly Site Average (g/m^2) +/- Std. Error				**255.2**	225.4	**32.9**	13.0	**96.6**	66.1	**44.1**	11.2	**29.2**	3.9	**98.8**	39.6

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 4	July-97	27	1	23.3		7.8		24.5		12.8		8.1		19.7	
			2	11.5		9.0		8.8		16.3		5.3		33.7	
			3	14.9		10.7		17.1		11.8		7.2		37.0	
			4	17.7		3.6		7.5		18.8		7.0		17.3	
			5	Tray lost		8.8		14.8		Tray lost		7.7		24.1	
Monthly Site Average (g/m^2) +/- Std. Error				**16.9**	8.0	**8.0**	3.3	**14.5**	8.6	**14.9**	5.2	**7.1**	1.3	**26.4**	10.8

Percentage Organic Matter (%)	**6.6**	**24.3**	**15.0**	**33.8**	**24.2**	**26.7**

Table 159: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of July 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 5	August-97	29	1	995.0		154.6		59.4		94.0		252.7		37.5	
			2	460.0		147.3		73.7		79.2		281.6		92.6	
			3	280.4		Tray lost		80.3		58.3		318.4		Tray lost	
			4	630.7		Tray lost		Tray lost		79.9		201.9		Tray lost	
			5	869.6		Tray lost		Tray lost		56.8		216.2		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**647.1**	365.2	**151.0**	47.5	**71.1**	26.6	**73.6**	19.8	**254.2**	59.6	**65.1**	358.2

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 5	August-97	29	1	49.4		31.8		16.3		18.1		40.3		8.0	
			2	19.7		31.9		14.6		12.0		53.4		14.0	
			3	26.0		Tray lost		4.9		11.2		66.7		Tray lost	
			4	30.8		Tray lost		Tray lost		13.9		41.0		Tray lost	
			5	42.1		Tray lost		Tray lost		8.4		30.8		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**33.6**	15.1	**31.9**	0.6	**11.9**	15.3	**12.7**	4.5	**46.4**	17.4	**11.0**	39.0

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**5.2**	**21.1**	**16.8**	**17.3**	**18.3**	**16.9**

Table 160: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of August 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
St 6	Sep-97	28	1	48.7		20.4		164.4		32.6		18.4		15.5	
			2	37.2		22.9		80.2		13.7		45.0		42.9	
			3	29.3		19.1		Tray lost		Tray lost		18.6		16.0	
			4	32.3		11.1		Tray lost		Tray lost		12.8		13.5	
			5	32.8		18.7		Tray lost		Tray lost		50.2		24.4	
Monthly Site Average (g/m^2) +/- Std. Error				**36.1**	9.5	**18.4**	5.5	**122.3**	547.3	**23.2**	122.9	**29.0**	21.6	**22.5**	15.2

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
St 6	Sep-97	28	1	4.7		4.9		14.0		5.8		5.1		3.7	
			2	3.6		5.4		16.1		3.3		10.1		9.0	
			3	3.5		4.2		Tray lost		Tray lost		5.0		3.8	
			4	2.9		2.8		Tray lost		Tray lost		3.4		3.0	
			5	3.1		4.5		Tray lost		Tray lost		12.1		5.0	
Monthly Site Average (g/m^2) +/- Std. Error				**3.6**	0.9	**4.4**	1.2	**15.1**	13.7	**4.6**	16.3	**7.1**	4.7	**4.9**	3.0

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**9.9**	**23.6**	**12.3**	**19.7**	**24.6**	**21.8**

Table 161: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of September 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 7	October-97	28	1	54.5		9.5		24.3		7.7		8.9		10.4	
			2	37.9		24.6		Tray lost		18.0		38.3		25.6	
			3	33.6		28.5		Tray lost		8.1		19.1		20.5	
			4	45.8		18.3		Tray lost		3.6		23.8		29.6	
			5	44.6		Tray lost		Tray lost		Tray lost		99.3		16.9	
Monthly Site Average (g/m^2) +/- Std. Error				**43.3**	10.0	**20.2**	13.3	**24.3**		**9.4**	9.8	**37.9**	45.0	**20.6**	9.4

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 7	October-97	28	1	7.5		1.8		6.0		1.8		2.4		2.0	
			2	2.7		2.8		Tray lost		4.2		4.8		5.2	
			3	2.6		4.0		Tray lost		2.1		3.4		4.2	
			4	2.7		3.8		Tray lost		1.1		4.4		7.1	
			5	4.5		Tray lost		Tray lost		Tray lost		9.4		3.4	
Monthly Site Average (g/m^2) +/- Std. Error				**4.0**	2.6	**3.1**	1.6	**6.0**		**2.3**	2.1	**4.9**	3.4	**4.4**	2.4

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**9.2**	**15.3**	**24.7**	**24.6**	**12.9**	**21.3**

Table 162: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of October 1997.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 8	Nov-97	28	1	80.6		40.6		25.0		16.4		7.0		4.8	
			2	41.8		36.3		29.9		29.7		9.6		1.0	
			3	28.3		35.4		31.7		17.8		8.9		3.1	
			4	25.0		33.0		Tray lost		14.8		23.5		4.2	
			5	29.6		Tray lost		Tray lost		14.6		Tray lost		4.3	
Monthly Site Average (g/m^2) +/- Std. Error				**41.1**	28.8	**36.3**	5.1	**28.9**	8.6	**18.7**	7.9	**12.3**	12.1	**3.5**	1.9

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site S1		S2		S3		S4		S5		S6	
St 8	Nov-97	28	1	8.3		8.5		7.0		2.4		1.7		1.3	
			2	3.5		3.3		7.9		5.1		1.6		1.1	
			3	4.1		4.4		10.5		4.9		1.6		0.8	
			4	2.6		6.8		Tray lost		5.0		3.9		1.4	
			5	3.0		Tray lost		Tray lost		2.6		Tray lost		1.3	
Monthly Site Average (g/m^2) +/- Std. Error				**4.3**	2.9	**5.8**	3.8	**8.5**	4.5	**4.0**	1.7	**2.2**	1.8	**1.2**	0.3

Percentage Organic Matter (%)	**10.5**	**15.8**	**29.3**	**21.4**	**18.0**	**33.9**

Table 163: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of November 1997.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	St 10	January-98	27	1	38.3		44.9		7.6		2.9		16.1		14.1	
				2	25.5		46.6		6.1		19.0		22.2		23.8	
				3	45.5		32.9		3.4		7.8		15.4		6.3	
				4	52.6		Tray lost		Tray lost		20.4		22.8		9.0	
				5	40.9		Tray lost		Tray lost		5.2		Tray lost		9.6	
	Monthly Site Average (g/m^2) +/- Std. Error				**40.6**	12.5	**41.5**	18.5	**5.7**	5.3	**11.1**	10.1	**19.1**	6.3	**12.6**	8.6

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
					S1		S2		S3		S4		S5		S6	
	St 10	January-98	27	1	9.2		17.5		2.3		0.9		6.2		5.5	
				2	2.7		22.6		2.1		6.6		8.1		10.3	
				3	9.7		15.2		0.9		3.0		5.6		2.2	
				4	15.0		Tray lost		Tray lost		3.4		7.5		3.7	
				5	7.6		Tray lost		Tray lost		1.4		Tray lost		4.5	
	Monthly Site Average (g/m^2) +/- Std. Error				**8.8**	5.5	**18.4**	9.4	**1.8**	1.9	**3.1**	2.8	**6.9**	1.8	**5.2**	3.9

Percentage Organic Matter (%)	**21.8**	**44.5**	**31.0**	**27.7**	**35.8**	**41.7**

Table 164: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of January 1998.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 11	Feb-98	28	1	94.0		192.0		Tray lost		22.7		107.3		19.6	
			2	95.8		199.1		Tray lost		40.9		121.8		17.2	
			3	66.8		Tray lost		Tray lost		Tray lost		90.3		20.5	
			4	121.9		Tray lost		Tray lost		Tray lost		100.0		19.1	
			5	Tray lost		Tray lost		Tray lost		Tray lost		Tray lost		33.4	
Monthly Site Average (g/m^2) +/- Std. Error				**94.6**	36.0	**195.6**	46.1			**31.8**	118.3	**104.9**	21.2	**22.0**	8.1

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site											
				S1		S2		S3		S4		S5		S6	
St 11	Feb-98	28	1	18.0		56.6		Tray lost		6.3		17.9		3.2	
			2	23.4		54.9		Tray lost		10.6		25.0		3.4	
			3	11.0		Tray lost		Tray lost		Tray lost		19.0		4.6	
			4	25.3		Tray lost		Tray lost		Tray lost		10.4		1.6	
			5	Tray lost		Tray lost		Tray lost		Tray lost		Tray lost		7.1	
Monthly Site Average (g/m^2) +/- Std. Error				**19.4**	10.3	**55.8**	11.0			**8.5**	28.0	**18.1**	9.6	**4.0**	2.6

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**20.5**	**28.5**		**26.6**	**17.2**	**18.1**

Table 165: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of February 1998.

Dry Weights at 103°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
St 12	March-98	29	1	131.9		148.6		Tray lost		Tray lost		99.5		21.5	
			2	177.6		145.4		Tray lost		Tray lost		94.6		42.0	
			3	148.2		Tray lost		Tray lost		Tray lost		Tray lost		97.4	
			4	100.0		Tray lost		Tray lost		Tray lost		Tray lost		38.8	
			5	Tray lost		Tray lost		Tray lost		Tray lost		Tray lost		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**139.4**	51.8	**147.0**	20.8					**97.1**	31.8	**49.9**	52.6

Ash Free Dry Weights at 500°C

Sample code	Exposure period	Length of exposure (days)	Replicate no.	S1		S2		S3		S4		S5		S6	
St 12	March-98	29	1	41.7		38.0		Tray lost		Tray lost		17.4		4.6	
			2	38.6		23.0		Tray lost		Tray lost		10.1		9.5	
			3	28.5		Tray lost		Tray lost		Tray lost		Tray lost		16.4	
			4	14.6		Tray lost		Tray lost		Tray lost		Tray lost		9.4	
			5	Tray lost		Tray lost		Tray lost		Tray lost		Tray lost		Tray lost	
Monthly Site Average (g/m^2) +/- Std. Error				**30.9**	19.5	**30.5**	97.5					**13.8**	47.4	**10.0**	7.8

	S1	S2	S3	S4	S5	S6
Percentage Organic Matter (%)	**22.1**	**20.7**			**14.2**	**20.0**

Table 166: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of March 1998.

Dry Weights at 103°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site					
					S1	S2	S3	S4	S5	S6
	St 13	April-98	34	1	98.3	168.7	52.4	52.0	180.5	43.8
				2	124.8	170.1	46.2	132.3	340.6	60.2
				3	55.2	308.7	Tray lost	76.6	Tray lost	50.6
				4	54.1	Tray lost	Tray lost	87.2	Tray lost	50.9
				5	65.6	Tray lost	Tray lost	83.3	Tray lost	Tray lost
	Monthly Site Average (g/m^2) +/- Std. Error				**79.6** 38.8	**215.8** 199.7	**49.3** 40.3	**86.3** 36.5	**260.6** 1040.7	**51.4** 10.8

Ash Free Dry Weights at 500°C	Sample code	Exposure period	Length of exposure (days)	Replicate no.	Sample site					
					S1	S2	S3	S4	S5	S6
	St 13	April-98	34	1	10.0	53.4	14.7	16.5	26.3	8.2
				2	11.7	53.4	13.3	26.4	31.9	12.9
				3	8.9	74.8	Tray lost	20.1	Tray lost	12.4
				4	8.4	Tray lost	Tray lost	26.1	Tray lost	10.4
				5	9.7	Tray lost	Tray lost	20.1	Tray lost	Tray lost
	Monthly Site Average (g/m^2) +/- Std. Error				**9.7** 1.6	**60.5** 30.7	**14.0** 9.1	**21.8** 5.4	**29.1** 36.4	**11.0** 3.4

Percentage Organic Matter (%)	**12.2**	**28.0**	**28.4**	**25.3**	**11.2**	**21.4**

Table 167: Dry weight, ash free dry weight and organic matter data from replicate artificial substrates (submerged trays of washed stone) exposed at sampling sites in the littoral zone of Lough Gill for the month of April 1998.

IX. Plates

Plate 5: Brown periphyton coating stones and sand at the rowing club landing station Bunowen Bay (S5), 2nd June 1998. A truck tyre can be seen in the water in the top right corner of the frame. Stones and attached material can be seen drying out on the left of the plate where lake levels dropped leaving them exposed.

Plate 6: Site S1, Half-moon Bay in Hazelwood on the western shores of Lough Gill. The sampling station was situated along the left-hand shores of the bay, in shadow during this early morning photograph. The Ox Mountains and the southern shores of the lake can be seen across the water on the right of the frame.

Plate 7: Site S2, Corwillick along the northern shores of the lake. The sampling station was located along the macrophyte beds in the middle of the frame. The West of Ireland Activity Centres' landing station is to the right of the frame (out of shot).

Plate 8: Site S3, Sriff Bay on the eastern shores of the lake. The road joins the lake behind the vegetation on the right hand side of the plate. The sampling station was located in front of the macrophyte bed on the bottom right hand side of the plate.

Plate 9: Site S4, Whites' Bay on the hard metamorphic rock of the Ox Mountains. The sampling station was in front of the macrophyte beds on the left hand side of the plate. The Dromahair road runs behind the trees on the same side.

Plate 10: Site S5, the rowing club in Bunowen Bay on the southern metamorphic shores of Lough Gill. The sampling station was in front of the macrophytes on the left of the frame. The Benbulbin Mountains and the northern shores of the lake can be seen in the distance.

Plate 11: Site S6 in Tobernalt Bay was situated along the shore north of the jetty. The mouth of the Garavogue River can be seen in the middle of the frame. Note the blue/green algal bloom in front of the slip. The plate was taken on 23rd September 1997 during the autumnal blooms.

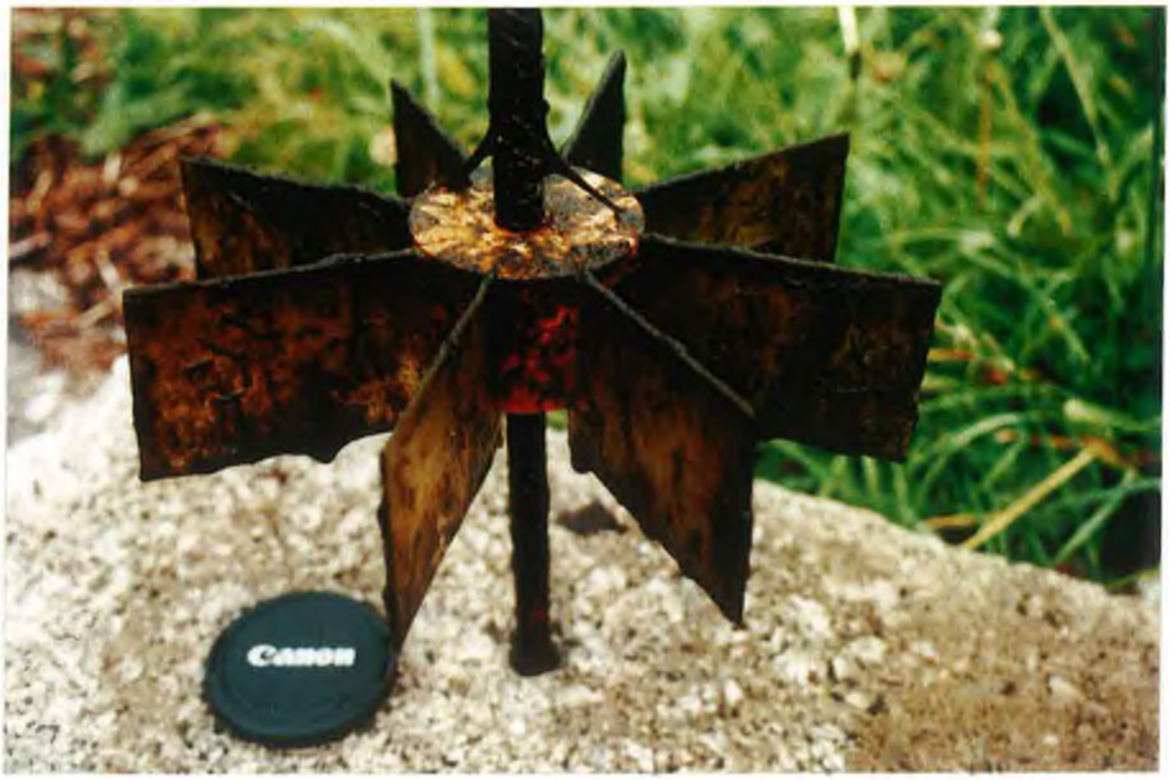


Plate 12: Glass slide structure used as an artificial substrate for growing periphyton at the six sampling stations along the littoral zone of Lough Gill. The eight glass slides are slotted into the rubber bung, which in turn is held in a metal pole. (The camera dust-cap shows scale)

Plate 13: Set-up of glass slides exposed for a one month period at Sriff Bay (site S3) during May 1998. The slides and rubber bung attached to the metal pole. The pole is slotted in to a hole in the concrete block which supports the structure on the bed of the littoral zone. (The camera dust-cap shows scale)

Plate 14: Trays of stones submerged at the six sample stations around the littoral zone of Lough Gill. The tray on the right has been exposed for a one-month period during April/May 1997 in Bunowen Bay (site S5). Note the brown periphytic material coating the stones and the plastic of the tray.

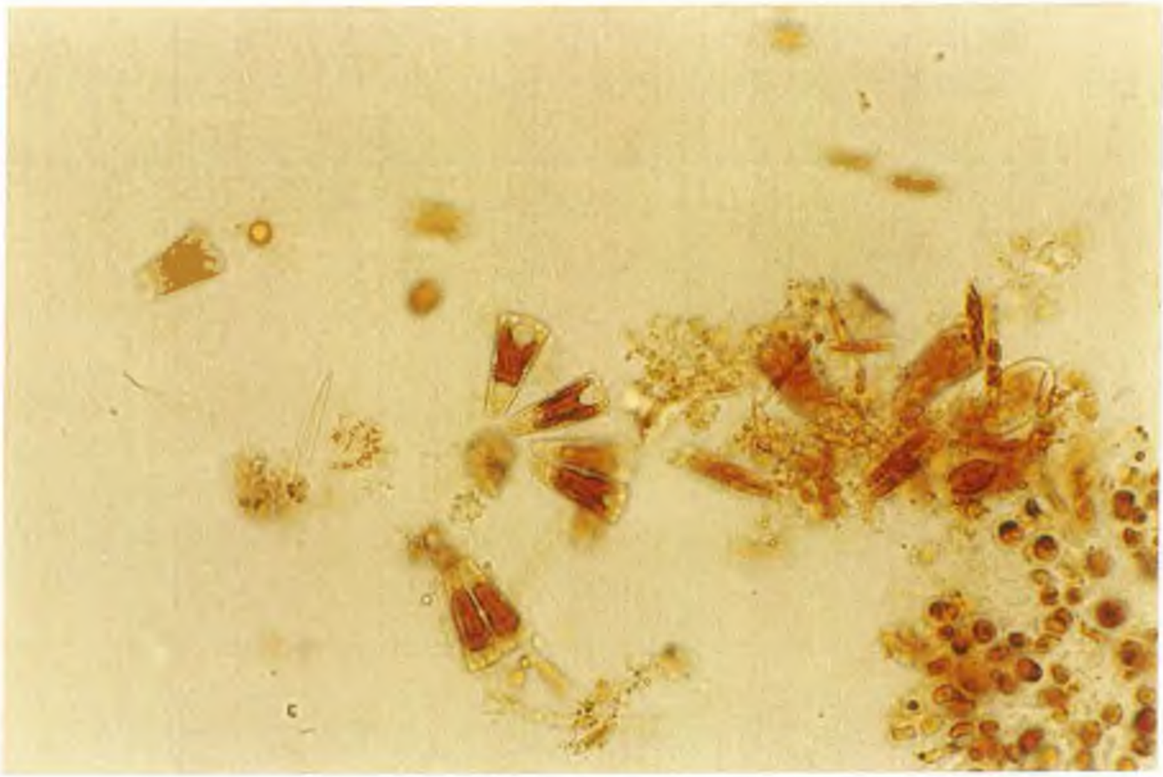


Plate 15: *Gomphonema*, the cake shaped algae in the centre of the plate, was one of the most common attached algae found in Lough Gill.

Plate 16: The algae, *Fragilaria*, with a long ribbon of cells side by side is presented in the centre of the frame. *Diatoma*, with long rectangular shaped cells and irregular transverse ribs, can be seen around the *Fragilaria* colony.

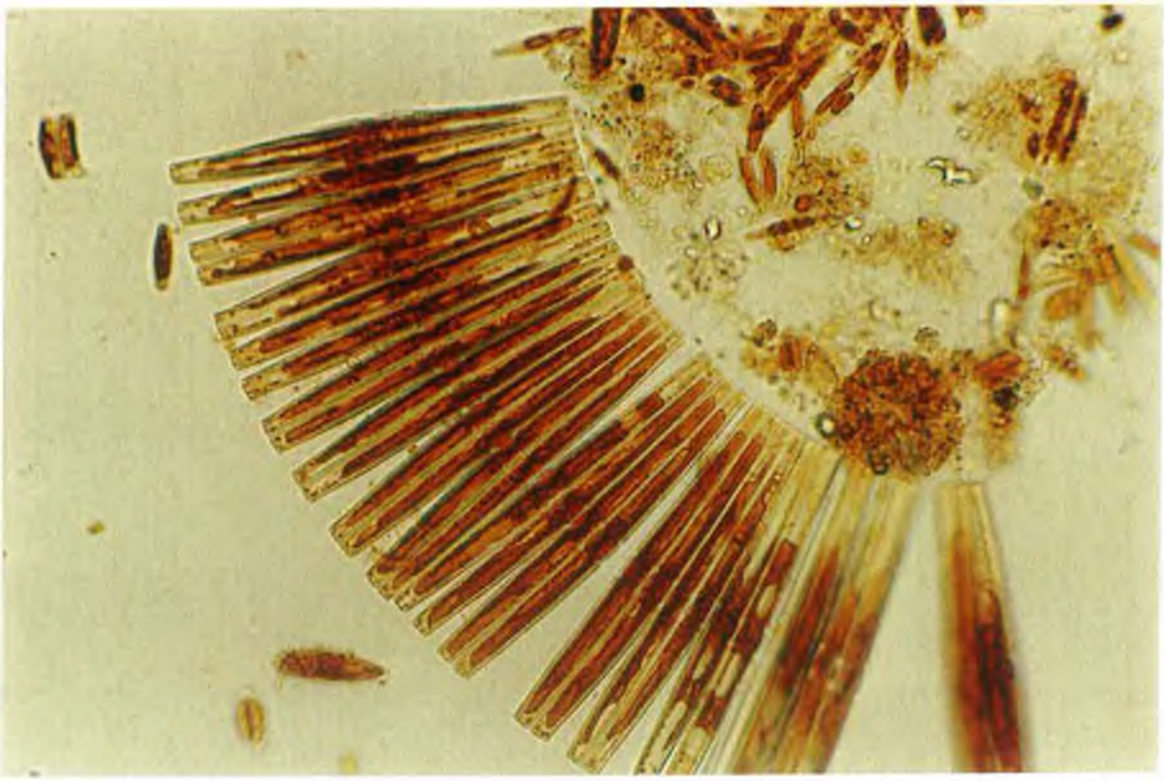


Plate 17: A fan shaped colony of *Synedra* cells all attached to organic debris and its associated attached algal cells on the bottom left hand corner of the frame. This material was scrapped of glass slides exposed for one-month periods.

Plate 18: Round *Cocconeis* cells attached onto a filament of green algae (three cells on top filament). Other attached algae, including *Gomphonema*, can be seen on the other filament at the bottom of the plate.

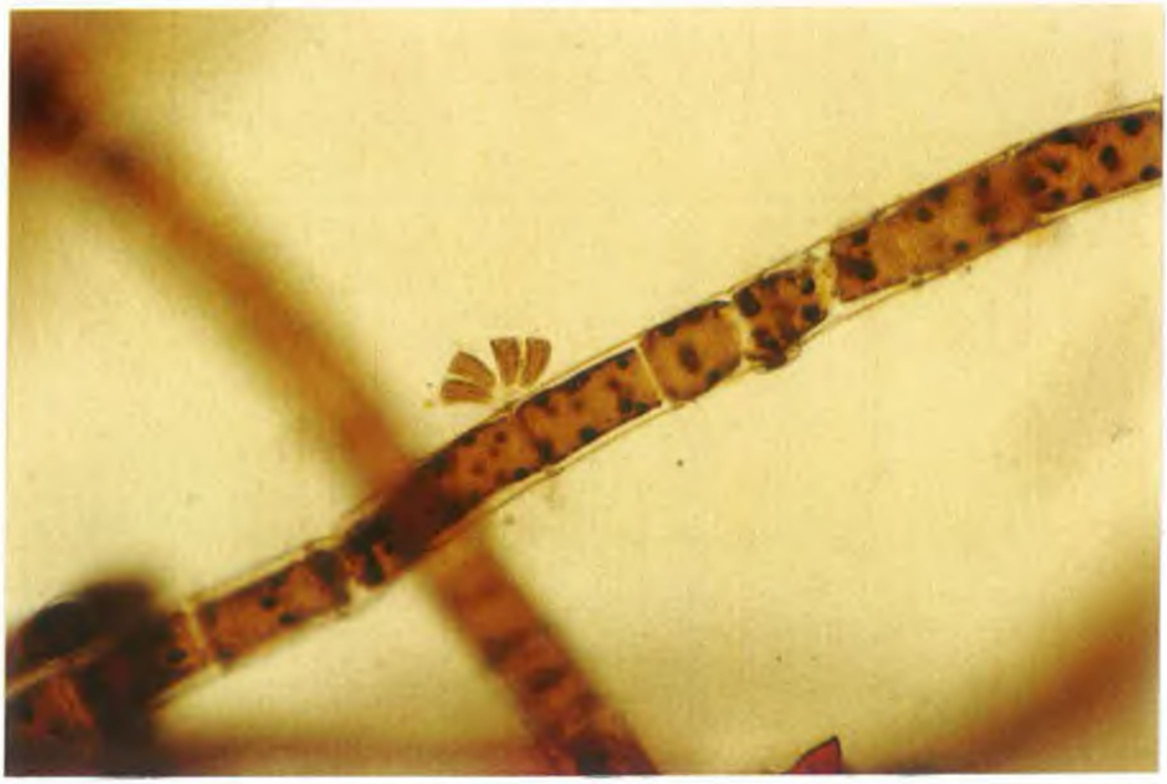


Plate 19: A filament of green algae running from the bottom left to the top right hand side of the frame. Four curved *Rhoicosphenia* cells attached to the upper side of the filament.

Plate 20: Littoral zone macrophytes in Corwillick Bay (site S5). These are above the water line after lake levels dropped suddenly. A combination of strong winds and dry weather washed free-floating mats of algae ashore during this period and these can be seen coating the above plants, particularly between the two stones in the centre of the plate. (Plate was taken on 23rd September 1998)