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LITTORAL MACROINVERTEBRATES IN LAKES: PATTERNS OF DISTRIBUTION AND POTENTIAL USE IN ECOLOGICAL ASSESSMENT

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SUMMARY

The forthcoming European Council Directive establishing a framework on water policy will require Member States to monitor the ecological status of lakes. Biotic as well as physicochemical criteria must be included in monitoring programs. Benthic macroinvertebrates are used in river assessment as their distributions are influenced by biotic and abiotic factors including anthropogenic impacts. These factors and simple sampling procedures make them potentially useful for lake assessment. This work aimed to assess this potential, while taking into account natural spatial and temporal variability in macroinvertebrate distributions.

The primary impacts on lakes in Ireland are eutrophication (characterised by increased concentrations of limiting nutrients) and acidification. Phosphorus (P) and less frequently nitrogen (N) usually limit production in freshwater, and their largest sources are anthropological activities. There is evidence that lakes with low alkalinity have been affected by decreasing pH from atmospheric precipitation containing increased concentrations of carbon dioxide, sulphate and nitrogen oxides from anthropogenic activities and plantation forestry.

Between April 1996 and June 1997 29 lakes in the Irish Republic were sampled at either monthly (11 lakes) or approximately quarterly (18 lakes) intervals. Integrated samples of the upper 6 m of water were taken over the deepest point in each lake for chemical analysis. Standard macroinvertebrate samples were collected with a 12 second kick/sweep net (frame 25 cm^2, mesh 1 mm) covering 1 m of cobble/pebble substratum in the littoral zone. Individuals were identified and enumerated. Samples were shown to provide representative collections of fauna with a demonstrated repeatability.

Mid-summer samples had the highest taxa richness and total abundance. They were differentiated from those collected in spring and autumn by Hierarchical cluster analysis. To provide most information in monitoring programs, samples should ideally be collected in mid-summer.

Multivariate analysis showed that macroinvertebrate assemblages from 28 lakes formed 9 lake types. Six of 22 biotic metrics showed linear correlations to conductivity, total phosphorus, total nitrogen or pH and 9 were associated in a CCA to macroinvertebrate assemblages with an $r^2 \geq 0.2$. Macroinvertebrate abundance and taxonomic richness

showed significant correlations with 18 of 23 chemical variables. Forty taxa showed significant correlations with conductivity, total phosphorus, total nitrogen or pH. The extent of only four land uses in lake catchments were correlated with macroinvertebrate abundance or taxa richness, and in a CCA only mixed pasture and unexploited peat bogs were associated assemblages with an $r^2 \geq 0.2$. Of 11 physical variables relating to lake and catchment size, none were related to macroinvertebrate abundance or taxa richness while 7 were associated in a CCA to macroinvertebrate assemblages with an $r^2 \geq 0.2$.

Triplicate samples from 11 lakes from cobble/pebble substratum showed that assemblages within lakes were less variable than among lakes. From 21 lakes differences between assemblage in macrophyte stands and cobbles/pebbles were also less than among lakes. Fifteen distinct substrata (meso-habitats) were identified in Lough Inchiquin, County Clare, based on substrata composition, particle size, macrophyte species, density and structure. Multivariate analysis of 5 replicate samples from each meso-habitat identified distinct assemblages characteristic of 10 meso-habitats. Identification and enumeration of meso-habitats may be useful in assessing ecological status, as they are distinct units of substrata, plant and macroinvertebrate assemblages that perform discrete biological functions in the larger ecology of lakes.

Twenty replicate samples from each of four meso-habitats in Lough Inchiquin showed that taxa richness was randomly distributed in *Scirpus* stands and cobbles & pebbles, regularly distributed in marl & coarse particulate organic matter (CPOM) and clumped in *Phragmites* stands. Total abundances were clumped in all four meso-habitats. Of taxa that occurred in 5 or more replicate samples 12 had clumped distributions in the marl & CPOM meso-habitat, 21 in cobbles and pebbles, 16 in *Phragmites* stands and 8 in *Scirpus* stands. Patterns of aggregation were, however, not uniform among meso-habitats. Although many taxa showed clumped distributions, Multidimensional Scaling suggested that, at least for the more abundant taxa, most of the 20 replicate samples contained similar animal assemblages.

Findings are discussed in relation to the development of a rapid analysis method for assessing the ecological quality of lakes. Consideration is given to physicochemical variations among lakes, natural variations in the spatial distribution of macroinvertebrates within lakes and the implications of this upon scientific studies and management, and practical limitations inherent to monitoring programs.

DECLARATIONS

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1. INTRODUCTION

1.1. The Need for Water and Ecological Quality Assessment

During the last century the impacts of human activities on water resources have on occasions been problematic. Degradation of water quality was noted as a result of increasing industrialization (Cairns & Pratt, 1993) and the increases in human population (Kristensen & Hansen, 1994). Outbreaks of typhoid and cholera in England during the eighteenth century stressed the anthropogenic importance of water quality, during which time the river Thames "produced a stench so nauseating that sheets soaked in vinegar were hung in Parliament to partly offset the noxious air wafting in from the river" (Cairns & Pratt, 1993). Even so, monitoring of water quality did not begin in earnest until the twentieth century and still, over a century later between the 1950's and 1970's, the poor water quality in the River Rhine earned it the reputation of being the largest sewer in Europe (Cals *et al.*, 1998).

Throughout Europe and in many parts of the world, anthropogenic activities have affected most areas of land and water. Boon (1992) defined impacts under five headings (Table 1.1) and, although referring to river systems, many of these categories are also pertinent to lakes. It has become important to identify the ecological status and conservation value of sites in order to protect areas from further degradation and provide management objectives for their rehabilitation (Lake, 1980). To achieve this, ecological status needs to be measured. This is required to identify sites of high conservation value worthy of physical and legal protection, sites of a degraded state that require enhancement, and to conduct routine monitoring (Rosenberg & Resh, 1993; Holmes, Boon & Rowell, 1998). This has recently been emphasized by the European Council's proposed Directive establishing a framework for a Community action in the field of water policy (European Union Environment Council, 1998) (hereafter referred to as The Water Framework Directive). This requires all lakes, rivers, ground waters and marine coastal waters to be assessed from an ecological perspective, and lists as one of its objectives the prevention of deteriorating ecological status and pollution of surface waters. The crucial factor in achieving these aims is the measure (the yardstick) by which evaluations and comparisons are made.

Table 1.1. Major anthropogenic activities affecting river systems. (After Boon, 1992).

Impact category	Impact to rivers
Supra-catchment effects	Acid deposition
	Inter-basin transfer
Catchment land-use change	Afforestation and deforestation
	Urbanisation
	Agricultural development
	Land drainage/flood protection
Engineering	Removal of riparian vegetation
	Flow regulation – dams etc.
	Dredging
Instream impacts	Organic and inorganic pollution
	Thermal pollution
	Abstraction Navigation
	Exploitation of native species
	Introduction of alien species

1.2. Irish Lakes

Compared with other European countries the population density of Ireland is low, having approximately 54 people per square kilometer in 1998, below half of the EC average (Eurostat, 2000) and correspondingly the ecological state of its lakes is relatively good (Kristensen & Hansen, 1994). Ireland has over 200,000 hectares of standing waters (Murray 1996) with 5327 lakes indicated on the 1:126,720-map range (Allott *et al.,* 1998). Relatively few have been assessed, with only 120 lakes surveyed for water quality between 1995 and 1997. Ninety-seven of these were assigned an unenriched trophic status (oligotrophic or mesotrophic) with a low probability of pollution. The remaining 23 were less than satisfactory and of impaired beneficial use based on a modification of the trophic classification scheme proposed by the

Organisation for Economic Cooperation and Development (O.E.C.D., 1982) (Lucey *et al.*, 1999).

1.3. Macroinvertebrates as Indicators of Water and Ecological Quality

Macroinvertebrates are defined as "organisms that inhabit bottom substrata (sediments, logs, macrophytes, filamentous algae etc.) or the surface of freshwater for at least part of their life cycles and are retained by mesh sizes ≥ 200 – 400 μm" (Rosenberg & Resh, 1993). They are useful indicators of water and ecological quality for several reasons relating to their physiology (Calow *et. al.,* 1990, Chapman & Baker, 1964), their abundances and distribution (Mason, 1996, Rosenburg & Resh, 1993), their life histories (Hellawell, 1986, Mason, 1996), simple sampling procedures (Mason, 1996), their significant contribution to species diversity (Harper, Smith & Barham, 1992), and their key positioning in the pathway between primary production and detritus and fish species (Rasmussen & Kalff, 1987; Harper, Smith & Barham, 1992; Hauer & Resh, 1996).

As with all biological systems, freshwater macroinvertebrate distribution is not ubiquitous or uniform (Hellawell, 1986). This is owing to geographical variations among freshwater bodies or spatial variations within them. Both abiotic and biotic factors can affect distribution patterns.

Abiotic influences upon invertebrate communities include wave action (Rasmussen & Kalff, 1987; Grelsson & Nilsson, 1991), the stability of the water column and hydraulic stress (Statzner & Higler 1986), the probability of droughts and spates (and associated influx of sediment), shading (Minshall & Minshall, 1977), light climate (Hellawell, 1986), water colour and turbidity. Substratum material and size is important (Minshall, 1984; Harper *et al.,* 1995), as is its texture, stability and the proximity and size of prospective habitats and oviposition habitats, (Hynes, 1970a; Wolf & Waltz, 1988; Ladle & Ladle, 1992). Water temperature can have a major influence (Hynes, 1970b) as can altitude, owing to its effect upon temperature. At a larger scale, catchment land use and geographical perspective (Allen, 1995) and the zoogeography of the region (Hynes, 1970a) are important. Water chemistry also affects macroinvertebrate ecology and distribution, and detrimental chemical additions to water can be classified into three, although not necessarily exclusive, groups; biological enrichment (or in its more extreme forms, eutrophication or organic pollution); toxic pollution and acidification.

The degree of biological enrichment can be characterised by the concentration of limiting nutrients in the water. Phosphorus (P) usually limits production in freshwater systems (Parr & Smith 1976; Moss, 1988; Hart & Robinson 1990) although nitrogen (N) and more infrequently micro-nutrients can be limiting in some systems or at certain times (Reynolds 1984; Hellawell 1986; Kristensen & Hansen, 1994; Mason 1996). Anthropological activities provide by far the largest source of nutrients, either as point source or diffuse in-puts. Point sources include outfall pipes from storm drainage systems, domestic sewage treatment works and industrial wastes. These may release treated, partially treated or untreated effluent into a watercourse, in most instances rivers, which can in turn flow into lakes. Nitrogen and phosphorus removal from wastewater is possible, although expensive. If enrichment has occurred over many years, remobilization of nutrients back into the water column from stores in the sediment can prevent any immediate benefits of reduced external supply (Marsden, 1989; Armitage *et al.*, 1993). An attempt to reduce the enrichment of Lake Washington, USA, by limiting point source inputs was, however, successful (Edmondson, 1972). Diffuse sources are run-off from the catchment and are a function of land use. This form of nutrient input is more common to lakes. Agriculture adds P and N in the form of inorganic fertilisers, animal excrement and slurry spreading to enhance productivity. Phosphorus enrichment is primarily associated with sewage treatment discharge (Parr & Smith 1976) and run-off from arable and tillage agriculture (Allott *et al.*, 1998; Lucey *et al.*, 1999), while the primary source of nitrogen is diffuse run-off following additions to land of N-rich industrial fertiliser and slurry (Mason 1996).

The dissolved oxygen concentration in the water also exerts an influence upon macroinvertebrates to which certain taxa, for example species of the ephemeropteran family Ecdyonuridae, are very sensitive. In lakes, dissolved oxygen in the littoral zone can be increased by wave action and photosynthesis and decreased by high respiration and decomposition. High concentrations of algae or submerged plants can result in supersaturation of oxygen during the day, but depress concentrations to harmful levels during the night (National Rivers Authority, 1995).

The major types of toxic pollutants are listed by Mason (1996) as metals (e.g. lead, nickel, cadmium, zinc, copper and mercury), organic compounds (e.g. organo-chloride pesticides, herbicides, solvents, polychlorinated biphenyls) and anions (e.g. fluorides, sulphides and sulphites). The toxicity of many chemicals is modified by temperature (which influences both metabolic activity and behaviour of biota) and the physical and chemical nature of the pollutant. Ionic transfer across biological membranes is affected by pH, and changes in acidity can increase availability of toxic chemicals without change in overall concentrations (Hall *et al.,* 1980; Hildrew, Townsend & Francis, 1984; Friday, 1987; Ormerod *et al.,* 1993; Mason, 1996). Acidification has been shown to affect macroinvertebrate biota (Townsend, Hildrew & Francis, 1983; Giller, O'Connor & Kelly-Quinn, 1998). Sutcliffe & Hildrew (1989) proposed three hypotheses for the impact of acidification on macroinvertebrates; firstly the chemical conditions in acidified waters may have a direct effect, which will be intolerable to some species or have sublethal physiological effects. Indirect acidification will impact upon the food chain, and thirdly, the lack of fish in most acidified waters will remove predation pressures.

Acidification problems have been apparent in Europe since the early 1900, with fish kills recorded in Scandinavia in the 1920s (Mason, 1996). The main factors responsible for acidification are carbon dioxide, sulphur dioxide and nitrogen oxide emissions (Muniz, 1991). Ireland, being on the extreme west of Europe is less susceptible to these gaseous pollutants because of prevailing westerly winds, although there is evidence that lakes with low alkalinity in the east of the country have been affected by decreasing pH owing to acid deposition (Cox & Murray 1991; Flower *et al.*, 1994). Afforestation can also lead to increased acidity of a lake (Hall *et al.,* 1980, Weatherley *et al.,* 1993). Many lakes in Ireland are naturally acidic as a result of the high percentage of peatland in the catchment, and afforestation in these catchments may affect pH where bedrock has low weathering rates, such as the granites of south east Galway (Allott, Mills & Dick, 1990; Bowman, 1991).

Biotic factors that affect macroinvertebrate populations include inter and intra-specific competition for food resources and space (Vannote *et al.*, 1980; Hildrew, Townsend & Francis, 1984; Feminella & Resh, 1990), predation (Cooper, Walde & Peckarsky, 1990), disease and parasitism (Moravec, 1995; Covich, Palmer & Crowl, 1999), food availability (Cummins, 1964, 1973), size and type of macrophyte stands (Wolf & Waltz, 1988; Gibbons & Pain, 1992; Friberg *et al.*, 1994) and immigration/emigration abilities (Hynes, 1970a; Ladle & Ladle, 1992).

Hynes (1970a) provided three simple predictions concerning diversity, abundance, rarity, dominance and stability of macroinvertebrate communities:

- The greater the diversity of the conditions in a locality the larger is the number of species which make up the biotic community.
- The more the conditions in a locality deviate from the normal, and hence from the normal optima for most species, the smaller is the number of species which occur there and the greater the number of individuals of each of the species which do occur.
- The longer a locality has been in the same condition the richer and more stable is its biotic community.

A range of more complex models has superseded these views and there is still much debate over the primary influences and subsequent effects upon community structure. Allen (1995) lists three schools of thought:

- Local environments vary from harsh to benign, resulting in a shift of importance form abiotic to biotic forces, producing a gradient between the two extremes.
- Biological interactions are of greater importance, especially competition, in structuring communities. In constant environments, strong biotic forces permit a few superior competitors to maintain populations resulting in species poor communities. Abiotic disturbance then prevents dominance by these species and allows others, for instance rapidly colonizing, easily displaced species, to coexist. (It should be noted that the 'constant environment' mentioned here is comparable to 'the long established locality in the same condition' of Hynes (1970a) and that the predicted comminutes are opposites; poor, and rich communities respectively).

- Diversity, abundance, rarity, dominance and distribution are a consequence of the dispersal ability of species and the shifting mosaic of environmental conditions. Described as Patch Dynamics this theory relates to the migration capabilities and reproductive rates of species in addition to their competitiveness and the biotic variables that recreate the habitat structure and redistribute resources and substratum.

In reality, much of the evidence for these three models is circumstantial and no one model fits all field situations. It is probable that all three apply to a greater or lesser degree in any one system.

The range of susceptibility shown by macroinvertebrate taxa to environmental conditions has enabled the development of biotic scores that assign a quality value to water bodies. These scores are well developed in rivers, but their development in standing waters is at an early stage. Different taxa exhibit varying sensitivity to environmental stress and any score that evaluates changes brought about by anthropogenic disturbances such as nutrient enrichment and acidification, needs to take into account the sensitivity shown by each taxa or the assemblage as a whole. Various species of the insect order Plecoptera (stoneflies) for example, are known to be tolerant of acidic conditions. For many lake invertebrates, however, tolerance to changing environmental conditions is unknown.

1.4. Biotic Scores and Indices

Many macroinvertebrate-based biotic scores for river water quality have been devised (Woodwiss 1964; Chandler 1970; Hellawell 1986; Extence *et al.,* 1987; Maitland, 1997) and their attributes well documented (Hynes 1970a; Whitton 1975; Calow *et al.,* 1990; Rosenberg & Resh 1993; Mason 1996). In contrast, few methods employing these animals exist for the assessment of the water or ecological quality of lakes and relatively little attention has been paid to lake water quality (Maitland, 1997). Resh & Jackson (1993) listed 27 biotic scores, of which only two were suitable for use in the littoral zone of lakes; one specifically for assessing acid drainage from mines and the other unpublished.

Table 1.2 classifies analytical methods suitable for assessing environmental quality from macroinvertebrate samples under seven general headings. Hellawell's group of pollution indices and Mason's group of biotic indices are essentially the same, with both containing indices designed to determine biological pollution/enrichment. Some are extremely simple. Examples given by Hellawell include percentage species deficit comparisons of pre and post (spatial or temporal) discharge/disturbance (Kothè, 1962). Indices of this type carry no consideration of abundance, although these can be readily incorporated. Examples are the ratio of wet weight of insects to tubificids (King & Ball, 1964) or numbers of *Gammarus* to *Asellus* (Hawkes & Davis, 1971) as indices of organic enrichment.

More elaborate analytical techniques apply values to taxonomic groups depending upon their known tolerance to pollution. The values are then summed to attain a score for the site. These can be either qualitative, taking no account of abundance, for example the Trent Biotic Index (Woodwiss, 1964), the Biological Monitoring Working Party (BMWP) Score (National Water Council, 1981), or at least semi-quantitative such as the Chandler Biotic Score (Chandler, 1970) and the EPA's Q-value score (Environmental Protection Agency, 1996). Mason (1996) considers the merits and sensitivity of the BMWP and its more robust derivative, the Average Score Per Taxa (ASPT) in which the total BMWP score is divided by the number of scoring taxa.

Diversity indices have had a long tradition in ecology, with the general assumption that a healthy biotic community has low dominance, with several frequently occurring species, and many present in low numbers. In contrast, a highly stressed environment would be expected to contain relatively few species, with one or two in high abundance, resulting in a low diversity score. Diversity indices applied to freshwater invertebrates, however, need careful interpretation, as in practice an increasing score is not necessarily indicative of increasing water quality. Hellawell (1997) stated that a reduction in community diversity is often associated with environmental perturbation, however, the cause of the perturbation may have to be sought by the application of other methods. Assessment methods using comparative indices compare samples from sites unaffected by pollution (a reference) with those that are affected. They may compare species composition in terms of joint presence (joint absences should not be relied upon as they are not conclusive) and/or absolute or rank abundance within communities.

Table 1.2. Examples of published categories of biotic analysis techniques for freshwater macroinvertebrates.

Analysis category	Description	Reference
Basic data / Assemblage metrics	Taxa richness, taxa abundance and total abundance.	Hellawell (1986) Mason (1996)
Pollution indices / Biotic indices	Calculated figure reliant upon the response of certain indicator taxa to pollution loading.	Hellawell (1986) Mason (1996)
Diversity indices	Mathematical expression of the species diversity and abundance of a community.	Hellawell (1986) Mason (1996)
Comparative indices	Compare the degree of similarity between stressed and unstressed communities (in either a spatial or temporal context).	Hellawell (1986)
Bio-indicators	Measured LC_{50}s and tissue concentrations of pollutants for many plants and animals.	Hellawell (1986) Mason (1996) Beach & Pascoe (1998)
Multivariate analysis	Ordination and clustering techniques retain information on taxa and can be performed on qualitative or quantitative data.	Mason (1996) Hill (1979a; 1979b) Clarke & Warwick (1994)
Habitat surveys	Numeration of different biologically coherent habitats.	Brooker (1981) Boon (1992) Kershner *et al.* (1992) Harper *et al.* (1995) Armitage, Pardo & Brown. (1995)

The use of a single or limited number of 'Bio-indicator' taxa for monitoring is an attractive and simple tool, but requires widespread, or ubiquitous, natural distributions of the selected indicators or the ability to rear them cheaply and effectively in the lab. For toxic pollutants this approach has been employed based on LC_{50} tests and the measurement of toxicant bioaccumulation. An example of this was published by Beach & Pascoe (1998) who advocated the use of *Hydra vulgaris* in acute lethal and sub-lethal toxicity tests for the heavy metals copper, cadmium and zinc. Whole assemblages have also been used to assess metal contamination in streams (Winner, Boesel & Farrel, 1980; Clements, Cherry & Cairns, 1988; Gowner *et al.*, 1995).

In recent years there has been increasing use of multivariate analytical techniques and habitat surveys as means of assessing river quality and macroinvertebrate communities. Unlike many of the indices described above, multivariate analysis does not reduce the macroinvertebrate count or presence/absence data to a single parameter. By comparing all samples together a cluster or dendrogram ordination of the samples is achieved in which similarities and differences between samples are displayed as distances from one another. Habitat surveys depend on the nature of habitat heterogeneity, by defining *functional* or *meso-habitats*, and assessing invertebrate communities associated with them (Allen, 1995; Harper, Smith & Barham, 1992; Boon, 1992; Armitage, Pardo & Brown, 1995). A meso-habitat is defined as a visually discrete unit of habitat that has distinct hydro-biological and biological characteristics (Kershner *et al.*, 1992) and will be formed as a consequence of changes in the biotic and abiotic variables. Meso-habitats are the basic unit used in the UK's River Habitat Survey (Environment Agency, 1996; Raven *et al.*, 1997; Harper, Ebrahimnezhad & Cot, 1998), which is founded upon the assumption that species are dependent upon habitats and that greater habitat heterogeneity supports greater biodiversity (Harper & Everard, 1998).

While the methods using macroinvertebrates to assess river quality provide a useful starting point to similar work in lakes, there are sufficient fundamental differences between standing and running waters to suggest that new methodology is required. Many of the macroinvertebrate species that have proved so useful in the river work simply do not occur in lakes and the nature of the spatial heterogeneity of lake habitats may make comparisons both within and among lakes difficult. In order to respond to the requirements of the forthcoming Water Framework Directive (1998), and the use of macroinvertebrates as one of the biological elements of assessment, it is first necessary to either identify reliable indicator species or determine the ecological status of macroinvertebrate communities. As the term 'ecological value' is itself poorly defined (Maitland, 1997) a useful starting point is the assessment of the associations between physicochemical variables and species occurrence and the identification of invertebrate communities that correspond to recognisable or established parameters of lake quality.

1.5. Choice of Sampling Unit

Resh & Jackson (1993) suggested that the choice of habitats in rapid assessments of lakes could be either limited to a specific habitat or use a proportional combination of representative sub-habitats. They recognized associated problems with both of these approaches. A specific habitat may not be affected by an impact and the sensitivity of organisms in different habitats can vary. Proportional sampling of all habitats found at a site may provide a better characterization of a site, and is employed in the British Institute of Freshwater Ecology's RIVPACS (River Invertebrate Prediction and Classification Scheme for running waters) (Wright *et al.*, 1997). This approach may make comparisons with reference sites difficult because of intersite differences in the habitats present, and confidence is needed that inter-habitat variation is not mistaken for biological impairment (Parsons & Norris, 1996). Single habitat sampling has been advocated by and is used in, the United States Environmental Protection Agency's Rapid Biological Assessment Protocols (Plafkin *et al.*, 1989) and work by Parsons & Norris (1996) found a high degree of data redundancy from four test habitats in rivers. Consequently, they recommended single habitat sampling (specifically riffles), as comparisons between equivalent environmental units was less confounded by inter-habitat variation and additional sampling was deemed a costly waste of resources.

1.6. The Meso-Habitat Sampling Scale

There are three categories of information available for the management of rivers, these relate to water quality, physical structure and ecological information usually gathered for specialist scientific studies (Harper *et al.*, 1995). Water quality is of paramount anthropogenic importance for obvious health reasons (Cairns & Pratt, 1993) and so this area of freshwater ecology has received much attention. For management purposes ecological information is largely of a structural nature concerning the ecosystem as whole, while ecologists have collected both structural and functional information. While the two are not mutually exclusive, failure to understand ecological function can lead to management errors when structure alone is addressed (Harper *et al.,*1995). Since the 1980's there has been a growing appreciation in the UK, of the dichotomy of information available for managing rivers. In order to resolve the issue, more holistic river assessment methods have been devised. In the UK this began with the River Corridor Survey (Nature Conservancy Council, 1984, 1990; National Rivers Authority, 1993) and was extended to the development of the River Habitat Survey (Raven *et al.*, 1998). This change in the perspective of river assessment is a direct result of the understanding that the biological function of a river as a whole, and its constituent habitats, are as important as the structural aspects. It is now believed that both structure and biological function need to be assessed to assure that the system is properly conserved.

One of the keystones to the River Habitat Survey is the definition of the habitat. The physical habitat has been cited as providing a useful element in evaluating river health as it provides a link between physical environment and its inhabitants (Maddock, 1999). This was illustrated by Harper, Smith & Barham (1992) (Figure 1.1). Habitat appraisal in the River Habitat Survey has been defined at the meso-habitat scale. This scale proves very useful for a number of reasons. Meso-habitats can be easily recognised visually, which makes them ideal for recording, especially with regard to inherent time limitations frequently imposed upon river assessment. They have been shown to contain distinctive macroinvertebrate assemblages and as such each performs a different biological function within the stream or river channel (Brooker, 1981; Kershner *et al.,* 1992; Armitage Pardo & Brown, 1995; Harper *et al.,*1995). Their enumeration alone can provide a measure of conservation value and additionally the distinctive macroinvertebrate assemblages provide information on the species richness and diversity that a stream can support. Meso-habitats also provide a valuable tool in restoration management, accommodating the "building block" approach to stream reconstruction (Harper *et al.,*1995). It could also be argued that the diversity of meso-habitats along a reach would provide not only a measure of conservation value but also a score of ecological wealth or wellbeing.

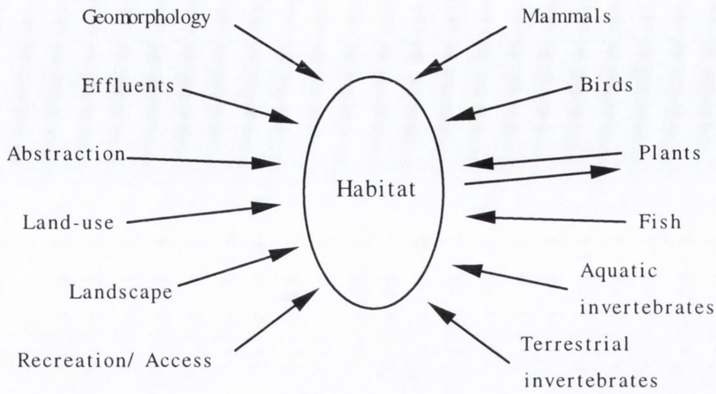

Figure 1.1. The concept of habitats as the natural link between the environment and its inhabitants. (After Harper *et al.*, 1992).

1.7. Review of Lake Classification

Besides the two biotic scores listed by Resh & Jackson (1993) that used littoral macroinvertebrates, many methods for determining lake status have been suggested in the literature; however, few of these employ littoral macroinvertebrates, (a notable exception is the work of Brodersen, Dall & Lindegraad (1998), which is reviewed in Section 1.8). The main biological groups which have been used to assess the trophic state of lakes are algae (phytoplanktonic and benthic), zooplankton and profundal macroinvertebrates (Harper, 1992). There are however, relatively few classification "methods" employing these groups and their use has tended to be through scientific studies rather than monitoring programmes. An array of dynamic models for predicting changes in the trophic state of lakes have also been devised. These simulate rates of change between different "compartments" within a lake. Simple models may simulate only two compartments, for instance phosphorus exchange between the lake and the sediment, while the more advanced consider multi-dimensional aspects of the hydrodynamics of a lake as well as nutrient and biological compartments (Harper, 1992 should be consulted for a full review of dynamic models).

Johnes, Moss & Phillips (1994) and Moss, Johnes & Phillips (1996) reviewed the early development of lake classification. Auguste Thienemann and Einar Naumann in the early 1900's recognised that many features of lakes were connected. Thienemann

(1909, 1915) associated benthic fauna with the degree of deoxygenation of the hypolimnion while Naumann (1917) related the nature of the phytoplankton to the geological nature of the catchment. They began to conceive that two types of lake existed, oligotrophic lakes found in alpine regions and eutrophic lakes found in the lowlands. Around the same time Teiling (1916) developed the earlier work of West & West (1909) and devised a classification of European lakes based upon dominant phytoplankton taxa. Deep highland lakes in Britain and Scandinavia were dominated by the unicellular green algal group, desmids, which are typical of neutral or acid lakes, with few genera found in alkaline lakes and at the other end of the scale, shallow lakes of the Baltic were dominated by species of blue-green algae (Cyanophyta). Meanwhile Thienemann and Naumann's initial division of lakes soon spawned many lake types and added to the list were dystrophic, mesotrophic, acidotrophic and argillotrophic. Work in Cumbria by Persal in the 1920s dispelled this idea of distinct lake types in favor of a continuum of lakes existing between the extremes of oligotrophic and eutrophic. This concept now forms the basis of modern limnology. While defining boundaries between lake types is fraught with difficulties, it does, however, aid management.

Zooplankton occupy a central role in the trophic pathways of a lake and may affect both upper and lower trophic levels (McQueen, Rast & Mill, 1986). The majority are filter feeders and are affected indirectly by nutrient content and quantity of algae, bacteria and detrital food sources, and to a lesser extent, directly by physicochemical conditions (Harper, 1992). Zooplankton indices of trophic state have been developed (Gannon & Stemberger, 1978) and much is known of their ecology and their roles in eutrophication (Moss, 1988; Harper, 1992), however Moss *et al.* (1996) considered that predation, particularly by fish, was the strongest determinant of community composition and outweighed the influences of water quality. Much work has also been done on the profundal benthos of lakes (Harper, 1992) which comprises mainly of four groups, oligochaetes, amphipoda, insect larvae (mainly chironomids), and sphaeriid and unionid bivalves (Horne & Goldman, 1994). Sæther (1979) proposed a scheme for classifying lakes based upon benthic chironomid assemblages. He identified fifteen characteristic assemblage groups and produced a key to separate them. Six of these groups corresponded to a range of oligotrophic states, three to mesotrophic states and six to eutrophic states. The groups were correlated with total phosphorus/mean depth and chlorophyll *a*/mean depth for a range of lakes in North America and Europe.

The O.E.C.D. (1982) classification of lake types is shown in Table 1.3, and is based upon concentrations of chlorophyll *a* and total phosphorus. This has become a standard methodology and these two variables have been almost exclusively used for categorizing lakes. The Irish Environmental Protection Agency (EPA) use a modified version of the O.E.C.D. scheme based on annual maximum chlorophyll *a* concentrations (Lucey *et al.*, 1999). This is shown in Table 1.4.

Table 1.3. Trophic classification scheme for lake water proposed by the O.E.C.D. (O.E.C.D., 1982).

Lake Category	Total Phosphorus (mg/m^3) Mean	Chlorophyll *a* (mg/m^3) Mean	Chlorophyll *a* (mg/m^3) Max	Transparency (m) Mean	Transparency (m) Max
Ultra –Oligotrophic	< 4	< 1.0	< 2.5	> 12	> 6
Oligotrophic	< 10	< 2.5	< 8.0	> 6	> 3
Mesotrophic	10 – 35	2.5 – 8	8 – 25	6 – 3	3 – 1.5
Eutrophic	35 – 100	8 – 25	25 – 75	3 – 1.5	1.5 – 0.7
Hypertrophic	> 100	> 25	> 75	< 1.5	< 0.7

Changes in trophic state are usually accompanied by changes in macrophyte species composition (Jupp & Spencer, 1977; Phillips, Eminson & Moss, 1978; Moss, 1988; Palmer; 1989; Palmer, Bell & Butterfield, 1992). Palmer (1989) and Palmer *et al.* (1992) used this to produce a scheme for classifying the water quality of standing waters in Great Britain based on submerged and floating flora. Shoreline and shallow water vegetation was surveyed by walking the perimeter of a water body, while deeper water was sampled by grapnel thrown from the shore or a boat. A subjective "DAFOR" abundance scale (Dominant; Abundant; Frequent; Occasional; Rare) was used and records from over 1,100 lakes, meres, reservoirs, pools, ponds, gravel pits and canals were incorporated. The results were analysed using multivariate techniques (TWINSPAN and DECORANA) which recognised 12 site types. These were compiled into 7 groups based on trophic states, defined by pH, conductivity and alkalinity. Groups are summarized in Table 1.5. Palmer (1989) stated that although there was considerable overlap in pH, conductivity and alkalinity, there was a general trend from low to high values.

Table 1.4. Modified version of O.E.C.D. scheme based on annual maximum chlorophyll *a* concentrations. Indicators related to water quality and the probability of pollution are also shown. (After Lucey *et al*, 1999).

Classification Scheme			**Category Description**			
	Lake trophic category	**Annual max. chlorophyll *a* (mg/m^3)**	**Algal growth**	**Degree of deoxygenation in hypolimnion**	**Level of pollution**	**Impairment of use of lake**
	Oligotrophic (O)	<8	Low	Low	Very low	Probably none
	Mesotrophic (M)	8 – 25	Moderate	Moderate	Low	Very little
Eutrophic	Moderately(m-E)	25 – 35	Substantial	May be high	Significant	May be appreciable
Eutrophic	Strongly (s-E)	35 – 55	High	High	Strong	Appreciable
Eutrophic	Highly (h-E)	55 – 75	High	Probably total	High	High
	Hypertrophic (H)	>75	Very High	Probably total	Very high	Very high

From the TWINSPAN analysis, Palmer (1989) also defined the trophic requirements for the 58 submerged and floating macrophytes found, and assigned each with a score based on a "DOME" code (Dystrophic, Oligotrophic, Mesotrophic & Eutrophic) where each trophic state was assigned a numeric value. From this, a Trophic Ranking Score (TRS) was calculated, based upon the cumulative value of the DOME code divided by the number of trophic states the species could be found in. Lakes could then be assigned an average TRS based on all plants that were found. Palmer (1989) stated that the average TRS would give a more subtle assessment of the trophic status of a site than would be obtained from keying out plant assemblages to site types. In a test of 22 lakes, the average TRS was significantly correlated to minimum pH and mean conductivity, however a problem with this methodology is the time required to conduct comprehensive macrophyte surveys of this type, and the potential for missing species is high.

Table 1.5. Site types defined by macrophyte communities and associated trophic states. (After Palmer, 1989).

Type	Characteristic macrophytes	Alkalinity (mg l^{-1})	Conductivity (µmhos)	pH	Trophic State
1	*Sphagnum; Juncus bulbosus; Potamogeton polygonifolius.*	< 2	< 100	5 – 6	Dystrophic
2	*Juncus bulbous; Potamogeton polygonifolius; P. natans; Littorella uniflora; Lobelia dortmanna*				
3	*Juncus bulbous; Potamogeton polygonifolius; P. natans; Littorella uniflora; Lobelia dortmanna; Myriophyllum alterniflorum; Isoetes lacustris; Fontinalis antipyretica.*	2 – 30	< 100	6 – 7	Oligotrophic
4	*Littorella uniflora; Potamogeton natans; P. filiformis; P. praelongus; Chara* spp.*; Myriophyllum Alterniflorum.*	Wide range			Wide range
5a	*Littorella uniflora; Myriophyllum alterniflorum; Nitella* spp.; *Potamogeton brechtoldii; Elodea canadensis.*	10 – 30	> 100	7 – 8	Mesotrophic
5b	*Potamogeton natans; Nymphaea alba.*				
6	*Potamogeton pectinatus; Ruppia* spp.; *Fucus ceranoides.*	–	> 5, 000	–	Brackish
7	*Potamogeton filiformis; Chara* spp.				
8	*Lemna minor; Polygonum amphibium.*				
10a	*Elodea canadensis; Lemna minor.*	> 30	> 200	> 7	Eutrophic
10b	*Potamogeton pectinatus; Chara* spp.				
9	*Nuphar lutea; Nymphaea alba.*	As for 7, 8 & 10, but wider ranging			Eutrophic & some mesotrophic

The O.E.C.D. (1982) scheme, the use of profundal macroinvertebrates (Thienemann, 1925; Brundin, 1956; Sæther, 1979; Wiederholm, 1980), phytoplankton and zooplankton (Harper, 1992) have predominated in the classification of lake quality, although there are moves toward classifying lakes based upon a broader collection of variables. The Water Framework Directive (1998) requires more biological information to be used in lake classification, proposing the inclusion of information on phytoplankton, aquatic flora, benthic invertebrates and fish fauna. It also advocates comparisons to "base line states", lake conditions prior to anthropogenic impacts. To achieve this lakes should be classified into types, based upon a range of physical and environmental variables and then compared against corresponding reference sites, whose conditions correspond to high ecological value (Water Framework Directive 1998). Johnes *et al.* (1994 & 1996) and Moss *et al.* (1996), working on UK lakes, proposed a scheme based upon a "state of change" that compared a lake's baseline state with its present state. The baseline state reflects a land usage in the catchment that was determined by the natural character of the catchment geology and soils as opposed to land management. Driving variables (retention time, conductivity, inflow of N and P) were then hindcast from existing databases and 13 biological and environmental variables were derived from this. These were then compared with present biological and environmental variables and an index of change calculated. The biological and environmental variables included lake volume; maximum depth; conductivity; secchi disc transparency; pH; total alkalinity; calcium; total nitrogen; winter total oxidized organic nitrogen; total phosphorus; chlorophyll *a*; a score based on the nature of submerged and emergent plant community; and the presence or absence of fish. This method is much more wide ranging, taking into account the land use of the catchment and the anthropogenic influences upon it.

The method of Johnes *et al.* (1994, 1996) is a measure of change within a lake, as opposed to a measure for comparing lakes. As lakes should be viewed on a continuum basis rather than being categorised into types, this method is advantageous as it does not rely on lake types or a series of reference lakes for comparison. It does however, require measurements of variables from at least six sampling dates through the course of a year and relies on readily available, accurate historic information on land use (Irvine *et al.*, in press a); although information of this type is often freely available throughout much of Europe. With exception of macrophyte data, Johnes *et al.* (1994, 1996) deliberately excluded the physical diversity and biological functionality of the littoral zone. This is not, however, an unusual omission from lake classification systems. They rationalized the exclusion of macroinvertebrate fauna from their method on several points. They argued that the variable nature of littoral substratum makes it difficult to obtain quantitative samples that characterize the lake and that the less extreme physical conditions owing to the lack of the continuous flow that is found in rivers, creates a relatively impoverished fauna. They also believed that the prevalence of biotic interactions, the variety of impacts that might affect community composition in a complex manner, the influence of randomness and accidents affecting colonization and extinction in "island" type habitats such as lakes, would hamper the interpretation of result. The first and last of these reasons for not including macroinvertebrate fauna refer to the distribution of macroinvertebrates at two scales; the former to distributions within lakes and the latter to distributions amongst lakes.

With the aim of developing a conservation classification scheme for lakes, Allott & Monteith (1999) studied 31 sites in Wales between 1993 and 1997. They compiled data on 20 water chemistry variables, eight bathymetric/catchment variables, thirteen lake habitat variables and 6 biological groups, including macroinvertebrates. They concluded that, ideally, classification should be based on the full range of ecological variants at a site, but reported difficulty in attempting this owing to the continuous nature of physicochemical and biological variation within lakes. They also acknowledged the unfeasibility of attempting to collect such an array of data for all lakes and proposed a two-tier approach to classification. The first tier was based on physicochemistry and the second on biological assessment using macrophytes. Macroinvertebrate classification using TWINSPAN showed comparisons to the classification of the other biological groups in only broad terms, and the end group structure based on all data collected reflected the primary environmental gradient of pH and total phosphorus concentrations.

Fozzard, Doughty & Leatherland (1997) reviewed a scheme introduced in 1995 for classifying Scottish Lochs. The method was based around a decision tree, incorporating phosphorus concentration, acid neutralizing capacity and toxic substances. Lakes were classified in to one of four categories that defined water quality and ecological quality.

The work of Johnes *et al.* (1994, 1996) assessed the ecological and water quality of lakes, as did that of Fozzard, *et al.* (1997). Palmer (1989) and Palmer *et al.* (1992) defined water quality and conservation value, while the method of Allott & Monteith (1999) was aimed at defining conservation value. The three categories of water quality, ecological quality and conservation value, are all components of freshwater evaluation, and while they may at first appear obvious, definitions in the literature are not clear. To achieve specific definitions of the three terms is difficult as many contrasting views exist. In an attempt to explain the application of the three terms and assess the information that should be used to determine them, the following discussions are useful for this work:

- Water quality: Many attributes of open water can determine its quality and this makes it difficult to define (Johnes *et al.*, 1996; Maitland, 1997). Water quality generally refers to the level of pollutants that it contains. Mason (1996) stated that some 1,500 substances have been listed as pollutants to freshwater ecosystems and categorizes them into fifteen groups, which have already been listed here. All of these tend to be mixed with, dissolved or suspended in the water column. Kristensen & Hansen (1994) defined water quality as a term that expresses the suitability of water to sustain both various human and ecological uses. Pugh (1997) reviewed the many EU Directives on water quality and the views of more than 80 British organizations interested in the aquatic environment. The difficulty in defining water quality was widespread. Pugh subscribed to the following definition. "Freshwater quality is the totality of features and characteristics of the water that bear upon its ability to support an appropriate natural flora and fauna, and to sustain legitimate use."

- Ecological quality: Although 'ecological value' is generally poorly defined (Maitland, 1997), it may be viewed as a measure of the diversity of fauna and flora and the naturalness of an area taking into account the water quality and geomorphology. Ecological status is defined in the Water Framework Directive

(1998) as an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters.

- Conservation value: This can be aimed at individual species, taxonomic groups, habitats, sites or full drainage basins and is required to maintain aesthetic, utilitarian and ecological status (Spellerberg & Hardes, 1992). Importance may be assigned to rarity, representativeness, ecological quality, financial value, beauty and even public notoriety (Boon, 1992). Boon (1992) considered that both species and habitats need to be surveyed to make a scientific case for conservation and that the attribution of "value" involves a degree of subjectivity. Sites with high conservation value also have a secondary value, as they can provide a reference or template that restoration of other areas can be modeled upon (Kondolf & Downs, 1996).

These definitions suggest that the three concepts are inter-linked in an hierarchical manner, with water quality being a component of ecological quality (Edwards, 1995; Pugh, 1997), which in-turn should be an element for consideration in conservation evaluation (Lake, 1980). Evans (1992) stated that all of the criteria which arguably contribute towards conservation value are important and should be given full consideration in a comprehensive classification technique. The majority of criteria however, cannot be compared objectively on the same scale (Kirkby, 1993). This requires either value judgements to be made on how to scale the different criteria or key criteria to be chosen that are thought to be important and comparable.

There are clear differences between the management recommendations that these three criteria imply. While there are great differences in the claimed purposes of assessment methods proposed in the literature, there appears to be little distinction between the way in which they define their respective "condition" with methods often using similar data. It may be argued that this is justifiable, but it would appear to be contradictory to define them as comparable or to make judgements or management decisions across all three based on any one category. To define ecological value or conservation value on results of water quality would appear to be crude and no different than a description of "water quality".

Lassière & Duncan (1997) advocated an integrated approach to assessing the conservation value of standing waters and questioned methods based on single biotic groups because they assume that broad environmental gradients can be used as surrogates for ecosystem variations. A methodology for defining lake conservation value developed in Sweden seems to be more advanced than those previously cited. "System Aqua" (Willén, Andersson & Söderbäck, 1997) takes into account biodiversity evaluated by five criteria (structural diversity, naturalness, rarity, species richness and representativeness). Six biotic groups are used (riparian vegetation, macrophytes, algae, macroinvertebrates, fish and nesting birds) and the method seems to come close to assessing conservation value on a suitably broad set of criteria.

Although the subject of lake classification and assessment is advancing (Maitland, 1997), management decisions are still often made on the same traditionally used variables (phosphorus and chlorophyll *a*) used in the trophic classification scheme of the O.E.C.D. (1982). In comparison to this, the assessment of rivers has evolved from the early saprobian index (Kolkwitz & Marsson, 1908, 1909; Sládecek, 1983) through diversity and biotic indices (Hellawell, 1986) up to present systems of River Habitat Survey (Environment Agency, 1996). It is acknowledged that the different mechanisms at work in the two systems (for example erosional and depositional processes, nutrient availability and cycling) make riverine and lakes systems very dissimilar for a large number of respects. In addition to variations in total P and chlorophyll *a* concentrations, profundal fauna, zooplankton and phytoplankton communities, which have historically been measured to determine lake condition, the possibility of finding other useful information should not be discounted until fully explored. With the exception of macrophytes, potential indicators of lake quality residing in the littoral zone have been largely ignored.

1.8. Macroinvertebrates as Indicators of Lake Water and Ecological Quality

The distribution of littoral macroinvertebrates between and within lakes has not been well-studied (Harrison & Hildrew, 1998). Early work carried out by Macan (1981) documented different macroinvertebrate assemblages in the unproductive lake Ennerdale and productive lake Esthwaite in the English Lake District. Brodersen, Dall

& Lindegraad (1998) examined the macroinvertebrate assemblages in 39 Danish lakes. Although they reported difficulties in disentangling the multivariate nature of the factors determining macroinvertebrate distributions, they were able to estimate species optima and tolerances to chlorophyll *a* concentrations, which they identified as being indicative of trophic status. They did however, acknowledge potential problems owing to substratum heterogeneity and associated difficulties of quantitative sampling, and restricted sampling to stony littoral habitats (see also Hunding 1971; Dall, Heegard & Fullerton, 1984; Rasmussen, 1988; Harrison & Hildrew, 1998).

Quinn, Lake & Schreiber (1998) investigated patterns of colonization of macroinvertebrates on exposed and sheltered shores of Lake Purrumbete in Australia by placing scrubbed bricks on the substratum and recovering them after extending periods of time. They compared colonization rates in the two substrata with those of riffles in the outflowing river and reported that colonization in the lake was very rapid, with little species turnover in comparison to the turnover in the stream. They suggested that the rapid colonization of the lake may have been a consequence of limited food resources, and areas of substratum that were not already inhabited. They also found little difference between the colonization patterns of the two lake shores, and between the early colonization assemblage and the natural assemblage in the surrounding, undisturbed substratum. This suggests that macroinvertebrates in the littoral zones of lakes respond rapidly to disturbances and the community forms quickly, implying that disturbances are a common feature of the littoral zone.

To date no attempt has been made to assess the ecological state of lakes from the perspective of, or with the inclusion of the meso-habitat concept employed in the UK's River Habitat Survey. The littoral zone of lakes may be divided into meso-habitats, upon similar grounds of visually distinctive substratum and macrophyte communities as used to define river meso-habitats (Harper *et al.*, 1992; Armitage, Pardo & Brown, 1995). The littoral zone is important in the energy budget of lakes because of the high primary and secondary production that occurs there relative to the limnetic zone (Jonasson & Mathiesen, 1959; Dall, Heegard & Fullerton, 1984; Kajak, 1988; Harrison & Hildrew, 1998), and as a result, its exclusion from assessment methodologies may be an oversight. The littoral zone, as the interface between water, land and the atmosphere has been identified as a major component in the metabolism of lakes (Hammer, Sheard & Kranabetter, 1990; Wetzel & Likens, 1991, Anderson & Battarbee, 1994).

1.9. The Littoral Zone of Lakes

The littoral zone is the interface between lake water and the shoreline (Moss, 1988) and can be defined as being above the aphotic zone and the thermocline. This position results in it being significantly effected by both diel and seasonal variations in physical and chemical variables (Brönmark & Hansson, 1998). Its position with regard to the pelagic and profundal zones is shown in Figure 1.2. The littoral zone includes part of the lake bottom and the water above it. The depth to which it extends may be expressed as the depth at which algae can colonize the bottom sediments, this is the euphotic depth, where net photosynthesis occurs in a light intensity of approximately 1% of that at the surface (Moss, 1988). The littoral zone therefore also supports rooted plant communities, and these, in addition to phytoplankton and periphytic algae, provide for high primary production. This in addition facilitates high macroinvertebrate diversity by providing a range of micro-habitats, primary food sources for grazing species, and inputs of course particulate organic material (CPOM) which are utilized by macroinvertebrate shredders. Wave disturbance is the primary determinant of the sediment type in the littoral zone.

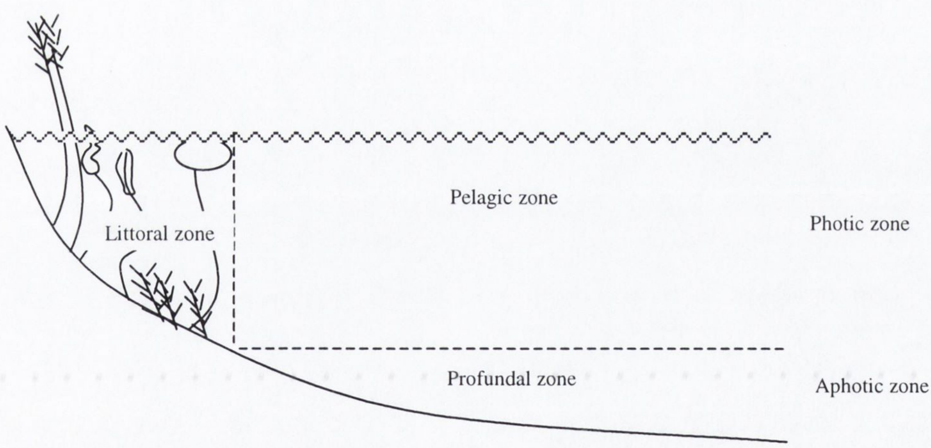

Figure 1.2. The littoral zone with regard to the pelagic and profundal zones. (After Brönmark & Hansson, 1998).

Moss (1988) divided the littoral zone into upper and lower components, with the upper portion being most disturbed with a predominance of wave induced erosion. The lower part was defined as being below the influence of wave action and a depositional area, however, the two were not deemed to be disjunct, but graded into one another forming a continuum from silt free areas of cobbles and boulders, through to finer silt particle sizes. Clearly a lakes aspect, size and shelter will also be influential upon the degree of wave action a shoreline experiences and it will be the finer sediments that become colonized by aquatic plants, which in turn will reduce water movement further and increase the rate of deposition. Moss (1988) summarized anticipated biological communities (considering micro and macroscopic plants and animals) and substrate materials into four groups, being dependent upon the extent of wave action and light availability. These were communities attached to bare rock (associated with the highest degree of wave action), gravely, poorly colonized areas, sand areas with attached and free living organisms and some plants, and silts and muds (experiencing least wave action) with complex communities including algae and aquatic plants. This view of the littoral zone, while admirably summarizing the basic features of the edges of lakes, does not encompass the potential diversity of substrate types or give any indication of the potentially useful aspects of the zone in assessing the ecological quality of lakes.

1.10. Aims

The main criticism raised in the literature for the use of littoral macroinvertebrates and their derived meso-habitats in the assessment of lake ecological (and/or conservation) quality refers to the heterogeneity of the littoral zone and aggregation of animal distributions, and because of this the availability of standard sampling substratum (Wetzel & Likens, 1991). To determine the potential use of macroinvertebrates in assessing lake ecological quality many questions need to be addressed. At this early stage, and with little information regarding the potential use of macroinvertebrates in assessing lake ecological quality in the literature, a series of questions concerning animal distribution are apparent. Firstly, do macroinvertebrates and/or their assemblages mirror in anyway the water or ecological quality of lakes on a continuum or ordinal scale? Secondly, does their distribution within lakes vary around the littoral zone and is this a result of differing substrata? If variations in assemblages within different substrata do exist are these variations stable, i.e. are macroinvertebrate distributions within a substratum type uniform or do they show signs of clumping? This is important as clumping may result in samples containing uncharacteristic collections of the macroinvertebrate assemblages present in a substratum, diminishing their use as indicators of ecological quality. This work aimed to answer these questions in order to evaluate the potential of using littoral macroinvertebrates as determinants of the ecological state of freshwater lakes.

1.11. Approach of the study

The following paragraphs describe the approach that was taken to answer the questions presented above. This approach, and the order in which the Chapters are presented, may appear to be in reverse order, with the assessment of the potential use of macroinvertebrates as indicators of ecological quality preceding the assessment of their spatial distribution within a lake, and this preceding work on their distribution within uniform substrata. This approach however, was necessary owing to the constraints of time and funding, and the required deliverables of the project of which this work was part (Ecological Assessment of Irish Lakes: The development of a new methodology suited to the needs of the EU Directive for Surface Waters). This was commissioned by the Irish Environmental Protection Agency and undertaken in the Department of Zoology, Trinity College Dublin by Irvine *et al.* (in press b). Intuitively, spatial distributions of macroinvertebrates within a substratum would have been assessed first to ensure that an appropriate sampling method was employed. Following this, assessment of macroinvertebrate assemblages among different substrata (meso-habitats) would have followed, and finally comparisons among lakes to determine the potential of creating an index of ecological quality based upon macroinvertebrate distributions would have been undertaken. While this approach may have been scientifically more justified it was not feasible. It is believed however, that the questions raised above have been addressed with commensurate scientific validity.

This study investigated distribution patterns of littoral macroinvertebrates in lakes in relation to varying water quality, seasonality, environmental variables, and different habitat and substrata types, in order to assess their potential uses as indicators of ecological quality. Twenty nine lakes were chosen across Ireland that represented a spectrum of physical and chemical conditions. Lakes varied in their trophic status, acidity, altitude, proximity to the sea, colour, depth, conductivity and concentrations of dissolved metals. It should be noted that not all 29 lakes were included in each of the investigations presented in this work. This was owing to differences in the substrata sampled in certain instances. The lakes that are included in each of the investigations is indicated in each section.

2. SITE DESCRIPTIONS

Macroinvertebrate and chemical samples were collected from 29 lakes between April 1996 and June 1997. For the standard sampling, eleven lakes were sampled approximately monthly, in April, June, July, August, September and October in 1996, and in January, March, April, May and June in 1997. These are listed in Table 2.1. The remaining 18 were sampled in April, June, July and September 1996, and January, April and June 1997 (Table 2.2). The locations of the lakes are shown in Figure 2.1.

Table 2.1. Lakes sampled in April, June, July, August, September and October 1996, and January, March, April, May and June 1997. (National lake identification code is the coding system used by the E.P.A. to identify specific lakes. O.S. Catchment name is the name of the catchment in which the lake is found as defined by the Ordinance Survey (After Irvine *et al.,* in press b).

Lake	County	National lake identification code	O.S. catchment name	Location (GPS)
Ballyquirke	Galway	30-00143-0100-000	Corrib	23°17’00” N.12°32’00” E.
Dan	Wicklow	10-00171-0070-000	Ovoca	20°36’52” N.31°52’84” E.
Doolough	Clare	28-00152-0050-000	Annageeragh	17°20’00” N.11°22’00” E.
Feeagh	Mayo	32-00107-0070-000	Srahmore	30°02’41” N.09°67’09” E.
Gowna	Cavan	36-00123-4050-000	Erne	29°22’00” N.22°88’00” E.
Inchiquin	Clare	27-00158-1320-000	Fergus	18°96’00” N.12°70’00” E.
Lene	Westmeath	07-00159-1150-000	Boyne	26°83’00” N.25°15’00” E.
Lickeen	Clare	28-00149-0080-000	Inagh	19°10’00” N.11°76’00” E.
Moher	Mayo	32-00126-0050-000	Owenwee	27°66’00” N.09°77’00” E.
Owel	Westmeath	26-00157-0260-000	Inny	25°81’00” N.24°00’00” E.
Ramor	Cavan	07-00159-0600-000	Boyne	28°68’00” N.26°03’00” E.

Table 2.2. Lakes sampled in April, June, July and September 1996, and January, April and June 1997. (National lake identification code is the coding system used by the E.P.A. to identify specific lakes. O.S. Catchment name is the name of the catchment in which the lake is found as defined by the Ordinance Survey (After Irvine *et al.,* in press b).

Lake	County	National lakecode identification code	O.S. catchment name	Location (GPS)
Ballycullinan	Clare	27-00158-0770-000	Fergus	18°58'00" N.12°90'00" E.
Bray	Wicklow	10-00169-0040-000	Dargle	21°62'53" N.31°37'04" E.
Bunny	Clare	27-00158-1760-000	Fergus	19°66'00" N.13°75'00" E.
Cullaun	Clare	27-00158-1190-000	Fergus	19°06'00" N.13°15'00" E.
Dromore	Sligo	27-00158-0560-000	Fergus	18°58'00" N.13°44'00" E.
Easky	Gara	35-00114-0150-000	Easky	32°30'00" N.14°46'00" E.
Egish	Monaghan	36-00123-5970-000	Erne	31°34'00" N.27°94'00" E.
Gara North	Sligo	na	Shannon Upr.	29°65'00" N.16°95'00" E.
Gara South	Sligo	26-0155a-2260-000	Shannon Upr.	29°65'00" N.16°95'00" E.
Graney	Galway	25-0155b-0320-000	Shannon Lwr.	19°28'00" N.15°57'00" E.
Lettercraffroe	Galway	30-00143-0710-000	Corrib	23°76'00" N.10°58'00" E.
Maumwee	Galway	30-00143-1460-000	Corrib	24°84'00" N.09°77'00" E.
Muckno	Cavan	06-00094-0280-000	Fane	31°91'00" N.28°51'00" E.
Mullagh	Monaghan	07-00159-0220-000	Boyne	28°54'00" N.26°77'00" E.
Oughter	Cavan	36-00123-3230-000	Erne	30°51'43" N.23°49'35" E.
Pollaphuca	Wicklow	09-00168-0230-000	Liffey	21°01'15" N.29°98'75" E.
Rea	Galway	29-00145-0180-000	Kilcolgan	21°57'00" N.16°15'00" E.
Talt	Sligo	34-00110-0630-000	Moy	31°50'00" N.13°98'00" E.

Table 2.3 shows physical characteristics of the sample lakes. The largest surface area was found at Pollaphuca Reservoir, which covers an area of 1974 hectares and has a volume of 135 x 10^6 m^3. The smallest lake was Ballycullinan with a surface area of 4.7 ha and a volume of 170 x 10^3 m^3. Lough Oughter had the largest catchment (147874 ha) and Mullagh the smallest (114.2 ha). The deepest lake was Lough Bray where maximum recorded depth was 45.7 m and mean depth 19.8 m. Lough Ramor had the

shallowest maximum depth (5.5 m) and Gara south the shallowest mean depth (1.0 m). The elevation of Lough Ballyquirke is only 6 m above sea level while Bray is at 378 m above sea level. Lough Owel had the longest single axis, at 6.2 km and Lough Gowna, which has a vary convoluted shape, the longest shoreline at 86.1 km.

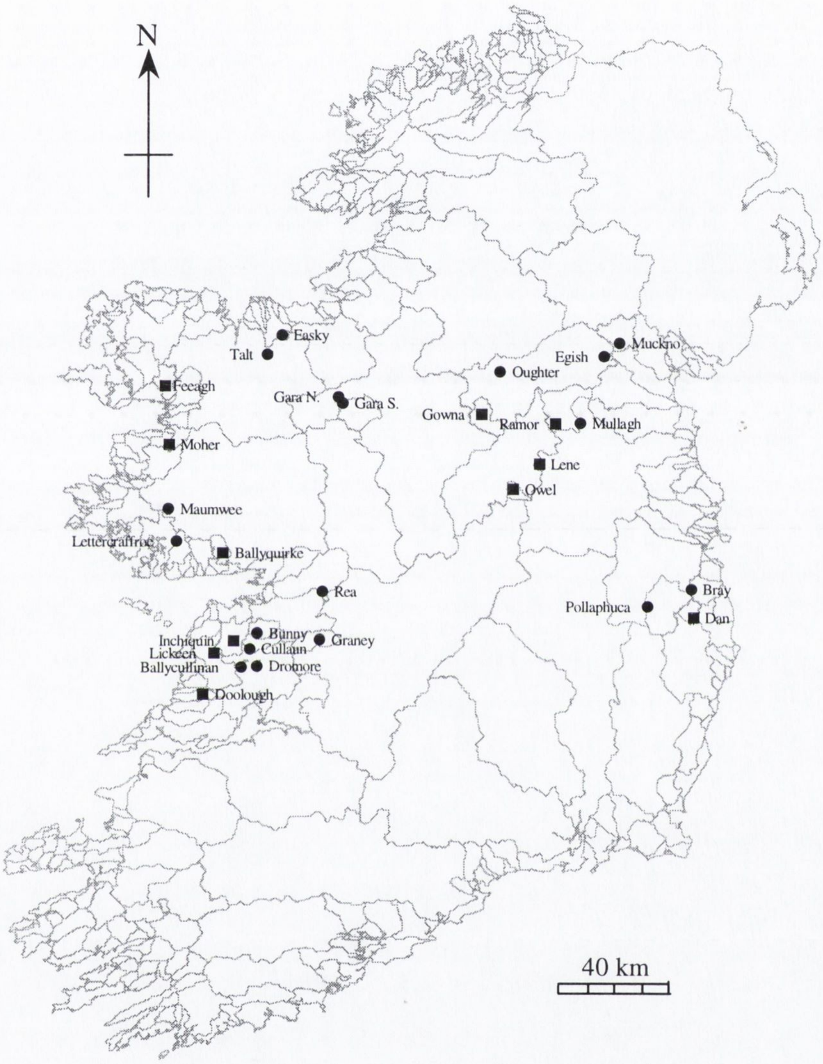

Figure 2.1. Locations of the 29 sample lakes. Lakes sampled in April, June, July and September 1996, and January, April and June 1997 denoted by ●. Lakes sampled in April, June, July, August, September and October 1996, and January, March, April, May and June 1997 denoted by ■. Grey lines indicate watersheds. (Irvine *et al.,* in press b).

Table 2.3. Physical characteristics of the 29 study lakes. (After Irvine *et al.*, in press b).

Lake	Lake area (ha)	Catchment area (ha)	Mean depth (m)	Maximum depth (m)	Lake volume (x10^3 m^3)	Altitude (m)	Max length (Km) of lake	Shoreline length (Km)
Ballycullinan	4.7	143.0	3.4	10.0	170	20	0.7	1.0
Ballyquirke	79.2	7318.8	2.5	12.2	1988	6	1.9	6.9
Bray	24.8	142.8	19.8	45.7	4871	378	0.8	2.1
Bunny	101.7	7624.2	1.4	13.0	1389	17	2.0	7.2
Cullaun	62.6	8436.2	6.7	23.0	4215	16	1.8	4.6
Dan	105.2	6313.3	13.0	37.9	13677	200	2.5	6.3
Doolough	126.6	2197.8	3.4	14.9	4270	83	2.5	5.7
Dromore	53.3	317.8	5.9	19.0	3172	16	1.6	5.5
Easky	122.6	1160.6	2.4	10.8	2914	185	1.9	5.9
Egish	121.7	784.3	2.0	8.4	2488	70	2.7	7.7
Feeagh	405.7	10033.3	14.5	45.3	58890	11	4.1	12.0
Gara south	202.7	18499.7	1.0	na	2027	66	3.9	8.9
Gara north	na	na	na	na	na	66	na	na
Gowna	1118.6	12834.1	4.0	na	42170	61	2.5	29.8
Graney	382.3	11171.5	3.7	18.6	14249	46	4.2	12.5
Inchiquin	115.7	14893.3	10.2	29.0	11777	19	1.7	5.7
Lene	423.5	1169.0	6.0	22.9	25410	93	4.3	13.0
Lettercraffroe	84.3	385.9	2.2	16.4	1886	155	1.6	4.5
Lickeen	83.9	818.2	3.9	23.6	3275	70	2.6	6.0
Maumwee	27.2	425.2	2.0	7.9	534	46	0.9	2.2
Moher	40.4	934.4	2.9	13.4	1178	88	1.1	3.2
Muckno	364.4	16072.3	5.9	27.0	21376	90	1.6	20.2
Mullagh	35.1	114.2	2.3	8.1	780	120	0.7	2.5
Oughter	1105.5	147874.0	3.0	14.0	24181	45	2.1	86.1
Owel	1029.4	4694.3	7.2	22.8	73716	97	6.2	16.8
Pollaphuca	1973.9	30265.0	6.8	na	135000	180	6.0	58.0
Ramor	741.2	25150.2	3.0	5.5	22238	83	4.8	21.5
Rea	306.8	1353.0	4.0	20.9	12256	81	2.7	7.6
Talt	95.5	482.8	8.9	41.4	8458	136	2.1	5.0

Table 2.4 shows the two yearly average chemical variables of the 29 study lakes (Irvine *et al.*, in press b). The 29 lakes were chosen to provide a range of chemical variables. Acidity ranged from pH 4.87 in Lough Bray to 8.35 in Lough Bunny. The majority of lakes were circumneutral to alkaline, with two examples of acidic lakes (Lough Bray and Lough Dan). Conductivity ranged from 45 $\mu s\ cm^{-1}$ in Lough Bray to 431 $\mu s\ cm^{-1}$ in Lough Ballycullinan. Turbidity was lowest in Lough Cullaun (0.48 NTU) while Secchi disk depth was greatest in Lough Bunny at 6.3 m. Turbidity was greatest in Lough Ramor (12.10 NTU) where Secchi disk depth was also lowest (0.9 m). Colour ranged from 119 PtCo in Lough Dan to 5 PtCo in Loughs Lene and Rea. Chlorophyll *a* concentrations were greatest in Lough Ramor (58.1 $\mu g\ l^{-1}$) and lowest in Lough Dan (1.1 $\mu g\ l^{-1}$). Total phosphorus ranged from 344 $\mu g\ l^{-1}$ (Lough Egish) to 1 $\mu g\ l^{-1}$ (Loughs Bunny, Maumwee and Talt). Total nitrogen ranged from 2.00 mg l^{-1} (Lough Ramor) to 0.19 mg l^{-1} (Lough Talt). This included hypereutrophic, eutrophic, mesotrophic and oligotrophic lakes. Lakes also varied with regard to the use of the land surrounding them and the geomorphology of the catchments. These characteristics are described in Table 2.5 and 2.6 respectively.

Table 2.4. Mean biannual chemical values of the 29 sample lakes. (Trophic state after Lucey *et al.*, 1999.) = Oligotrophic, M = Mesotrophic, m-E = moderately Eutrophic, s-E = strongly Eutrophic, h-E = highly Eutrophic H = Hypereutrophic).

Lake	pH	Conductivity (μS cm $^{-1}$)	Turbidity (NTU)	Secchi depth (m)	Colour (PtCo)	Chlorophyll *a* (μg l^{-1})	TP (μg l^{-1})	TN (mg l^{-1})	Trophic state
Ballycullinan	8.24	431	3.42	2.7	21	21.3	31	1.16	s-E
Ballyquirke	7.79	184	4.36	1.2	88	10.4	20	0.86	M
Bray	4.87	45	1.85	1.6	58	19.2	9	0.42	s-E
Bunny	8.35	314	0.59	6.3	11	1.7	1	0.72	O
Cullaun	8.30	371	0.48	5.0	22	2.3	4	1.00	O
Dan	4.94	48	1.02	1.5	119	1.1	11	0.54	O
Doolough	6.87	101	2.07	1.6	80	6.6	16	0.72	O
Dromore	8.22	387	1.41	3.6	21	11.4	16	1.19	m-E
Easky	6.43	51	1.24	1.9	63	3.4	2	0.33	O
Egish	8.23	229	4.57	2.0	25	35.0	344	1.51	H
Feeagh	6.88	89	0.99	1.8	89	1.6	11	0.55	O
Gara south	8.21	366	4.43	1.0	134	4.0	29	1.37	M
Gara north	8.34	356	5.02	1.3	74	8.8	28	1.2	M
Gowna	8.01	206	5.56	1.4	31	20.3	43	1.14	h-E
Graney	7.66	117	4.49	1.1	84	8.5	16	0.86	M
Inchiquin	8.25	354	1.34	3.3	28	4.5	22	1.45	M
Lene	8.30	241	0.83	5.6	5	5.1	12	0.40	M
Lettercraffroe	5.81	78	1.05	2.2	53	8.0	10	0.30	M
Lickeen	7.64	157	3.58	1.9	57	13.1	16	0.84	s-E
Maumwee	6.42	64	0.57	2.8	27	2.2	1	0.28	O
Moher	7.29	126	1.47	2.5	46	4.2	11	0.78	O
Muckno	7.86	213	2.34	1.8	33	12.7	33	3.02	M
Mullagh	8.02	171	5.97	1.8	22	32.5	55	1.08	h-E
Oughter	7.93	233	4.87	1.2	49	20.3	72	1.53	H
Owel	8.33	254	0.76	5.3	6	6.3	10	0.60	M
Pollaphuca	7.55	86	3.27	1.4	73	5.2	8	0.83	M
Ramor	8.18	194	12.10	0.9	49	58.1	88	2.00	H
Rea	8.41	277	0.62	6.1	5	3.2	6	0.74	O
Talt	8.22	193	0.51	4.7	19	2.3	1	0.19	O

Table 2.5. Land use in the catchments of the sample lakes (expressed as a proportion of catchment area) (After Irvine *et al.*, in press b).

Lake	Arable	Artificial Surface	Bare Rocks	Broadleaf Forest	Complex Cultivation	Coniferous Forest	Inland Marshes	Mixed Forest	Moors and heathland	Natural grasslands	Pasture high productivity	Pasture low productivity	Pasture mix	Peat Bogs	Peat Bogs exploited	Peat Bogs unexploited	Principally Agriculture	Sparsely Vegetated Areas	Transitional woodland/scrub	Urban green	Fresh water
Ballycullinan	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.441	0.000	0.000	0.000	0.005	0.000	0.506	0.000	0.047
Ballyquirke	0.000	0.004	0.000	0.000	0.000	0.049	0.012	0.000	0.050	0.083	0.087	0.044	0.009	0.000	0.012	0.452	0.146	0.001	0.020	0.000	0.031
Bray	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.175	0.087	0.000	0.000	0.000	0.000	0.000	0.575	0.000	0.000	0.000	0.000	0.163
Bunny	0.000	0.000	0.410	0.009	0.004	0.000	0.023	0.000	0.000	0.000	0.308	0.016	0.012	0.000	0.000	0.000	0.072	0.053	0.055	0.000	0.038
Cullaun	0.005	0.000	0.154	0.000	0.000	0.000	0.017	0.000	0.027	0.006	0.350	0.062	0.107	0.000	0.005	0.040	0.045	0.068	0.088	0.000	0.025
Dan	0.000	0.000	0.000	0.000	0.000	0.091	0.000	0.000	0.150	0.371	0.010	0.000	0.000	0.015	0.000	0.334	0.000	0.000	0.003	0.000	0.026
Doolough	0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.000	0.130	0.000	0.031	0.200	0.000	0.000	0.000	0.445	0.060	0.000	0.000	0.000	0.077
Easky	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.896	0.000	0.000	0.000	0.000	0.104
Egish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.182	0.000	0.536	0.000	0.000	0.000	0.114	0.000	0.000	0.000	0.168
Feeagh	0.000	0.000	0.000	0.000	0.000	0.177	0.000	0.004	0.000	0.088	0.001	0.001	0.000	0.000	0.000	0.602	0.029	0.000	0.036	0.000	0.062
Gara south	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.127	0.320	0.154	0.246	0.000	0.061	0.058	0.012	0.000	0.009	0.000	0.006
Gara north	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.127	0.320	0.154	0.246	0.000	0.061	0.058	0.012	0.000	0.009	0.000	0.006
Gowna	0.000	0.004	0.000	0.014	0.003	0.004	0.001	0.000	0.000	0.000	0.612	0.106	0.139	0.000	0.000	0.026	0.002	0.000	0.000	0.000	0.090
Graney	0.000	0.000	0.000	0.000	0.000	0.254	0.000	0.000	0.212	0.010	0.069	0.037	0.176	0.000	0.006	0.174	0.032	0.000	0.021	0.000	0.009
Inchiquin	0.000	0.000	0.060	0.010	0.000	0.003	0.000	0.000	0.002	0.279	0.165	0.099	0.041	0.000	0.000	0.024	0.102	0.128	0.078	0.000	0.008
Lene	0.013	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.324	0.101	0.069	0.000	0.000	0.000	0.000	0.000	0.065	0.000	0.371
Lettercraffroe	0.000	0.000	0.000	0.000	0.000	0.392	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.386	0.000	0.000	0.004	0.000	0.218
Lickeen	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.445	0.005	0.000	0.000	0.239	0.194	0.000	0.000	0.000	0.117
Maumwee	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.934	0.000	0.000	0.000	0.000	0.066
Moher	0.000	0.000	0.000	0.000	0.000	0.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.563	0.323	0.000	0.000	0.000	0.044
Muckno	0.000	0.010	0.000	0.006	0.000	0.013	0.000	0.012	0.000	0.000	0.461	0.140	0.248	0.000	0.000	0.025	0.054	0.000	0.000	0.002	0.028
Mullagh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.456	0.290	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.243
Oughter	0.000	0.004	0.000	0.004	0.001	0.005	0.010	0.002	0.000	0.002	0.583	0.106	0.226	0.000	0.001	0.008	0.013	0.000	0.001	0.000	0.033
Owel	0.019	0.000	0.000	0.013	0.000	0.011	0.015	0.013	0.000	0.008	0.280	0.107	0.213	0.000	0.004	0.009	0.076	0.000	0.006	0.000	0.224
Pollaphuca	0.001	0.010	0.000	0.003	0.044	0.128	0.001	0.000	0.118	0.166	0.152	0.009	0.025	0.000	0.000	0.276	0.000	0.000	0.003	0.000	0.064
Ramor	0.000	0.000	0.000	0.002	0.004	0.011	0.000	0.006	0.000	0.000	0.666	0.091	0.146	0.000	0.000	0.001	0.013	0.000	0.020	0.000	0.039
Rea	0.000	0.017	0.000	0.000	0.008	0.004	0.000	0.000	0.000	0.000	0.461	0.051	0.192	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.222
Talt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.210	0.000	0.000	0.539	0.000	0.000	0.000	0.000	0.212

Table 2.6. Geological Composition of Core Lake Catchments (% of catchment area) (After Irvine *et al.*, in press b).

Lake	Granite	Diorite,Gabbro,Dolerite	Ryolites	Quartzite	Schist & Gneiss	Ordovician	Silurian Quartzite	Old Red Sandstone	Lower Avonian/Carboniferous	Upper Carboniferous Limestone	Middle Carboniferous Limestone	Lower Carboniferous Limestone	Upper Avonian Shales & Sandstones	Millstone Grit & Flagstone	Coal Measures
Ballycullinan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Ballyquirke	61.4	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	28.1	0.0	0.0	0.0	0.0	0.0
Bray	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bunny	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	99.9	0.0	0.0	0.0
Cullaun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Dan	79.0	0.0	0.0	0.0	0.0	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Doolough	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.6	54.4
Dromore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.9	69.1	0.0	0.0	0.0
Easky	42.0	0.0	0.0	0.0	58.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Egish	0.0	0.0	0.0	0.0	0.0	2.3	97.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feeagh	0.0	0.0	0.0	44.0	43.8	0.0	0.0	11.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Gara south	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	93.5	0.0	0.0	0.0	0.0	0.0
Gara north	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gowna	0.0	0.0	0.0	0.0	0.0	23.2	62.3	0.0	2.0	10.8	0.0	0.0	0.0	0.0	1.7
Graney	0.0	0.0	0.0	0.0	0.0	0.0	34.3	63.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Inchiquin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.6	15.1	7.3	0.0
Lene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Lettercraffroe	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lickeen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.1	48.9	0.0
Maumwee	41.8	0.0	0.0	58.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moher	0.0	0.0	0.0	0.0	0.0	46.8	53.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Muckno	0.0	0.0	0.0	0.0	0.0	2.2	97.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mullagh	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oughter	2.9	5.0	0.0	0.2	0.9	31.3	45.6	0.0	0.0	8.7	8.4	0.0	0.0	0.0	0.0
Owel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Pollaphuca	80.2	0.6	0.0	0.0	0.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ramor	0.0	0.0	0.0	0.0	0.0	1.8	98.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	98.5	0.0	0.0	0.0	0.0	0.0
Talt	33.4	0.0	0.0	0.0	66.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3. ASSOCIATIONS BETWEEN ENVIRONMENTAL VARIABLES AND MACROINVERTEBRATES, AND THEIR POTENTIAL USE IN ASSESSING ECOLOGICAL STATUS

3.1. Introduction

Macroinvertebrates contribute significantly to the species diversity of a water body (Harper, Smith & Barham, 1992) and are an integral part of lake ecosystems in terms of the food chain, productivity, nutrient cycling and decomposition (Reice & Wohlenberg, 1993). They have been used extensively to assess riverine water quality (Hellawell, 1986; Mason, 1996; Rosenberg & Resh, 1993) due to reductions of sensitive species and proliferation of tolerant ones in response to hydraulic, organic and toxic stress (Rossaro & Pietrangelo, 1993). They have not generally been used, however, for the assessment of water quality, ecological quality or conservation value of lakes (Resh & Jackson 1993; Maitland, 1997). There is consensus throughout the freshwater scientific community that the many riverine biotic scores which are used throughout Europe to assess water quality, are influenced both by pollution and natural variation (Armitage *et al.,* 1983; Moss *et al.*, 1987). The aim of this work was to assess changes in macroinvertebrate taxa and assemblages in response to water chemistry, environmental variables and seasonality, and determine their potential in providing information on the ecological state of Irish lakes while taking into consideration natural variation.

3.2. Methods

3.2.1. Standard Macroinvertebrate Samples

Standard sampling was undertaken with the temporal frequency indicated in Chapter 2, using a 0.25 x 0.25 m sweep net with a mesh size of 1 mm. The net was trawled with an 'S' type movement behind feet kicking the substrata for twelve seconds, covering a distance of approximately one meter and in water no deeper than 0.5 m. Samples were taken from mineral substrata of predominantly pebbles and/or cobbles (16 – 64 mm diameter and 64 – 256 mm diameter respectively) from all lakes. In all instances, samples were preserved in the field in 70% Industrial Methylated Spirits (IMS).

3.2.2. Macroinvertebrate Identification

In the laboratory samples were sorted by eye from a white sorting tray (0.25 x 0.35 m) which was subdivided into 16 equal segments to allow small subsections of the entire tray to be thoroughly examined.. After 2 minutes of no further specimens being found in a sample, the sample was considered to have had a sufficient proportion of its contents removed. Sample trays. Samples were stored in 70% IMS. Specimens were identified to the lowest practicable taxonomic level under X8 – X40 magnification. Wherever possible, animals were identified to species. In some instances this was either not possible or practicable. The larvae of many Coleoptera for example, cannot be identified beyond genus and early instars of many taxa cannot be reliably identified beyond family. The family Gammaridae in some samples was represented by several species and in very high numbers. To ascertain the exact number of each species did not always prove practical and in some instances the presence of non-dominant species was indicated but not enumerated. Oligochaetes and chironomids were not routinely identified beyond this taxonomic level. For certain samples, however, these two groups were identified beyond the family level to provide a more complete taxonomic list for each lake so that their distributions would be known and to create an historic record of their presence. For the following analysis the summed data for Chironomidae and Oligochaeta was used. The taxonomic keys used to identify macroinvertebrates are listed in Section 7.1. Taxonomic lists and abundances of macroinvertebrates from the standard samples collected between April 1996 and June 1997 are shown in Appendix 1.1 to 1.29 with lakes listed alphabetically.

3.2.3. Macroinvertebrate Sample Size

This work was conducted during the time scale of the standard sampling, and was intended to provide information on the efficiency of the standard sampling method with regard to sampling time and area covered, effectively investigating sampling effort. The work was not intended to provide information on the patchy nature of littoral macroinvertebrates, which is approached in Chapter 5. As was mentioned in the introduction, an investigation into the patchy nature of macroinvertebrates at the within meso-habitat scale, before the standard samples used to assess the potential of macroinvertebrates in assessing ecological quality were collected, may have been a more scientifically robust approach. The requirements of the project of which this work was part did not however, allow sufficient time or resources to undertake such an approach. This investigation in to sample size was therefore conducted to determine the reliability of the standard sampling method in providing a significant proportion of the macroinvertebrate community present in the littoral zone.

Samples were taken from Lough Inchiquin in June 1997 to test the efficiency of the standard sampling method. Sample size was varied both temporally (sample durations of 5, 10, 15, 30 and 60 seconds covering approximately 1 by 0.25 meters) and spatially (sample distances of approximately 0.25, 0.50, 1.00, 2.00 and 4.00 meters were sampled for 12 seconds). Samples were collected from predominantly cobble and pebble substratum with a kick/sweep net (frame 0.25 m x 0.25 m, mesh 1mm) in water no deeper than 0.5 m with the same 'S' type movement employed for the standard samples as described in Section 3.2.1. Three replicate samples of each size were collected.

Of the time series, the 30 and 60 second samples were subsampled owing to their size. Samples were drained and one quarter of the wet weight sample was removed, re-suspended and sorted for animals. The remaining sample was re-suspended and scanned for taxa that had not been found in the sorted portion, which were removed and enumerated. Of the size series the 0.25, 0.50 and 1.00 m by 0.25 m samples were also subsampled owing to their size. These were suspended in one litre of water and five subsamples of 0.2 litres were removed and sorted. To deal with taxa that were present in vary large abundances a process of approximation was adopted. The abundance of each taxon was cumulated after each subsample had been processed to keep track of the total number of individuals of each taxon found. If the cumulative abundance of a taxon reached 100 or greater animals in the sorted subsamples it was not counted in subsequent subsamples. Then the abundance for the whole sample was estimated by multiplying the counted abundance by $5/x$, where x was the subsample number for which that taxon was last counted. The abundance of taxa in the 2 m and 4 m by 0.25 m samples were calculated in a similar way; however 10 subsamples were taken after the sample had been suspended in 2 litres of water. Data are presented in Appendix 2.1 and 2.2 for varying sample time and distance, respectively.

3.2.4. Water Samples

Water samples were collected between March 1996 and December 1997. The intensity of sampling was approximately monthly for 11 lakes, and four times per year (April, June, July and September) for 18 lakes. The lakes included in these 2 sampling frequencies are indicated in Chapter 2.

Samples were routinely taken above the deepest point in each of the lakes from a small inflatable boat as at this point water chemistry is most stable (N. Allott, Pers. Com.). Integrated samples from the upper 6 m of water were collected using a plastic tube (25 mm diameter). Where depth of water was insufficient or the hypolimnion extended above 6 m a dip sample was taken at approximately 0.5 m. In the shallow littoral zone diffuse inputs to a lake, biological and chemical processes are capable of altering the chemical composition of water due to the relatively small dilution factor. As the overall status of the lake was under examination sampling from the littoral zone was not stringently conducted in order to avoid short-term fluctuations in chemistry. A post-hoc investigation of variation in water chemistry around the littoral zone of Lough Ballyquirke revealed little difference from the chemistry in the centre of the lake (unpublished data, G. Free, Pers. Com.)

Water chemistry analysis was undertaken by Mr. Gary Free of the Environmental Science Unit, TCD. Measurement of some variables, and preliminary preparation of samples for analysis of others, was done immediately on return to the laboratory and within two days of the samples being collected. Using unfiltered water, measurements were made of conductivity using a WTW LF96 conductivity meter (units reported for 25° C), pH using a Jenway meter with combination pH Reagecon GCFC11 probe suitable for low ion strength water and alkalinity by titration to pH 4.5. Alkalinity greater than 20 mg l^{-1} $CaCO_3$ was determined by titration (50 ml sample) to pH 4.5 with 0.01 molar sulphuric acid using a Metrohm burette (E 485). Alkalinity less than 20 mg l^{-1} $CaCO_3$ was determined by Gran titration (100 ml sample) to four end points between pH 4.3 and 3.8 (Mackereth *et al.* 1978).

Samples of filtered and unfiltered water were measured into reaction flasks for later determination of total phosphorus and nitrogen. All other chemical analysis was done in the TCD Environmental Sciences Unit analytical laboratory. Total phosphorus was determined by acid persulphate digestion followed by reaction with molybdate and measured spectrophotometrically (Eisenreich, Bannerman & Armstrong, 1975). Total dissolved phosphorus was determined on filtrate (GF/C) as for total phosphorus.

Total nitrogen and total dissolved nitrogen (performed on filtrate) was determined by alkaline persulphate digestion on 50 ml samples (Koroleff 1983). Samples were digested in duplicate. Samples were diluted by a factor of 10 to a final volume of 3.5 ml and buffered with ammonium chloride. This was followed by flow injection analysis (Tecator 5020, 5032, 5007) which involved cadmium reduction followed by azo dye colourimetry. Calibration of the instrument used a five point standard curve. Recalibration took place at regular intervals throughout the analysis.

Nitrate, chloride and sulphate were measured on filtrate by chemically suppressed ion chromatography (Dionex system). Samples were initially analysed in duplicate but this was reduced to a single determination owing to consistency of results. Determinations of nitrate, chloride and sulphate followed calibration with five standards.

Silicate, total silicon and total dissolved silicon were measured according to Koroleff (1983). Total silicon and total dissolved silicon were digested by alkaline persulphate oxidation as used for total nitrogen. The measurement of silicate involved reaction with ammonium molybdate which was stopped with oxalic acid. This yellow silicomolybdic acid was then reduced using ascorbic acid to a blue complex. Absorbance was determined at 810 nm using a PYE Unicam SP6-350 spectrophotometer with a 1 cm pathlength cell and auto-sipper. Silicate was measured in triplicate, total silicon and total dissolved silicon were measured in duplicate. All determinations of total silica and total dissolved silica followed calibration with six standards in duplicate. Calibration for silicate involved seven standards in triplicate.

3.2.5. Data Analysis

The results of the standard monthly and quarterly macroinvertebrate samples were initially investigated to determine associations with season, and the most appropriate sampling period for a survey investigating lake ecological quality. Seasonal variations in total macroinvertebrate abundance and taxa richness were assessed, the proportional and log $(x + 1)$ transformed abundances of predominant taxonomic groups were then investigated. The assemblage structure of each of the eleven intensively studied lakes were then investigated with Hierarchical cluster analysis to examine seasonal changes of assemblages among lakes over time.

Mean macroinvertebrate taxonomic richness and abundance recorded during the samplings period were then assessed in relation to mean chemical concentrations. Further investigations were conducted into the relationships between taxonomic richness, macroinvertebrate abundance and distributions of specific taxonomic groups with regard to total phosphorus, total nitrogen, conductivity and acidity. These chemical variables were considered the primary influence upon macroinvertebrate assemblage structure. Macroinvertebrate taxonomic richness and abundance provided an initial insight into the macroinvertebrate assemblages, which were then further investigated with multivariate techniques outlined below.

Several biotic scores and metrics were calculated. Community assessment of macroinvertebrates (see Table 1.2) attempts to classify environmental conditions on criteria other than the two factorial analyses of biological and chemical or environmental variables. A more specific list of scoring methods and their anticipated response to reduced ecological quality or biological enrichment are given in Table 3.1. These scoring methods were chosen as it was felt that owing to the extent of their use in riverine ecological assessments, and a general tendency of reliance upon them by the freshwater scientific community, that their potential value in lake ecological assessment should be determined. Shannon-Wiener and Simpson's diversity indices were calculated. Two diversity indices were chosen owing to ongoing altercation in the scientific community over the most appropriate and informative method. The Shannon-Wiener index was chosen for its popularity, and Simpson's index for its simplicity. A selection of the more popular biotic scores used in river surveys were also calculated. These included

Table 3.1. Potential macroinvertebrate scoring methods divided into categories of basic data, simple biotic/tolerance indices, diversity and biotic indices and the expected response of the scores to reduced ecological quality and/or enrichment (adapted from United States Environmental Protection Agency, 1995; Hellawell, 1986; Mason, 1996).

	Score	Expected response to reduced ecological quality and/or enrichment
Basic data	Taxa Richness	Increased
	Abundance	Increased
Simple Biotic indices /Tolerance indices	Mean abundance per taxa	Increased
	% Contribution of dominant taxa	Increased
	% Oligochaetes	Increased
	Ephemeroptera, Trichoptera, Odonata and Plecoptera taxa richness	Reduced
	% Non insects	Reduced
	Crustaceans and Mollusc abundance	Reduced in acidic conditions
	Gammarus abundance	Reduced
	Asellus abundance	Increased
	Ratio of *Gammarus* to *Asellus*	Reduced
	% Grazer-scraper taxa	Increased
	% Shredder taxa	Reduced
	% Collector taxa	Reduced
	% Predator taxa	Increased
Diversity indices	Shannon-Wiener diversity indices	Reduced
	Simpson's diversity indices	Reduced
Biotic indices	Chandler's Biotic Score	Reduced
	Trent Biotic index	Reduced
	Trent Biotic index – Average Score per Taxa (ASPT)	Reduced
	BMWP Score	Reduced
	BMWP ASPT.	Reduced
	Quality Rating System	Reduced

Chandler's Biotic Score, the Trent Biotic Index, (Mason, 1996), the Biological Monitoring Working Party score (BMWP) (and average score per taxa (ASPT) for these latter two) (Armitage *et al.,* 1983) and the Irish EPA Q-value (Environmental Protection

Agency, 1996). Each score was calculated for the twenty-eight lakes from mean macroinvertebrate abundance from stone substratum samples. The biotic scores and their means were calculated from June, July and September 1996 samples from stony substrata.

Multivariate analysis was performed using Hierarchical cluster analysis, Two-way Indicator Species Analysis (TWINSPAN), Detrended Correspondence Analysis (DECORANA) and Canonical Correspondence Analysis (CCA). These were conducted in order to assess similarities and dissimilarities between samples. These techniques consider each taxa to be a variable, and the abundance of each taxa to be an attribute of the sample (Norris and Georges, 1993).

Hierarchical cluster analysis was calculated as Euclidean distances between groups and performed in SPSS for Windows© Version 6.1.4, 1996. DECORANA (Hill, 1979b; Hill & Gauch, 1980), TWINSPAN (Hill, 1979a, Gauch & Whittaker, 1981) and CCA (ter Braak, 1986, 1990 & 1994) were performed on mean log $(x + 1)$ transformed data following Armitage, Pardo & Brown (1995) and Warren & Spencer (1996). Pseudospecies cut levels in TWINSPAN were set at 0, 0.301, 0.477, 0.778, 1.041, 1.415, 1.708, 2.004 and 2.70 to emulate log $(x + 1)$ abundances of 0, 1, 2, 5, 10, 25, 50, 100 and 500 respectively. Transformed data was used to give less weight to dominant taxa and more to qualitative aspects of the data (Sheldon & Haick, 1981; Armitage, Pardo & Brown, 1995). DECORANA, TWINSPAN and CCA were performed in PC-ORD for Windows© Version 3.18, (McCune & Mefford, 1997).

These multivariate methods have been extensively used in the literature and represent probably the most widely used methods available. Several authors have reviewed the merits and faults of these analytical tools (Manly, 1986; Luwig & Reynolds, 1988; Clarke & Warwick, 1994). With the exception of CCA, multivariate analysis allows trends in data to be analysed without confining it to specific environmental data.

TWINSPAN is a polythetic (based on all taxa) divisive (splitting rather than clumping) hierarchical (tree rather than mosaic) eigenanalysis technique (Norris & Georges, 1993; McCune & Mefford, 1997), while DECORANA is also polythetic and based on eigenvalues it produces a scatter plot ordination. TWINSPAN and DECORANA were developed specifically for biological data and are usually used in conjunction with each other (Hill 1979a & b).

Canonical Correspondence Analysis constrains biological data by a multiple regression to linear combinations of chosen environmental variables (Duigan & Kovach, 1994). This presumes that meaningful environmental variables are used in the analysis (McCune & Mefford, 1997) and indicates the strength and direction of the relationships of environmental variables with sample scores with vectors, with the direction of vectors indicates the direction of the relationship and length of line indicating the strength. In all CCAs performed, the cut off for displaying relationships was set at r^2 values > 0.2.

Hierarchical cluster analysis was not designed specifically for ecological data, but has a certain advantages over DECORANA and TWINSPAN. This technique produces a dendrogram by combining relatively homogeneous samples based on selected characteristics. It does this with an algorithm that starts with each group in a separate cluster and combines clusters. This has the advantage of removing from the user the end point that is chosen and it may be argued that this, along with the inability to fine tune the process, removes a degree of subjectivity from the method. The measure used in Hierarchical cluster analysis was Euclidean distances between groups, which gives more weight to abundant taxa (Norris & Georges, 1993).

Norris & Georges (1993) recommended comparisons among different multivariate methods to avoid misclassification of samples, and noted that in work involving sample collection from a mosaic of habitats, geographical areas or from multiple water bodies with differing impacts, misclassification could easily go unnoticed. To try and avoid misclassification in this study, analyses were conducted using at least two multivariate techniques in all but two instances. In the analysis of seasonal effects upon macroinvertebrate assemblages (Section 3.4.2), only Hierarchical cluster analysis was performed because of the large number of samples (99) and their complex organization in the analysis results. This complexity was more apparent in a DECORANA and TWINSPAN analysis, which would have confounded the description of the ordination.

3.3. Data Transformation

Macroinvertebrate sample data is discontinuous count data. Figure 3.1 displays the standard sample data as percentage frequencies per sample unit (kick/sweep sample). Data was clearly skewed to the right (skewness = 2.44, n = 244) and because of this it was necessary to transform the data in order to achieve a normal distribution, required for parametric statistical tests.

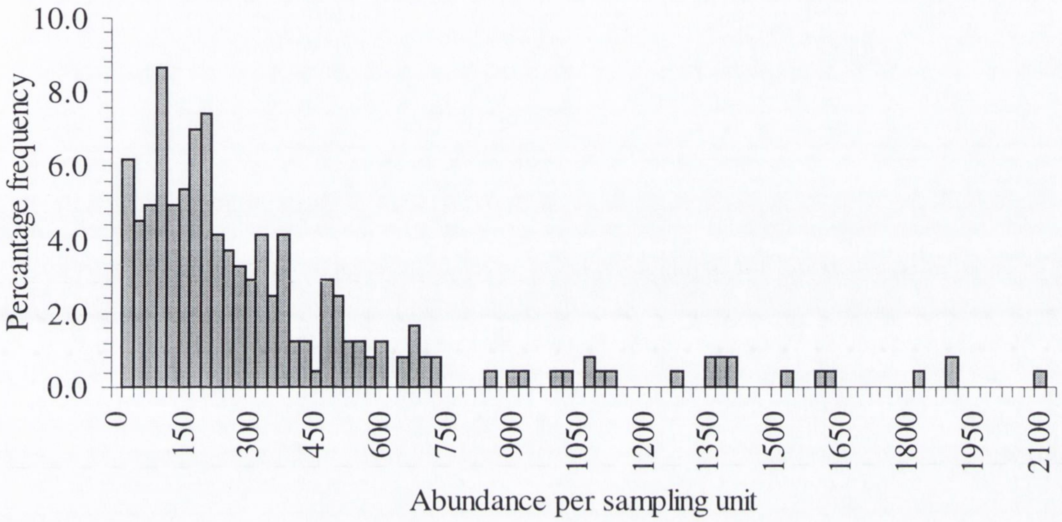

Figure 3.1. Frequency distribution of macroinvertebrate abundance per sample unit from stone substrata samples (n = 244).

Figure 3.2 shows the logged standard deviation (s) of the abundance of samples from stone substratum samples from each lake plotted against the logged mean abundance. These points approximate a straight line with a slope of 1.01 (r = 0.88, n = 28). Clarke & Warwick (1994) advised that data of this type be log transformed. As data sets contained zero values the transformation log (x + 1) was used (Elliott, 1977, Fowler & Cohen, 1990, Norris & Georges, 1993). Following transformation, the data show a lower skewing (-0.61, n = 244) and an apparently 'normal' distribution, shown in Figure 3.3.

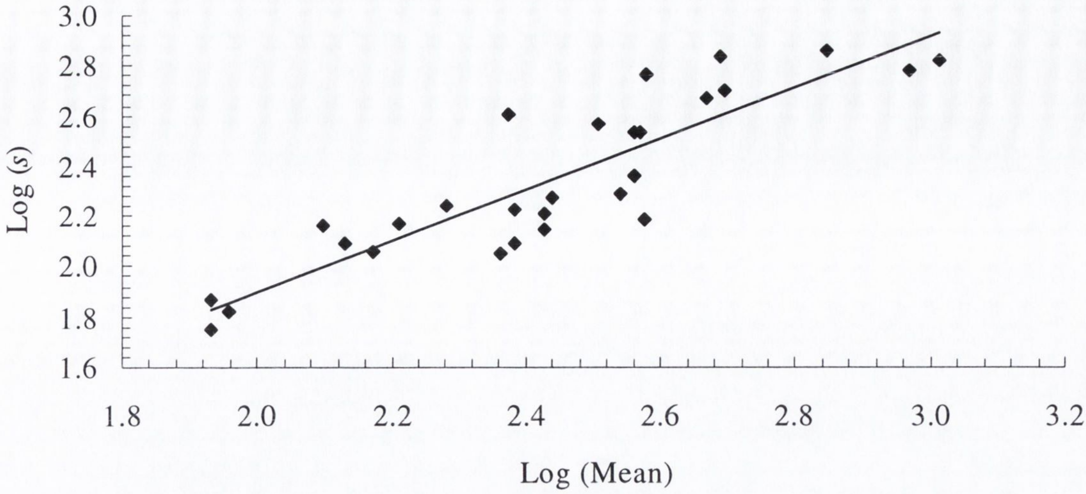

Figure 3.2. Log standard deviation (s) plotted against log mean abundance (y = 1.0141x - 0.1255, r = 0.884, n = 28).

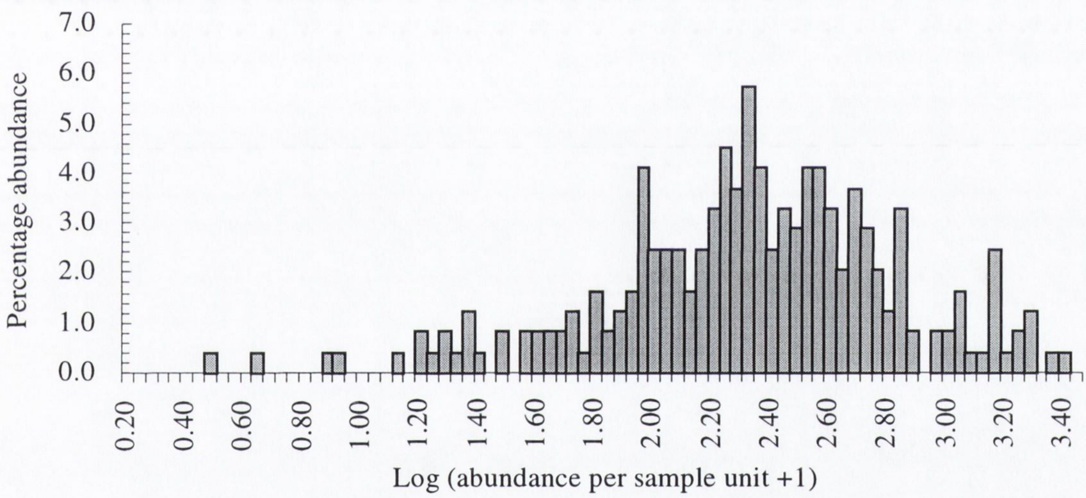

Figure 3.3. Frequency distribution of macroinvertebrate abundance per sample unit from stone substrata sample after log (x + 1) transformation (n = 244).

The influence of a log (x + 1) transformation on the abundance data may also be shown in the form of box plots, Figure 3.4 a) before and, b) after transformation. The mean abundance of non-transformed data was 7, with a standard deviation, larger than the mean, of 400. Fourteen extreme outliers were contained in this data. Logarithmically transformed data had a mean of 2.3 and a standard deviation of 0.5. The distribution of taxa richness data, defined as the count of the number of different taxa in a sample, is shown in Figure 3.4 c). This data shows a normal distribution. Mean taxa richness, encompassing all samples from stone substrata from all lakes was 12.8, with a standard deviation of 6.1 and 95%, confidence limits of ± 0.02.

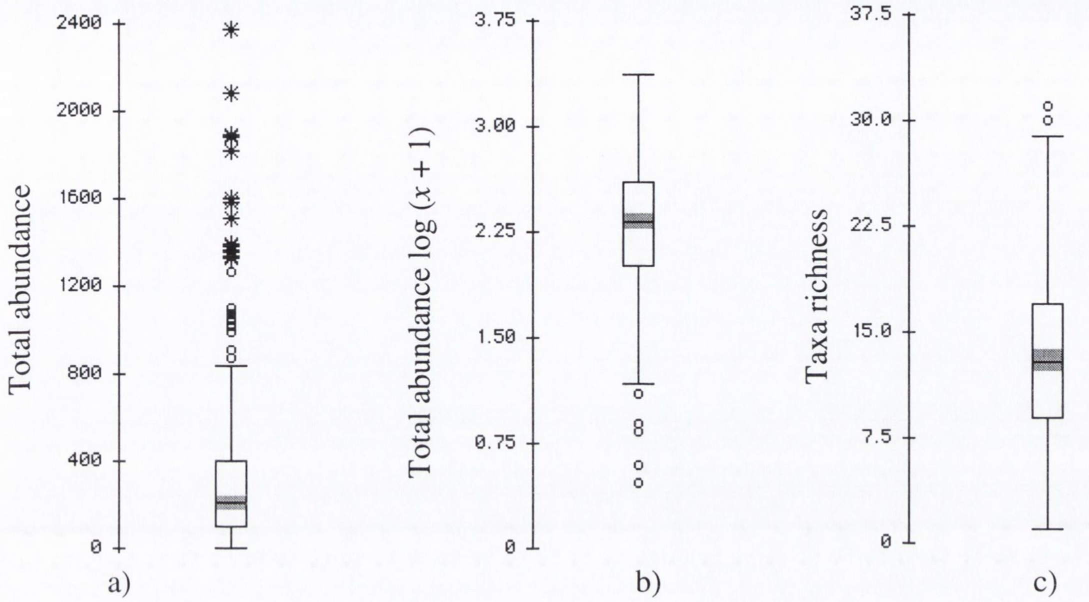

Figure 3.4. Distribution of macroinvertebrate total abundance data: a) before and; b) after log (x + 1) transformation; c) taxa richness data distribution. (Stone substrata data, n = 244). (Centre line = mean, shaded area = 95% *c.l.*, box = upper and lower quartiles, whiskers = main body of data, o = outliers, * = extreme outliers).

3.4. Results

3.4.1. Sample Size

Figure 3.5 shows the mean taxa richness and abundance of the time series samples. The mean taxa richness caught in 60 seconds was 29 (n = 3); 87% of this was caught in 10 seconds, 89% in 15 seconds and 97% in 30. Abundance data was log (x + 1) transformed to normalise its distribution. The mean abundance caught in 60 seconds was 2387 individuals; 40% of this was caught in 10 seconds, 69% in 15 and 85% in 30 seconds.

A one way ANOVA revealed that the difference in mean taxa richness of the 5 sets of samples was statistically significant ($F_{4,10}$ = 4.2, P < 0.05). There was also a strong significant difference between the transformed abundance of the 5 sampling times ($F_{4,10}$

= 33.7, $P < 0.01$). A post hoc Least Square Difference (LSD) test was conducted to identify which sample times gave samples with significantly different abundances and taxa richness. Results are shown in Table 3.2. Significantly fewer taxa were found in the 5 second samples than in the 10, 15, 30 and 60 second samples. Samples of 10 seconds or more did not contain significantly different numbers of taxa. Significantly different abundances were, however, found in all but the 15 - 30, and 30 - 60 second comparisons. (Some of these abundance differences were extremely significant).

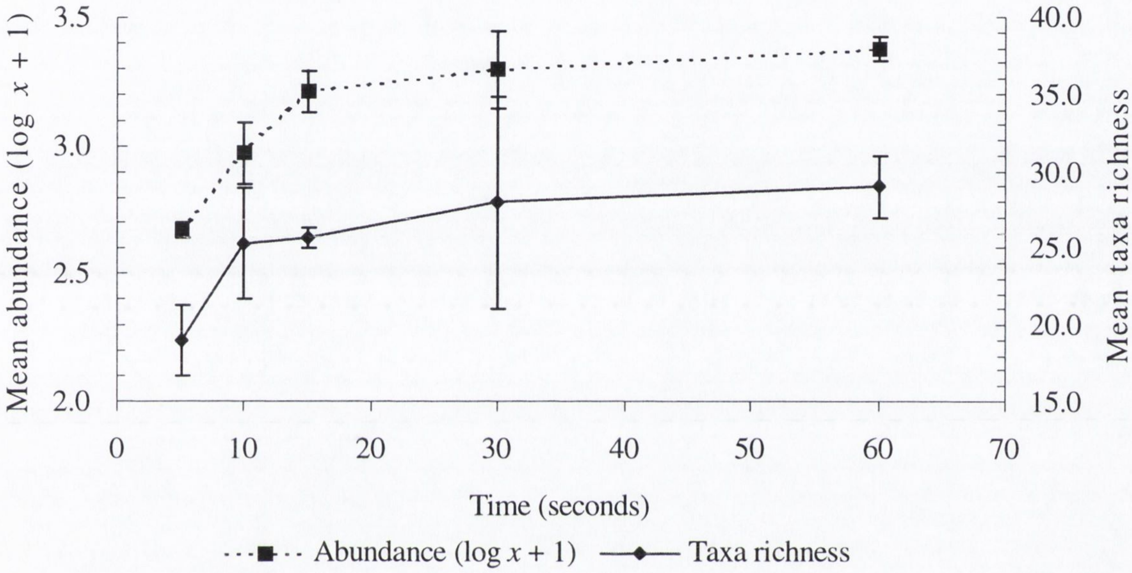

Figure 3.5. Varying mean taxa richness and abundance (log x + 1) caught with varying sample time (n = 3). Error bars are 95% *c.l.*

Table 3.2. Post hoc Least Squared Difference probabilities for taxa richness (top right of the table) and log (x + 1) abundance (bottom left) contained in samples of 5, 10, 15, 30 and 60 seconds (significantly different at * = $P < 0.05$ and ** = $P < 0.01$).

Sample time (seconds)		**5**	**10**	**15**	**30**	**60**
				Taxa richness		
5	Abundance (log x + 1)		6.3*	6.7*	9.0**	10**
10		0.30**		0.3	2.7	3.7
15		0.54**	0.2**		2.3	3.3
30		0.63**	0.33**	0.08		1.0
60		0.71**	0.41**	0.16*	0.08	

The range in taxa richness and log (x + 1) transformed abundance data over varying sample areas are shown in Figure 3.6. Differences in abundance and taxa richness occurred amongst the five different sample sizes (ANOVA for abundances, $F_{4,10} = 22.7$, $P < 0.0001$, ANOVA for taxa richness, $F_{4,10} = 13.6$, $P < 0.0001$). Table 3.3 shows the post hoc LSD probabilities between each of the sample distances. Differences in abundance and taxa richness were apparent between the majority of sample sizes.

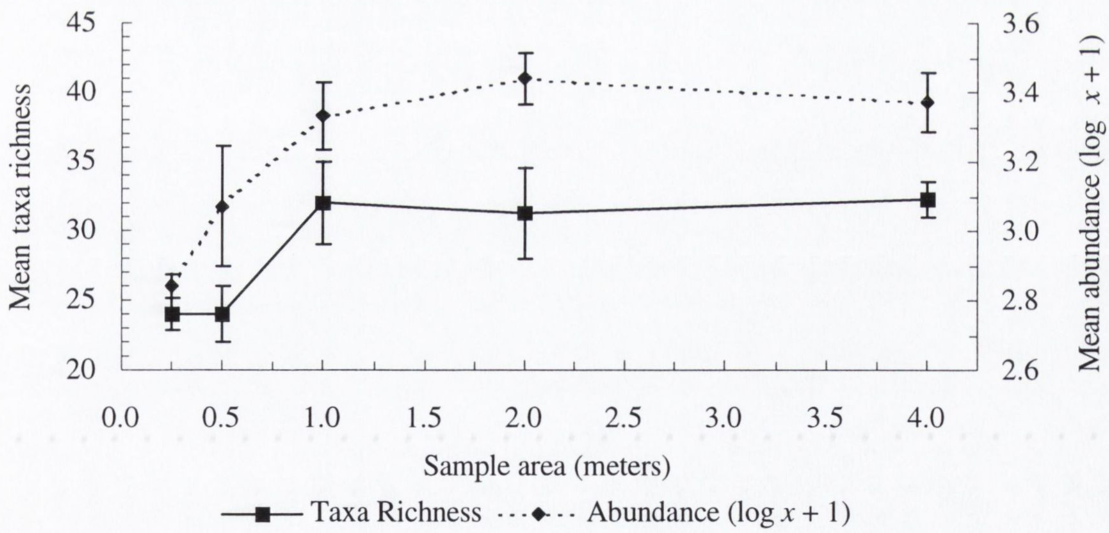

Figure 3.6. Varying mean taxa richness and abundance (log x + 1) caught over varying sample distance (n = 3). Error bars are 95% *c.l.*

Table 3.3. Post hoc Least Squared Difference probabilities for taxa richness (top right of the table) and log (x + 1) abundance (bottom left) contained in samples of 0.25, 0.50, 1.00, 2.00 and 4.00 by 0.25 meters (significantly different at * = $P < 0.05$ and ** = $P < 0.01$).

Sample distance (meters)		**0.25**	**0.50**	**1.00**	**2.00**	**4.00**
				Taxa richness		
0.25	Abundance (log x + 1)		$-1.8\text{x}10^{-15}$	8.00**	7.33**	8.33**
0.50		0.23*		8.00**	7.33**	8.33**
1.00		0.49**	0.26**		-0.67*	0.33
2.00		0.60**	0.37**	0.11*		1.00
4.00		0.53**	0.30**	0.04	-0.07*	

3.4.2. Sampling Season

Figure 3.7 shows the mean taxa richness and abundance found in the study lakes over the year of sampling. The two trends followed a similar pattern. Mean taxa richness for the lakes (n = 28) was highest in April 1997 and lowest in October 1996 and March 1997. It increased through the spring of 1997 and become approximately constant between June and September before falling in October. A rise was seen in January 1997. It declined again in March before increasing in April to reach a level comparable with the previous summer. Macroinvertebrate abundance increased from April to May and into June 1997, when it reached its maximum. This was followed by a decline in October. It then followed a similar pattern to taxa richness over the winter, with the same increase in January and then leveled out between April and June. Figure 3.8 compares the mean proportional abundances of taxonomic groups across the year. Although total abundance differed, most taxonomic orders were present throughout the year. Amphipoda, Isopoda and Oligochaeta tended to be the three most abundant macroinvertebrate groups. Seasonal patterns in the mean abundances (log x + 1 transformed) of the individual taxonomic groups are shown in Figure 3.9. The abundance of many groups followed similar trends, being highest in May 1996, declining towards winter and then rising again in spring and summer 1997. The January peak shown in the total mean abundance data was apparent for many of the taxonomic groups shown in Figure 3.9.

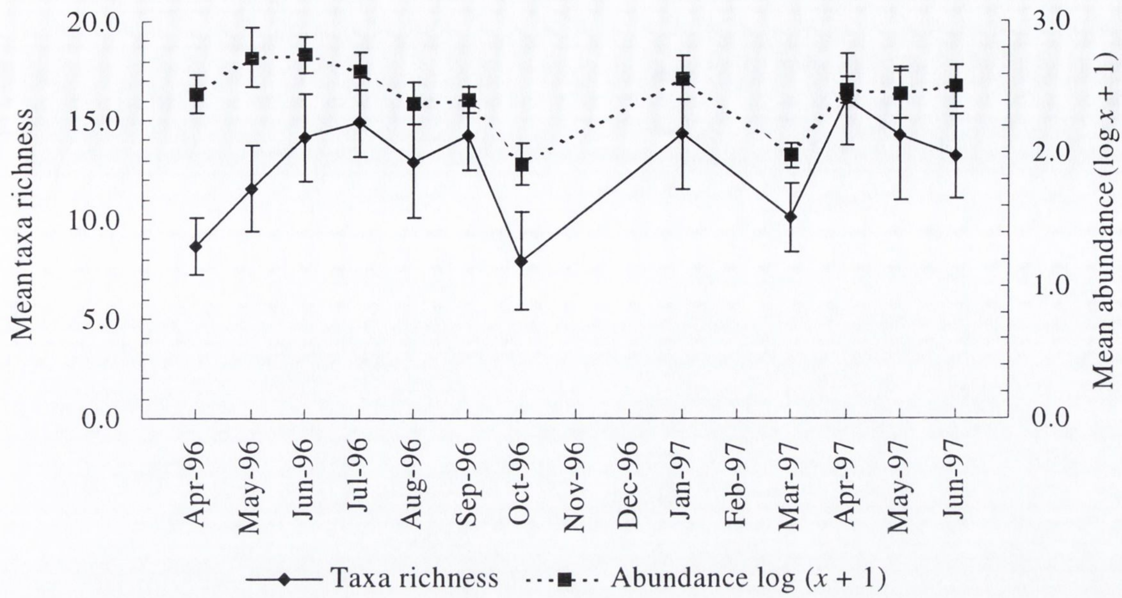

Figure 3.7. Mean summed taxa richness and abundances (log $x + 1$) of samples from stone substrata taken between April 1996 and June 1997 from the 28 sample lakes (n = 28, 7, 27, 28, 11, 26, 11, 26, 11, 31, 12, 27 respectively). Error bars are 95% *c.l.*

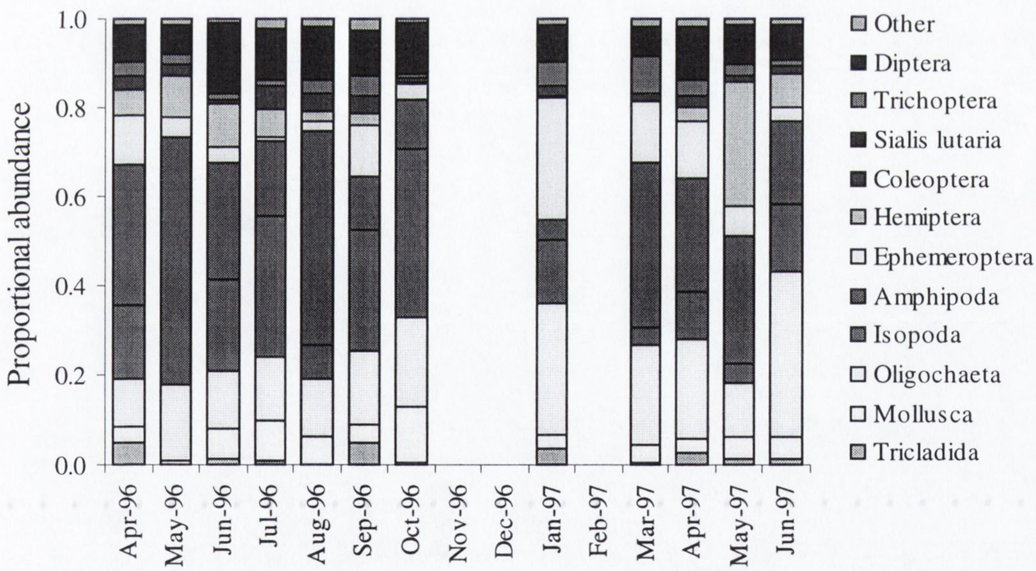

Figure 3.8. The mean proportional abundance of macroinvertebrate groups in samples from stone substrata taken between April 1996 and July 1997. Taxa that contributed to less than 2% of the abundance were grouped under "other." (For each month n of samples = 28, 7, 27, 28, 11, 26, 11, 26, 11, 31, 12, 27 respectively).

Figure 3.9. Mean abundances log $(x + 1)$ transformed, of the main taxonomic groups found in the 28 sample lakes over the year (for each month n of samples = 28, 7, 27, 28, 11, 26, 11, 26, 11, 31, 12, 27 respectively), Error bars are 95% *c.l.*

Multivariate analysis of samples collected from the eleven intensively sampled lakes (Figure 3.10) shows temporal variation among the macroinvertebrate assemblages. For example, April and May samples from Loughs Feeagh, Gowna and samples from Lough Lene from March and April were paired. January and March samples from Lough Feeagh were placed together in a later division with those from September and October. Lough Gowna samples from January and March were placed in the same group while those from June, July, August and October were clustered earlier. A similar pattern for Lough Ballyquirke was seen with midsummer samples grouped in the middle of the dendrogram while January, April, May and September samples were placed in a later cluster and March and October samples later still. This pattern of mid summer and spring/autumn clusters was apparent for many of the lakes, in addition there were instances of samples being grouped by lake, indicating that lake assemblages were often distinct.

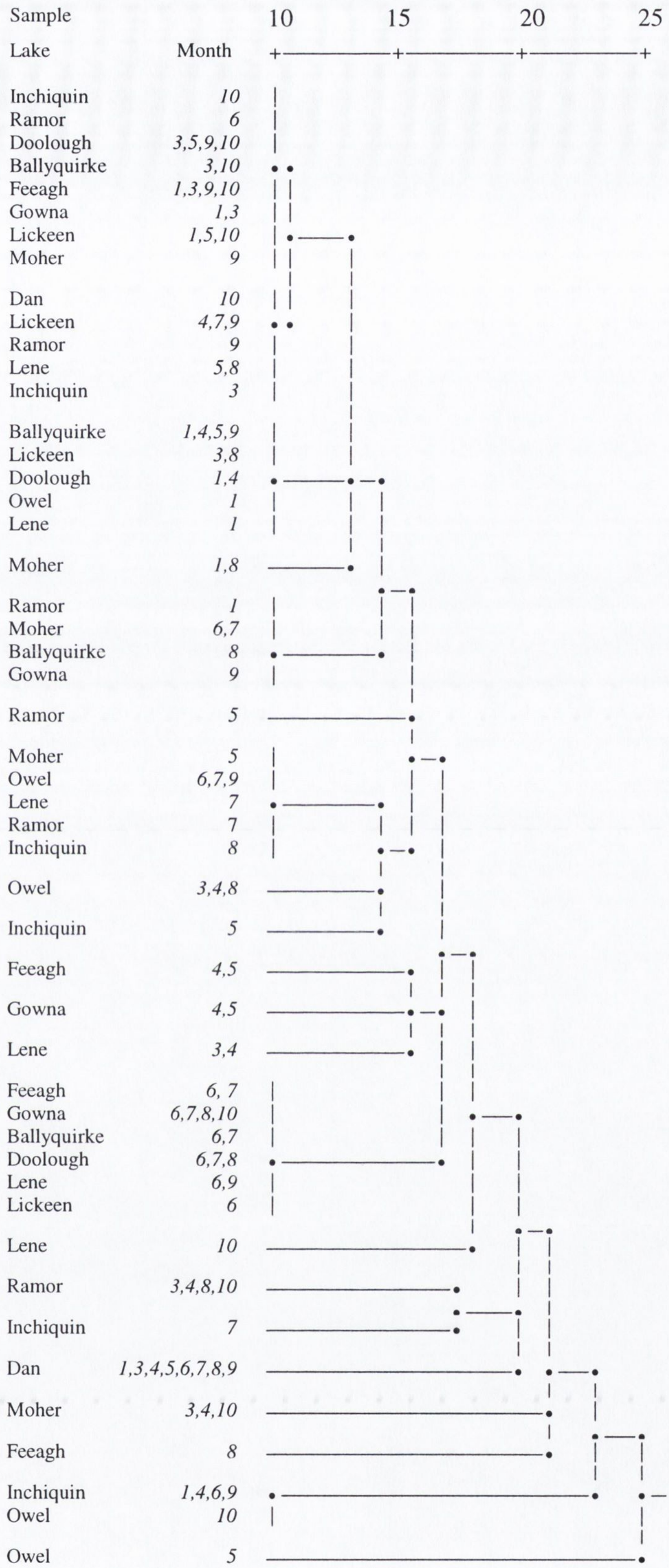

Figure 3.10. Hierarchical cluster analysis of macroinvertebrate samples (average Euclidean distance between groups) collected between June 1996 and May 1997 from the eleven intensively studied lakes ($n = 99$).

3.4.3. Determination of Lake Groupings Based Upon Macroinvertebrate Assemblages and Independent of Season

Mean macroinvertebrate samples taken from stone substrata from 28 study lakes (Lough Dromore was not included in this analysis as the standard sampling habitat of stones/ cobbles was not readily accessible) were subjected to multivariate analysis to investigate similarities in their macroinvertebrate assemblages and to see if lakes could be grouped upon the premise that lakes with similar ecological qualities would support similar assemblages. (Samples were averaged with regard to the number of samples collected from each lake respectively, and log $(x + 1)$ transformed). Nine distinct groups resulted from TWINSPAN classification (Figure 3.11). These groupings were also apparent in a DECORANA analysis. Axis 1 and 2 are shown in Figure 3.12, axis 2 and 3 in Figure 3.13; and axis 1 and 3 in Figure 3.14. These groupings are given in Table 3.4. In the DECORANA analysis several of the lake groups overlap or are superimposed on one another. In the portrayal of axis 1 and 2, groups 3 and 4 occupy a similar space, as do groups 6 and 7. Reference to the TWINSPAN diagram (Figure 3.11) confirms the similarity of groups 3 and 4, and groups 6 and 7 with their separations occurring late in the analysis. Similar overlaps are apparent in plots of DECORANA axis 2 and 3, and 1 and 3, however, envisaging the three dimensional nature of axis 1, 2 and 3, the proximity of points constituting the groups determined from the TWINSPAN analysis is evident, supporting these lake clusters and indicating that similar macroinvertebrate assemblages were supported in the groups. Interestingly, Lough Mullagh was classified by itself after being separated from lakes comprising groups 6 and 7. In the DECORANA analysis, Mullagh was placed relatively close to these groups and group 9, consisting of Lough Ballycullinan and Lough Egish. This indicates that the macroinvertebrate assemblage of Lough Mullagh was intermediate between those of groups 6, 7 and 9.

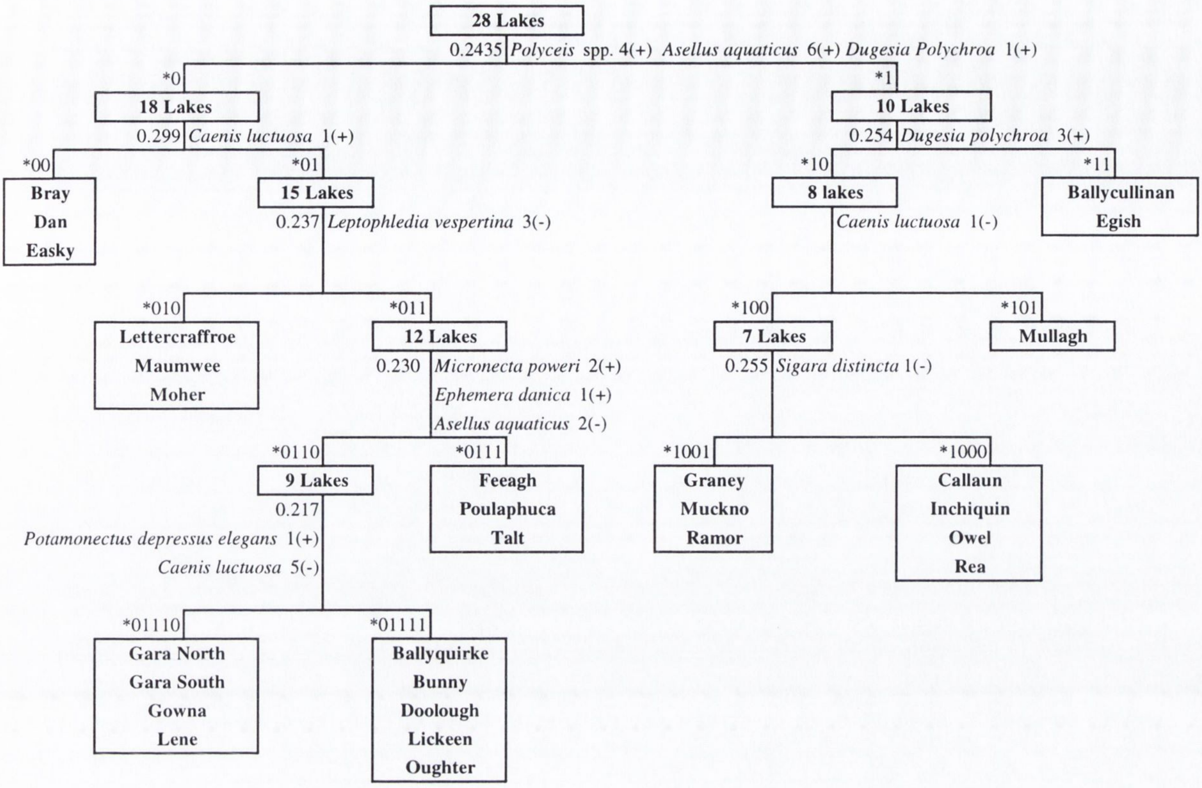

Figure 3.11. Twinspan classification of the mean (log x + 1) transformed macroinvertebrate samples taken from stone substrata from the 28 study lakes between April 1996 and June 97. Eigen values are given for each split along with indicator taxa, their relative abundances and the signs used at each division. Split levels defined at 0, 0.301, 0.477, 0.778, 1.041, 1.415, 1.078, 2.004 and 2.70 to reflect abundances of log 1+: 0; 1; 2; 5; 10; 25; 50; 100 and; 500).

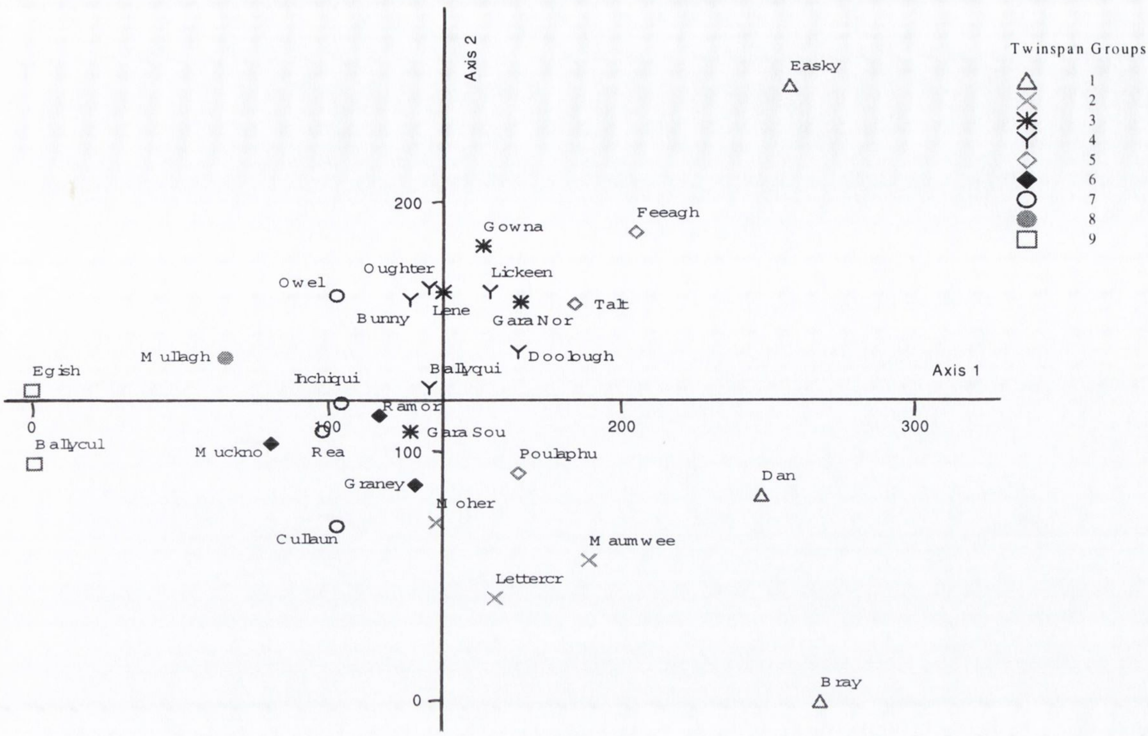

Figure 3.12. DECORANA axis 1 and 2 clustering of the mean (log x + 1) transformed macroinvertebrate samples taken from stone substrata from the 28 study lakes between April 1996 and June 97.

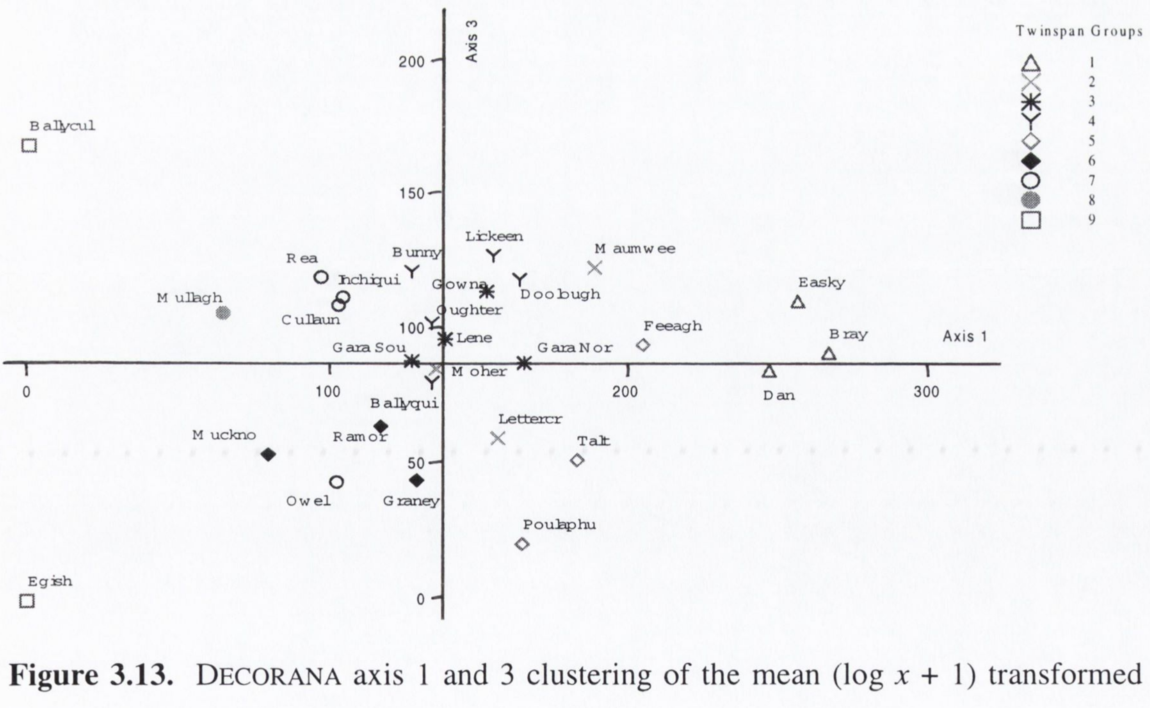

Figure 3.13. DECORANA axis 1 and 3 clustering of the mean (log x + 1) transformed macroinvertebrate samples taken from stone substrata from the 28 study lakes between April 1996 and June 97.

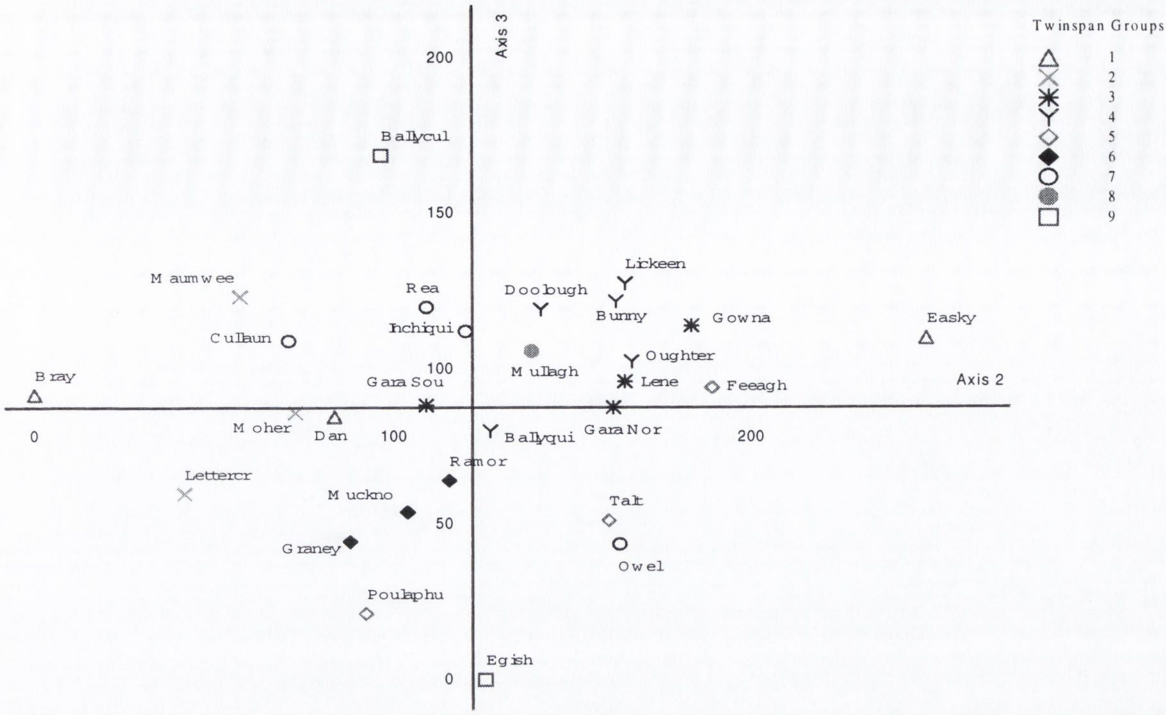

Figure 3.14. DECORANA axis 2 and 3 clustering of the mean (log x + 1) transformed macroinvertebrate samples taken from stone substrata from the 28 study lakes between April 1996 and June 97.

Table 3.4. Lake groups identified by TWINSPAN and DECORANA

Group number	Lakes
1	Bray, Dan, Easky
2	Lettercraffroe, Maumwee, Moher
3	Gara North, Gara South, Gowna, Lene
4	Ballyquirke, Bunny, Doolough, Lickeen, Oughter
5	Feeagh, Pollaphuca, Talt
6	Graney, Muckno, Ramor
7	Cullaun, Inchiquin, Owel, Rea
8	Mullagh
9	Ballycullinan, Egish

3.4.4. Community Classification and Biotic Scores

The Biotic scores and metrics listed in Table 3.1 were calculated and are given in Table 3.5. Abundance divided by Taxa richness ranged from 10 for Lough Easky, Lough Maumwee and Lough Bunny to 65 in Lough Egish, the percentage of dominant taxa ranged from 33% in Lough Graney to 69% in Lough Bray. Percentage abundance of Oligochaeta was as low as 6% in Lough Gonna and as high as 51% in Lough

Table 3.5. Measures described in **Table 3.1** calculated for the mean samples from each of the study lakes (* = mean of June, July and September samples). (Ordered by conductivity). Refer to text for further details.

Lake	Conductivity (μS cm^{-1})	TP (μg l^{-1})	TN (mg l^{-1})	pH	Abundance	Taxa Richness	Abundance/taxa	Dominant taxon %	Oligochaetes %	ETOP Taxon	Non insects %	Crustaceans+ Molluscs	*Gammarus* abundance	*Asellus* abundance	*Gammarus* /*Asellus*	Grazer-scrappers %	Shredders %	Collectors %	Predators %	Shannon Wiener div.	Simpson's diversity	Trent BS. *	Chandler's BS. *	Chandler BS. ASPT.	BMWP. *	BMWP. ASPT. *	Q-Value *
Bray	45	9	0.4	4.9	229	9	27	69	34	5	34	0	0	0	–	24	1	67	9	0.98	0.56	7.0	566	55	51	5.1	3-4
Dan	48	11	0.5	4.9	241	15	16	44	13	7	21	4	0	4	0.0	20	9	44	28	1.77	0.28	7.3	646	43	58	3.7	3-4
Easky	51	2	0.3	6.4	85	9	10	44	15	3	50	33	33	0	–	12	56	25	7	1.57	0.29	7.3	370	40	39	4.1	3.0
Maumwee	64	1	0.3	6.4	85	9	10	39	14	4	25	10	0	0	–	7	16	68	8	1.59	0.28	6.0	313	43	32	4.3	3.0
Lettercraffroe	78	10	0.3	5.8	372	11	34	57	51	4	58	6	0	2	0.0	1	2	82	15	1.20	0.44	5.7	249	25	31	3.2	3.0
Pollaphuca	86	8	0.8	7.6	148	6	25	65	23	2	29	4	2	0	13.0	1	2	56	41	0.92	0.53	6.7	337	39	35	3.9	3.0
Feeagh	89	11	0.6	6.9	323	12	28	55	7	4	75	245	201	0	1408	11	60	20	9	1.35	0.40	7.3	477	41	48	4.0	3.0
Doolough	101	16	0.7	6.9	125	7	17	51	32	2	64	41	38	0	–	5	27	65	3	1.25	0.40	6.7	314	35	25	2.7	3.0
Graney	117	16	0.9	7.7	363	19	19	33	17	6	40	58	0	32	0.0	18	12	59	11	1.65	0.21	8.7	464	27	63	3.6	3.0
Moher	126	11	0.8	7.3	191	15	13	38	28	4	54	54	5	2	3.1	13	8	71	8	1.74	0.24	8.0	646	37	59	3.5	3.0
Lickeen	157	16	0.8	7.6	236	8	29	54	19	2	86	171	156	13	12	2	66	27	5	1.25	0.41	6.3	341	30	37	3.4	3.0
Mullagh	61	3	0.3	7.0	932	17	54	68	23	3	93	532	91	436	0.2	1	66	27	7	1.09	0.55	7.7	525	30	57	3.4	3.0
Ramor	194	88	2.0	8.2	487	16	31	42	17	3	54	141	18	116	0.2	5	36	39	20	1.70	0.28	8.0	523	26	59	2.9	3.0
Talt	193	1	0.2	8.2	135	9	15	40	21	12	44	41	228	2	120	28	20	58	18	1.54	0.29	4.7	138	26	14	2.6	3.0
Ballyquirke	184	20	0.9	7.8	162	12	14	41	16	2	58	56	31	20	1.6	3	39	47	11	1.66	0.28	7.0	452	28	43	2.7	3.0
Gowna	206	43	1.1	8.0	494	9	56	67	6	2	81	377	326	12	27	7	69	23	1	0.95	0.54	6.7	382	33	42	3.8	3.0
Muckno	213	33	3.0	7.9	242	12	21	43	40	2	61	43	1	40	0.0	2	14	68	16	1.51	0.30	6.0	423	32	39	3.1	3.0
Oughter	171	55	1.1	8.0	701	11	62	53	19	2	77	532	336	167	2.0	4	52	41	2	1.31	0.38	6.7	429	32	43	3.1	3.0
Egish	229	344	1.5	8.2	1031	16	65	46	38	1	78	254	0	198	0.0	4	26	49	21	1.65	0.31	5.0	348	19	42	2.4	3.0
Lene	241	12	0.4	8.3	347	13	27	59	14	2	88	248	225	8	27	2	67	28	3	1.20	0.47	6.7	446	32	43	3.2	3.0
Owel	254	10	0.6	8.3	268	15	18	45	30	4	73	107	32	55	0.6	10	37	49	4	1.69	0.31	8.3	639	39	65	4.1	3.0
Rea	277	6	0.7	8.4	268	18	15	43	23	4	77	89	25	56	0.4	9	42	34	15	1.82	0.29	7.7	615	35	63	3.7	3.0
Bunny	314	1	0.7	8.4	90	9	10	56	46	2	80	34	26	5	5.4	0	22	68	10	1.28	0.41	5.0	297	26	28	2.3	3.0
Inchiquin	354	22	1.5	8.3	464	22	22	36	17	5	70	184	46	104	0.4	7	39	42	12	2.05	0.21	8.0	809	32	81	3.3	3.0
Gara North	356	28	1.2	8.3	453	16	28	42	15	6	63	272	249	0	–	7	43	49	1	1.65	0.30	8.5	629	37	73	4.3	3.0
Cullaun	371	4	1.0	8.3	377	16	24	50	24	5	76	144	1	139	0.0	3	42	45	11	1.50	0.36	7.3	566	38	60	4.0	3.0
Gara South	366	29	1.4	8.2	274	18	15	48	18	7	76	130	26	82	0.3	4	52	41	4	1.77	0.29	9.0	762	37	70	3.5	3.0
Ballycullinan	431	31	1.2	8.2	364	14	26	63	21	2	87	246	0	210	0.0	4	54	32	10	1.30	0.47	7.3	437	31	35	2.7	3.0

Lettercraffroe. The number of Ephemeroptera, Trichoptera, Odonata and Plecoptera (ETOP) taxa was highest in Lough Talt (12) and lowest in Lough Egish (1). Taxa richness of non-insects ranged between 21% (Lough Dan) and 93% (Lough Mullagh), whereas abundance ranged between 34% in Lough Bray and 93% in Lough Mullagh. *Gammarus* and *Asellus* abundance also ranged widely, as did the ratio between them.

The Trent biotic score did not separate the lakes to any great extent, ranging between 4.7 (Lough Talt) and 9 (Loughs Gara South, Graney and Gara North), while the Chandler score ranged from 138 (Lough Talt) to 809 (Inchiquin). The BMWP Score ranged from 14 (Lough Talt) to 81 (Lough Inchiquin). The EPA Quality Value score did not separate the lakes well as only values of 3 and 3-4 were obtained.

Spearman rank correlation coefficients of mean biotic scores with mean total phosphorus, total nitrogen, conductivity and pH are shown in Table 3.6. To test for auto-correlations between the mean total phosphorus, total nitrogen, conductivity and pH, correlation coefficients between each were calculated and are included in Table 3.6.

It is apparent that there was some auto-correlation among chemical variables. A highly significant relationship was found between total nitrogen and conductivity ($r_s = 0.61$, $P < 0.01$, $n = 28$), total nitrogen and total phosphorus ($r_s = 0.82$, $P < 0.01$, $n = 28$), pH and conductivity ($r_s = 0.91$, $P < 0.01$, $n = 28$), and between pH and total nitrogen ($r_s = 0.45$, $P < 0.01$, $n = 28$).

Macroinvertebrate abundance was significantly correlated to total phosphorus and total nitrogen ($r_s = 0.59$ and 0.49 respectively, $P < 0.01$ and $n = 28$ in both cases). Abundance was also correlated with conductivity ($r_s = 0.34$, $P < 0.05$, $n = 28$). Taxa richness was correlated to conductivity, total nitrogen and pH ($r_s = 0.44$, 0.40 and 0.43 respectively, $P < 0.05$ and $n = 28$ in all cases). Dividing abundance by taxa richness gives mean abundance per taxon. This was strongly correlated with total phosphorus ($r_s = 0.52$, $P < 0.01$, $n = 28$). The percentage of non insects showed significant correlations with conductivity, $r_s = 0.54$, $P < 0.01$ and pH, $r_s = 0.51$, $P < 0.01$, in both cases $n = 28$). The abundance of crustaceans + molluscs also showed strong, significant correlations with conductivity ($r_s = 0.50$, $P < 0.01$, $n = 28$), total phosphorus ($r_s = 0.54$, $P < 0.01$, $n = 28$)

and pH (r_s = 0.50, P < 0.01, n = 28). *Gammarus* abundance showed only week correlations as did the proportion of *Gammarus* to *Asellus*. *Asellus* abundance however, did show significant correlations; with conductivity, r_s = 0.55, P < 0.01; total phosphorus, r_s = 0.43, P < 0.05; total nitrogen, r_s = 0.52, P < 0.01; and pH, r_s = 0.49, P < 0.01; in all cases n = 28.

Table 3.6. Spearman rank correlation coefficients between macroinvertebrate scoring methods and conductivity, total phosphorus, total nitrogen and pH. (* = P < 0.05; ** = P < 0.01) (n = 28) (^{3} = Correlations calculated from the mean values of June, July and September samples).

Measure	**Conductivity**	**Total Phosphorus**	**Total Nitrogen**	**pH**
Conductivity µS cm^{-1}	1			
Total Phosphorus µg l^{-1}	0.35	1		
Total Nitrogen mg l^{-1}	0.61**	0.82**	1	
pH	0.91**	0.18	0.45**	1
Abundance	0.34*	0.59**	0.49**	0.31
Taxa Richness	0.44*	0.27	0.40*	0.43*
Abundance/taxa	0.01	0.52**	0.28	-0.01
% Dominant taxon	-0.13	-0.06	-0.20	-0.16
% Oligochaetes	0.09	-0.15	0.02	0.08
ETOP Taxon	-0.05	-0.33	-0.23	-0.05
% Non insects	0.54**	0.26	0.23	0.51**
Crustaceans + Molluscs	0.50**	0.54**	0.44**	0.48**
Gammarus abundance	0.17	0.10	-0.04	0.29
Asellus abundance	0.52**	0.43*	0.52**	0.49**
Gammarus /*Asellus*	-0.11	-0.23	-0.35	0.06
% Grazer-scrappers	-0.24	-0.10	-0.21	-0.20
% Shredders	0.35	0.23	0.11	0.32
% Collectors	-0.13	-0.22	-0.08	-0.14
% Predators	-0.10	-0.11	0.08	-0.04
Shannon Wiener diversity	0.30	0.17	0.31	0.29
Simpson's diversity	-0.09	-0.09	-0.22	-0.09
Trent BS.	^{3} 0.20	0.16	0.26	0.17
Chandler's BS.	^{3} 0.25	0.20	0.30	0.21
Chandler's BS. ASPT	^{3} -0.28	-0.30	-0.25	-0.33
BMWP.	^{3} 0.31	0.24	0.36	0.33
BMWP. ASPT.	^{3} -0.27	-0.33	-0.26	-0.27

Hawkes & Davies (1971) proposed that the ratio of abundance of *Gammarus* to *Asellus* in riverine systems is indicative of phosphorus loading. A plot of abundance of *Asellus* species and *Gammarus* species against total phosphorus reveals several points (Figure 3.15). At very low total phosphorus concentrations, *Gammarus* was more prevalent than *Asellus*. At higher concentrations however, the expected dominance of *Asellus* was not apparent. Using logarithmically transformed data, a significant correlation was found between total phosphorus and *Asellus* abundance ($r = 0.58$; $P < 0.01$; $n = 28$), but not with that of *Gammarus* ($r = 0.10$; $P > 0.05$, $n = 28$). Several species of *Gammarus* and two *Asellus* are included in this data. A plot of the dominant two, *Asellus aquaticus* and *Gammarus duebeni*, (Figure 3.16) showed that *A. aquaticus* could be present in high numbers at all concentrations of phosphorus but only in low numbers at lower concentrations. *Gammarus duebeni* had both high and low abundance at low phosphorus concentrations. As phosphorus concentration increased, there was a tendency for *G. duebeni* abundance to decline. The lines drawn on Figure 3.16 are included to aid description and do not represent any statistical analysis.

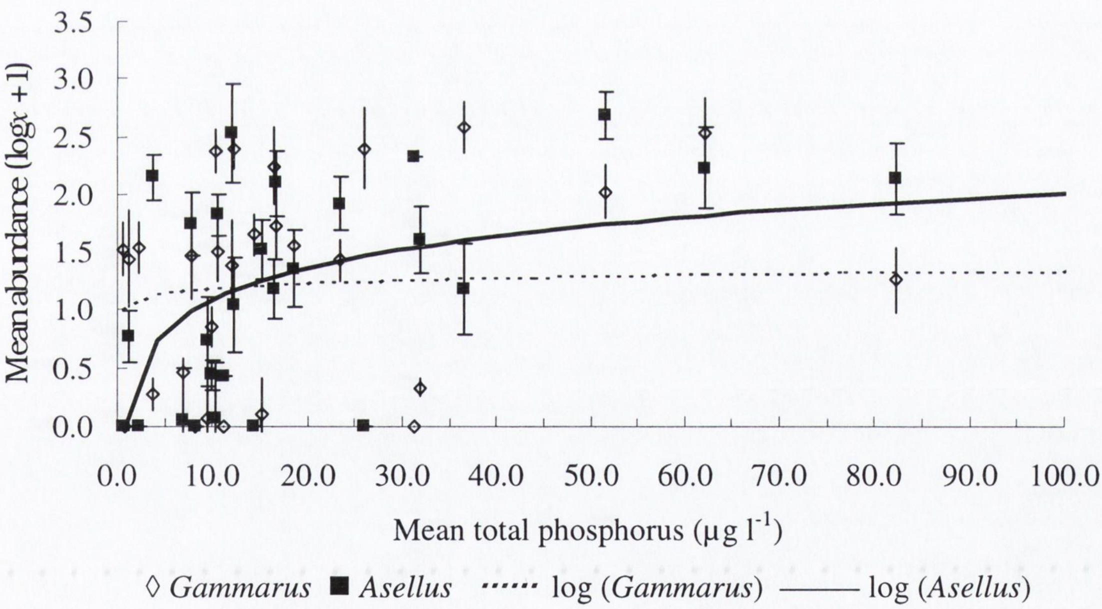

Figure 3.15. Mean *Gammarus* and *Asellus* abundance (log x + 1) with mean total phosphorus from the 28 study lakes sampled between April 1996 and June 97. Error bars are 95% *c.l.* Regression lines; *Asellus*, $y = 0.40 \log (x) + 0.1609$, $r = 0.58$. *Gammarus*, $y = 0.0639 \log (x) + 1.05$, $r = 0.10$.

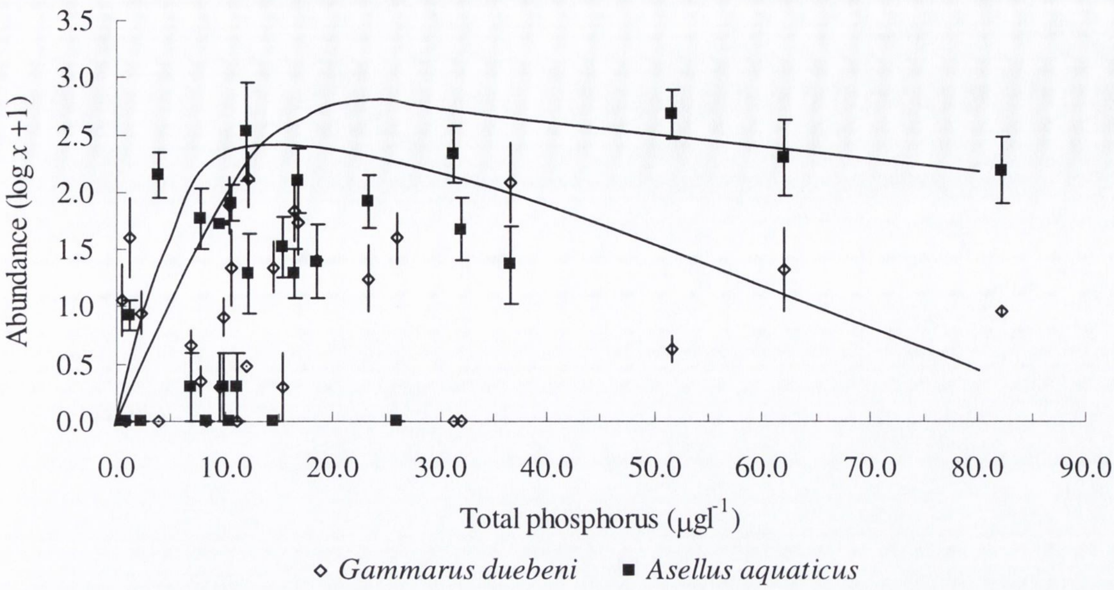

Figure 3.16. Mean *Gammarus duebeni* and *Asellus aquaticus* abundance (log x + 1) with mean total phosphorus from the 29 study lakes sampled between April 1996 and June 97. (Error bars are 95% *c.l.* Lines are to aid description and bear no statistical significance).

Feeding guilds were calculated as percentages of grazer-scrapers, shredders, collectors and predators. Taxa were divided into feeding guilds based on information from numerous sources, some of which were contradictory. No significant correlations between feeding guilds and the variables included in Table 3.6 were observed. The percentage abundances of the feeding guilds in most lakes was dominated by shredders and collectors (Table 3.5) indicating that the ecology of macroinvertebrates in the littoral zone of lakes is primarily driven by decomposing particulate organic matter rather than periphytic grazing. Neither the Shannon–Wiener or Simpson's diversity indices showed significant correlations with chemical variables. Non of the biotic scores show significant correlations with the chemical variables.

3.4.5. Macroinvertebrates and Chemistry

Spearman Rank correlations between water chemical variables and taxonomic richness and macroinvertebrate abundance are shown in Table 3.7. Many showed significant correlations. 40 taxa showed significant correlations with the chemical variables total phosphorus, total nitrogen, conductivity and pH (Table 3.8). Also shown in Table 3.8 are the autocorrelations between these chemical variables.

Table 3.7. Spearman Rank correlation coefficients between macroinvertebrate abundance, taxa richness and lake chemical and environmental variables. $n = 28$, * = $P > 0.05$, ** = $P > 0.01$

Variable	Abundance	Taxa Richness
Temperature	0.41*	0.33
Oxygen	-0.37	-0.23
pH	0.31	0.43*
Alkalinity	0.42*	0.49**
Conductivity	0.34*	0.44**
Turbidity	0.54**	0.18
Secchi depth	-0.22	-0.03
Colour	-0.11	-0.08
PO4-P	0.64**	0.38*
TP	0.59**	0.27
TDP	0.69**	0.36
NO3-N	0.44*	0.29
TN	0.49**	0.40*
TDN	0.61**	0.45**
SiO2-Si	0.41*	0.26
TSi	0.43*	0.25
TDSi	0.38*	0.25
Cl	0.12	0.17
SO_4	0.64**	0.39*
Mg	0.62**	0.50**
Na	0.19	0.15
K	0.57**	0.30
Ca	0.38	0.43*

Table 3.8. Spearman Rank correlation coefficients between specific taxa abundance and total phosphorus, total nitrogen, conductivity and pH. $n = 28$, * = $P > 0.05$, ** = $P > 0.01$

	TP	TN	Conductivity	pH
TP	1.00			
TN	0.82**	1.00		
Conductivity	0.35	0.61**	1.00	
pH	0.18	0.45**	0.91**	1.00
Dugesia lugubris	0.23	0.37	0.66**	0.65**
Dugesia polychroa	0.41**	0.48*	0.33	0.32
Dendrocoelum lacteum	0.18	0.37	0.47*	0.38*
Theodoxus fluviatilis	0.02	0.07	0.46*	0.59**
Viviparus fasciatus	0.00	0.29	0.54**	0.46
Valvata cristata	0.36	0.45*	0.35	0.17
Valvata piscinalis	0.38*	0.43*	0.07	0.04
Potamopyrgus jenkinsi	0.42**	0.31	0.10	0.11
Bithynia tentaculata	0.21	0.47*	0.70**	0.61**
Physa fontinalis	0.14	0.09	0.26	0.30
Lymnaea peregra	0.59**	0.58**	0.35	0.26
Planorbis contortus	-0.03	-0.01	0.32	0.46*
Planorbis laevis	0.43*	0.37	0.54**	0.44*
Sphaerium sp.	0.24	0.33	0.54*	0.53**
Oligochaeta Sum	0.28	0.36	0.39*	0.34
Erpobdella testacea	0.23	0.40*	0.40*	0.36
Dina lineata	0.21	0.35	0.42*	0.36
Asellus aquaticus	0.47*	0.56**	0.48*	0.45*
Centroptilum luteolum	0.29	0.40*	0.37	0.37
Caenis horaria	0.39*	0.48*	0.36	0.24
Caenis luctuosa	0.14	0.38*	0.41*	0.40*
Leuctra nigra	-0.42*	-0.44*	-0.27	-0.25
Capnia bifrons	-0.33	-0.47*	-0.10	0.04
Siphonoperla torrentium	-0.46*	-0.58**	-0.59**	-0.56**
Coenagrion mercuriale	0.11	0.03	0.25	0.38*
Enallagma cyathigerum	-0.21	-0.18	0.24	0.39*
Callicorixa praeusta	0.50**	0.44*	0.13	0.08
Sigara falleni	0.44**	0.45*	0.04	-0.09
Haliplus confinus	0.34	0.44*	0.38*	0.27
Haliplus (larvae)	0.13	0.33	0.48*	0.46*
Coelambus nigrolineatus	-0.20	-0.18	-0.40*	-0.36
Plectrocnemia geniculata	-0.18	-0.29	-0.39*	-0.45*
Tinodes maculicornis	-0.20	-0.33	-0.44*	-0.45*
Limnephilus affins/incisus	0.41*	0.42*	0.18	0.18
Limnephilus vittatus	-0.09	0.09	0.39*	0.53**
Athripsodes cinereus	0.11	0.20	0.40*	0.47*
Psychodidae spp.	0.30	0.46*	0.34	0.28
Chironomidae Sum	0.55**	0.46*	0.18	0.11
Ceratopogonidae spp.	0.36	0.37	0.35	0.41*
Stratiomyidae spp.	-0.16	-0.22	0.28	0.46*

The chemical variables in Table 3.7 were included in a CCA analysis with mean (log x + 1) transformed macroinvertebrate sample data from the 28 study lakes to investigate the associations between these variables and the macroinvertebrate assemblages in the lake groupings identified by TWINSPAN and DECORANA. The resulting plot is shown in Figure 3.17, with lake groups identified in Table 3.4 indicated. The lakes can again be seen to be grouping in a similar way. Of the chemical variables the CCA associated with the macroinvertebrate assemblages with an r^2 of greater than 0.2, all with the exception of oxygen concentration, are associated to the right of the plot, correlating with Axis 1 and indicating increasing concentrations in this direction. pH showed the strongest relationship, away from the acidic lakes of Groups 1 and 2. Also notable are the associations between total phosphorus and total dissolved phosphorus towards the positioning of lakes in the top right of the plot, group 9, which are nutrient enriched lakes. The inverse relationship between oxygen concentration and the other chemical variables is also of note, and may indicate a general relationship between productivity and oxygen utilization. It may be postulated from this that more productive lakes tend to have reduced oxygen concentrations. This is only speculative however, and while depressed concentrations of oxygen may be expected in enriched lakes at night due to the respiration of plants as well as animals, the abundance of plants associated with enrichment would be anticipated to produce elevated oxygen concentrations during the day. Therefore, while the inverse relationship between oxygen and nutrient concentrations is apparent, its cause is not determinable here.

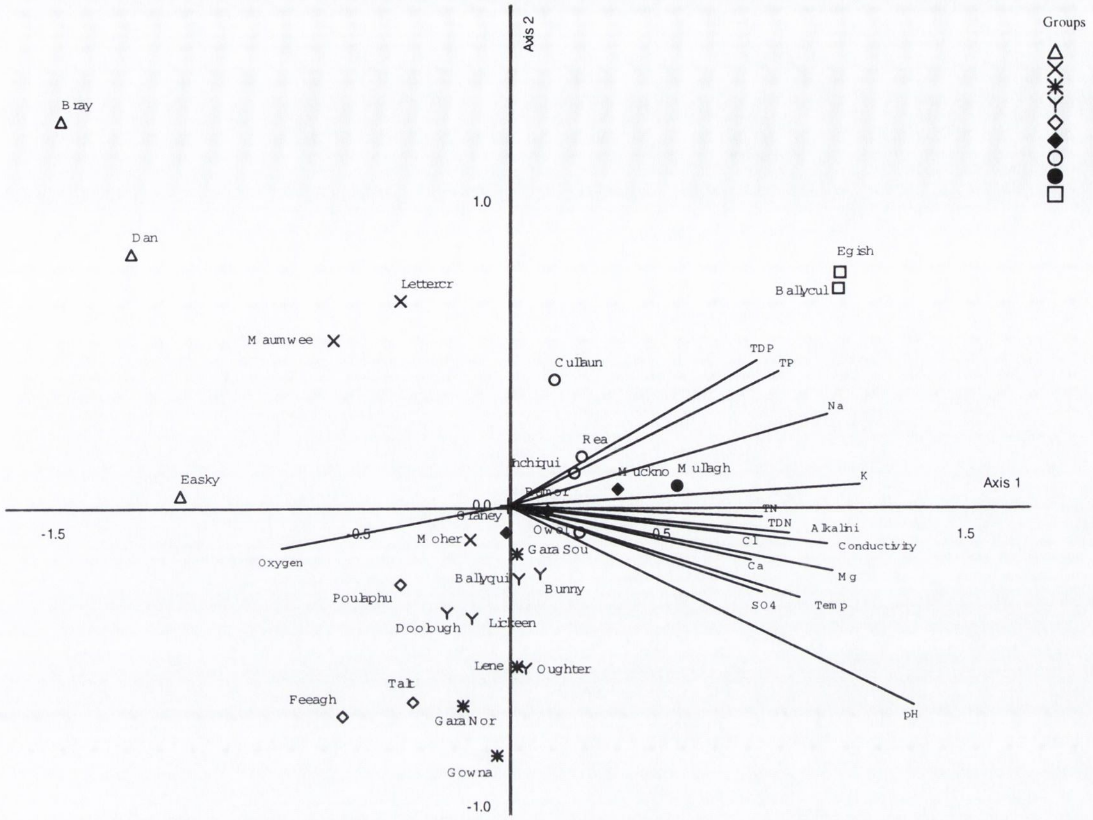

Figure 3.17. CCA analysis of mean log (x + 1) transformed macroinvertebrate samples with mean chemical attributes (Table 3.7). Samples taken between April 1996 and June 1997. Angles and lengths of lines indicate the direction and strength of relationships. . (Note: to make this plot more comprehendible vector scaling was set at 300%, so elongating the chemical vectors and therefore the strength of the chemical relationships is only half that which is shown in the plot).

3.4.6. Macroinvertebrates, Land Use and Physical Factors

The catchment is fundamentally influential upon the water chemistry of a lake, and land use tends to dictate the chemistry, nutrient availability and productivity (Moss, Johnes & Phillips, 96). Few of the land use activities however, showed significant correlations with abundance or taxonomic richness (Table 3.9). Those which did include high productivity pasture, correlated with abundance ($P > 0.01$, $n = 28$), mixed pasture and unexploited peat bogs, both significantly correlated with abundance and taxonomic richness ($P > 0.01$, $n = 28$ in all cases) and transitional woodland/scrub which was significantly correlated with taxa richness ($P > 0.05$, $n = 28$). (Land use from Irvine *et* *al.*, in press, included as proportional presence in the catchments). In CCA analysis including the proportional presence in the catchment of the 21 land use types listed in Table 3.9, only unexploited peat bogs and mixed pasture were associated with the macroinvertebrate assemblages of the study lakes with an r^2 greater than 0.02, both of which were correlated with Axis 1 (Figure 3.18).

Table 3.9. Spearman Rank correlation coefficients between land uses and macroinvertebrate abundance and taxonomic richness. $n = 28$, * = $P > 0.05$, ** = $P > 0.01$. (Land use from Irvine *et al.*, in press).

Land Use	Abundance	Taxa Richness
Arable	0.00	-0.01
Artificial Surface	0.13	0.04
Bare Rocks	0.03	0.16
Broadleaf Forest	0.21	-0.05
Complex Cultivation	0.09	-0.14
Coniferous Forest	-0.02	0.05
Inland Marshes	-0.02	-0.21
Mixed Forest	0.19	0.05
Moors and heathland	-0.19	-0.01
Natural grasslands	0.02	0.23
Pasture high prod.	0.48**	0.34
Pasture low prod.	0.28	0.14
Pasture mix	0.60**	0.50**
Peat Bogs	0.13	-0.00
Peat Bogs exploited	0.27	0.33
Peat Bogs unexploited	-0.60**	-0.46**
Principally Agriculture	0.05	0.22
Sparsely Vegetated Areas	-0.02	0.17
Transitional woodland/scrub	0.27	0.39*
Urban green	-0.06	-0.04
Fresh water	-0.07	-0.32

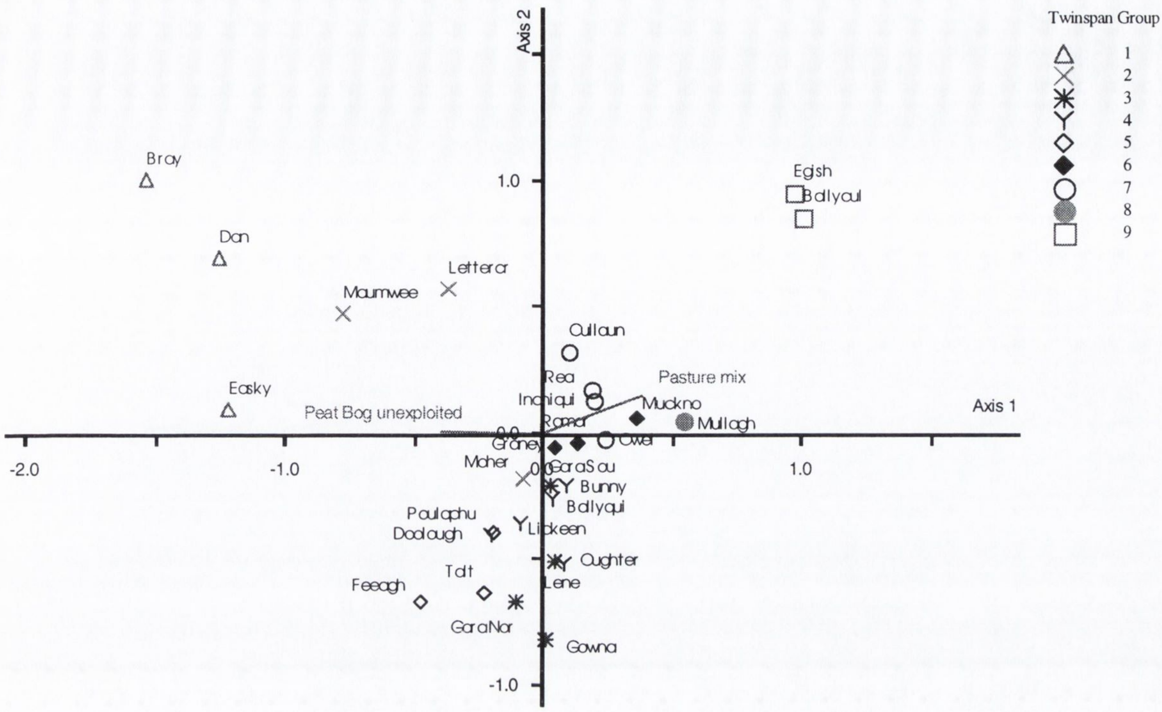

Figure 3.18. CCA analysis of mean log $(x + 1)$ transformed macroinvertebrate samples taken between April 1996 and June 1997 with land use (shown in Table 3.9). Angles and lengths of lines indicate the direction and strength of relationships.

Physical environmental variables of a lake are also influential upon lake ecology. The variables listed in Table 3.10 will influence the volume of water running into a lake, (lake area, drainage and catchment area) its retention time (the previous variables plus depth, and volume), temperature (altitude, depth, drainage area and catchment area), mixing (depth, volume, maximum length and shore length) and wave exposure (lake length, shore length and shore slope). With regard to the 28 study lakes however, no significant correlations were found between 11 variables and taxonomic richness or macroinvertebrate abundance (Table 3.10). CCA of mean log $(x + 1)$ transformed macroinvertebrate abundances with these variables is given in Figure 3.19. There appeared to be no similarity in the suggested association between shore length and the macroinvertebrate assemblages (referring to Table 2.5), however other variables pertaining to lake size (lake area, volume and length) were shown by the position of the lakes in the ordination, to be indicative of macroinvertebrate assemblages. Altitude, mean depth and maximum depth also agreed with the positioning of the deeper and higher lakes.

Table 3.10. Spearman Rank correlation coefficients between physical environmental lake variables and macroinvertebrate abundance and taxonomic richness. $n = 28$.

Lake	Abundance	Taxa Richness
Lake area	0.23	0.02
Drainage area	0.19	0.17
Catchment area	0.21	0.17
Mean depth	-0.05	-0.09
Maximum depth	-0.10	-0.09
Lake Volume	0.15	-0.07
Mean retention time (1960-90)	-0.01	-0.21
Shoreline slope	-0.24	-0.13
Altitude	-0.23	-0.23
Max length of lake	0.10	0.11
Shoreline length	0.26	0.04

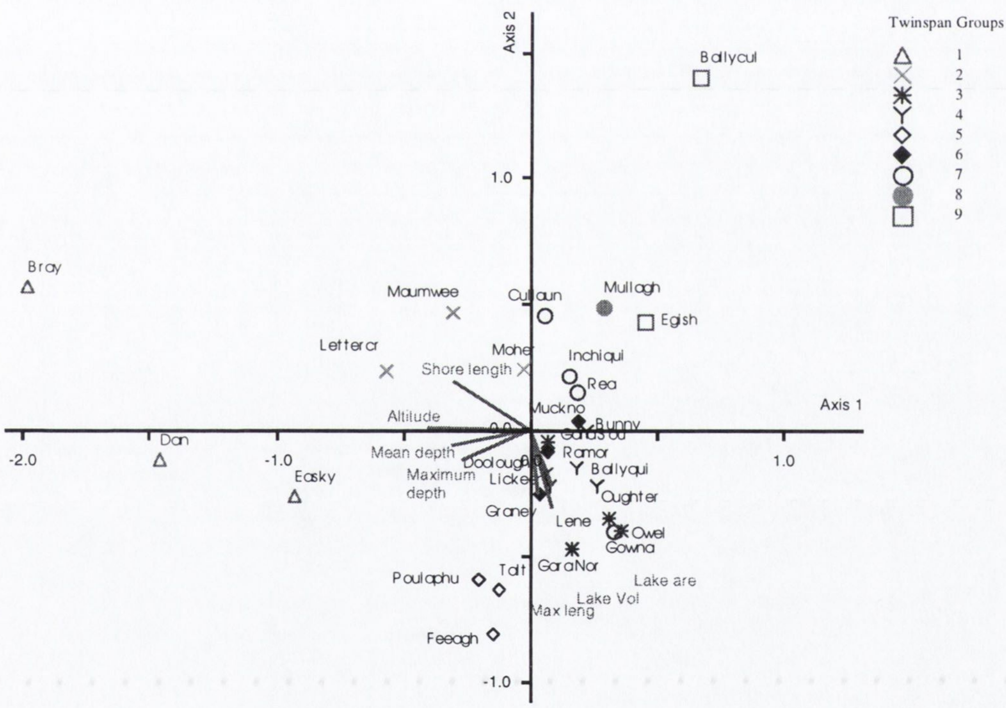

Figure 3.19. CCA analysis of mean log (x + 1) transformed macroinvertebrate samples taken between April 1996 and June 1997 with physical environmental lake variables (lake area, Drainage area, Catchment area, mean depth, maximum depth, lake volume, mean retention time (1960 – 90), shoreline slope, altitude, maximum length and shoreline length. Angles and lengths of lines indicate the direction and strength of relationships.

3.5. Discussion

3.5.1. Sample Size

The results of the analysis of sample size indicated that sampling over varying time and distance would yield significant differences in the taxa richness and abundance of animals caught. The taxa richness of samples did not significantly increase as time was increased above 5 seconds with the distance covered kept constant, however abundance did. Not unexpectedly, both taxa richness and the abundance of a sample increased with increasing sample distance.

By standardizing the sampling method to a 12 second kick/sweep sample covering a distance of approximately 1 m, however, it was anticipated that apparent variations in compared macroinvertebrate assemblages would be due to ecological differences and not to variability of the sampling technique. In support of the sampling method, the analyses of triplicate samples taken from uniform stone substratum of the eleven intensively sampled lakes tended, in all but two cases, to cluster together in order of lake (Chapter 4, Figure 4.5). This indicates that the variability of replicate samples from a lake was less than the variability between lake samples. In addition to this support of the sampling technique employed, the majority of comparable studies undertaken on lake (Verdonschot, 1992) and river (Townsend, Hildrew & Francis, 1983; Harper, 1995) macroinvertebrate assemblages used kick/sweep net sampling also. With regard to the sampling time, 12 seconds provided adequate and manageable abundances and may be regarded as a justifiable sample time from the analysis of variable sample size. Additionally, other work has employed sampling periods of similar durations, for instance Armitage, Pardo & Brown (1995) employed a sampling time of 15 seconds.

3.5.2. Sampling Season

Following an initial increase in the taxa richness of littoral macroinvertebrates at the start of the sampling period and with the exception of declines in October 1996 and March 1997, both taxa richness and abundance appeared to be relatively stable. While different taxonomic orders tended to show similar trends in abundance throughout the year the Hierarchical cluster analysis indicated that spring and autumn samples were similar, while those from summer months were markedly different. Abundance and taxa richness were highest in the summer and it is probable that this is the reason for their differentiation in the cluster analysis. This also identifies this time of the year as being the most useful for sampling as maximum taxonomic richness and abundance provide the highest return of information for monitoring effort. While there was an apparent seasonal effect in the assemblages of macroinvertebrates supported in the lakes, there was also a tendency for samples from a lake to cluster together, indicating that similar macroinvertebrate assemblages were supported within a lake over certain seasons.

3.5.3. Macroinvertebrates and Chemistry

Many associations were apparent between lake chemistry and their macroinvertebrate assemblages. Of these pH, alkalinity, total phosphorus (TP) and total nitrogen (TN) (all related to limitation of productivity of lakes) appeared to be most influential upon littoral macroinvertebrate assemblages. Conductivity too, showed strong relationships with abundance and taxa richness. Being a measure of the ionic concentration of waters, conductivity is indicative of other chemical variables, many of which were also significantly associated with abundance and taxonomic richness.

The lack of replication of macroinvertebrate samples from each sampling period may be viewed as an inherent short coming in this analysis, however, the relative stability of the faunal populations with regard to seasonality, and the correction of any adverse weighting (by using mean log $(x + 1)$ transformed abundances) resulting from using data collected over the course of the sampling period has provided a robust data set, indicated by the reliability of the lake groupings indicated in multivariate analysis. This work aimed to assess the potential of using littoral macroinvertebrates in determining the ecological quality of lakes. To this end it would have been short sighted to rely on data solely from one season as short term temporal and spatial variation in the ecology of a lake has not been determined by prior work. It is therefore acknowledged that from the perspective of the unknown reliability of single samples, macroinvertebrate data may be flawed due to unknown variance. The transformed, mean data that has been employed, however, has the advantage of taking into consideration longer term spatial and temporal stability, producing a more reliable indication of the potential use of macroinvertebrates in assessing ecological quality than replicate samples taken at a single sampling place and time.

pH was indicated as having a large influence upon macroinvertebrate assemblages and had high correlation coefficients with several individual taxa. This is probably a combined result of the influence of physiological differences among macroinvertebrate species, and the auto-correlation between acidity and productivity, as acidic lakes tended to be less productive then the more alkaline lakes.

Auto-correlations between pH and conductivity, total phosphorus and total nitrogen, were apparent. Although it is the net effect of these variables which influence macroinvertebrate communities, the strength of the regression coefficient between abundance and total phosphorus suggests that the concentration of phosphorus is a main driving variable for macroinvertebrate abundance. This may be surmised from the weight of research that has identified phosphorus as the key determinant for lake productivity.

Johnson & Wiederholm (1989) used CCA to determine that of eleven environmental variables, total nitrogen total phosphorus, phytoplankton, temperature, pH, HCO^-_3 and depth were associated with their lake groupings resulting from profundal macroinvertebrate assemblages. Similarly total phosphorus, total nitrogen, and indications of water hardness were indicated as being influential upon the assemblages. As mentioned in the results, dissolved oxygen was correlated with the CCA axis 1 in the opposing direction to the other chemical variables. This may have been as a result of heightened productivity reducing the concentration of oxygen in the more nutrient rich lakes, however, as mentioned in the results, this is merely speculative and in the context of this work this conclusion cannot be certain.

3.5.4. Macroinvertebrates and Physical Environmental Variables

The assessment of linkages between environmental variables and macroinvertebrate assemblages is important as the separation of these influencing factors from organic, or toxic factors is not always acknowledged in riverine biotic scores. Knowledge of assemblage responses to natural variables and the effect of pollution is needed (Rossaro

& Pietrangelo, 1993). Land use is influential upon water chemistry, but with the exception of the extent of unexploited peat bogs and mixed pasture in the catchments the land use was not shown to be correlated with the macroinvertebrate assemblages.
Of the physical environmental variables assessed in association with the macroinvertebrate assemblages, none showed significant correlations to macroinvertebrate abundance of taxa richness. Seven variables, however, were shown to be associated with the assemblages in a CCA. These were shore length, altitude, maximum depth, maximum length, lake volume and lake area, of which several may be considered to be influential upon the physical as opposed to chemical littoral habitat. An increased shore length would provide increased potential for variability in littoral habitat composition, and while a standard substratum was sampled, a greater habitat richness may have resulted in an increase the samples of transitory species.

Owing to the many correlations observed between chemistry, land use, lake size and the macroinvertebrate assemblages, it is not possible to determine which variables are of primary influence, and many of these variables will be inter-linked, indicating both direct and indirect influences upon both invertebrate assemblages. This work has, however, identified that the ecology and environmental variables of a lake are related to a number of features of littoral macroinvertebrate communities and suggests littoral macroinvertebrates as being potentially very useful in assessing the ecological quality of lakes.

3.5.5. Community Classification and Biotic Scores

The application of statistical analysis to calculated parameters such as the biotic scores and metrics in Table 3.6 is of questionable validity (Hellawell, 1986). To assess their potential in determining the trophic and/or ecological state of lakes however, it is also essential that the associations between them and chemical variables were investigated. To reduce the possibility of making a statistical type 1 error (rejecting the null hypothesis when it should be accepted) or, indeed a type 2 error (not rejecting the null hypothesis when, in fact it, it should be rejected), a non-parametric correlation technique was used (i.e. Spearman rank correlation).

As a measure of community structure, percentage of dominant taxa, although somewhat limited in the information that it provides, is easy to determine and may reflect the "balance" of the community. Similarly, estimation of taxa groups, such as the percentage of non-insect taxa and the number of crustacean + molluscs are also easy to determine, and (in contrast to % dominant taxa) produced some significant correlations with chemical variables. *Asellus* abundance was associated with nutrient enrichment, while *Gammarus* abundance was associated with lower levels of nutrients. The nature of the relationship (Figure 3.15) may, however, prove difficult to incorporate into a biotic score.

Macroinvertebrate feeding guilds may also be associated with productivity of lakes, as the food resource will fall into certain categories depending upon the main inputs. Grazers and scrapers would be expected to predominate in waters with high periphytic algal growth that in turn depends on nutrient loading. Shredders, dependent upon coarse particulate organic matter, would be expected in high abundances in areas with well developed macrophyte comminutes, and high allochthonous inputs from terrestrial macrophytes or peat substratum. Collectors (including filterers) rely upon algal crops and fine particulate organic matter in the water column, derived usually from the breakdown of coarse particulate organic matter. Of the feeding guilds examined however, none showed significant correlations with conductivity, total phosphorus, total nitrogen or pH.

Diversity indices describe the taxonomic richness and relative abundances of communities, with high scores often assumed to represent "balanced" communities. In this study, these were not found to be associated with total phosphorus, total nitrogen, conductivity of pH. Neither were the biotic indices which were investigated.

The way in which multivariate analyses techniques have been used is justified by the similarity of the outputs the methods produced. Differences in the groupings are inevitable as the different methods group samples under different criteria. The similarities indicated, however, that both the techniques and the data sets used were robust in nature, and that the divisions were a function of ecological variability as opposed to errors in either the analysis or sampling methods.

3.6. Conclusions

Multivariate analysis of the littoral macroinvertebrate communities of the 28 study lakes suggested 9 distinct groupings of lakes. These groupings are not in all cases indicative of the water chemistry. Low nutrient lakes, highly enriched lakes and acidic lakes were clearly identified, with some 'intermediate' lakes which did not separate out clearly. This is not entirely unexpected owing to the diversity of biotic and abiotic variables that affect macroinvertebrates and the obvious fact that lakes represent continua of conditions. The results suggest that there is potential in using macroinvertebrates and their communities in the classification and monitoring of lake ecological and water quality as there were associations between individual taxa and assemblages, and many of the variables investigated. There is little published work on the potential use of littoral macroinvertebrates in assessing lake ecological quality, Verdonschot (1992) identified different littoral macroinvertebrate assemblages in 10 lakes and Foster *et al.* (1992) used multivariate techniques to classify the aquatic coleopteran assemblages of a large number of Irish surface waters. No attempt was made by Foster *et al.* (1992) to decipher trophic state, and only the types of the water bodies were identified (for example deep rivers, rivers with riffles, puddles, ponds, lakes, bogs and montane flushes). The work of Brodersen, Dall & Lindegraad (1998) comes closest to the work presented here. They sampled littoral macroinvertebrates from 39 Danish lakes and acknowledged the small number of lakes that their work was based upon. This work is at a pioneering stage and the results presented here were also based on relatively few lakes. Further work to include a larger number of lakes and determine some of the autecological responses of littoral invertebrate taxa is recommended.

4. DIFFERENCES IN MACROINVERTEBRATE ASSEMBLAGES AMONG MESO-HABITATS WITHIN LAKES

4.1. Introduction

Since the development of the many biotic indices for assessing river water quality between the 1960s and 1980s a more holistic view of the assessment of ecological quality of rivers has evolved. Methodologies such as the River Habitat Survey, developed by the UK Environment Agency (1996), attempt to assess rivers on a series of characteristics ranging from channel morphology, hydrology, bank side vegetation and variations in substratum material as well as the biotic communities. The rationale behind this approach has been based upon the view that a loss of habitat richness tends to reduce the species richness and diversity of a river (Lewis & Williams, 1984). The assessment of instream habitat richness has become as important as water quality assessment in defining the state of rivers.

The development of these holistic views relates back to fundamental ecological issues. Levin, (1992) stated that "Understanding patterns in terms of the processes that produce them is the essence of science" and this view has achieved strong acclaim from many areas of aquatic ecology (Hildrew, Raffaelli & Giller, 1994). An aspect of this view is that the scale at which patterns are viewed is of great importance (Addicott *et al.*, 1987), as the processes producing the patterns differ with regard to scale. Indeed it must be scale that defines not only patterns but also the scientific investigation of them (Downes Lake & Schreiber, 1993). In many instances, the scale that systems are assessed at is a limiting factor to study. It is therefore important to determine, or at least predict, the scale within which a process occurs in order to investigate patterns produced by the process. In many biological instances, patterns caused by processes tend to be at a greater scale than the process. For instance, a biological process that causes clumping needs to be measured at a spatial scale greater than the scale of individual clumps (Elliott, 1977). This is diagrammatically represented in Figure 4.1.

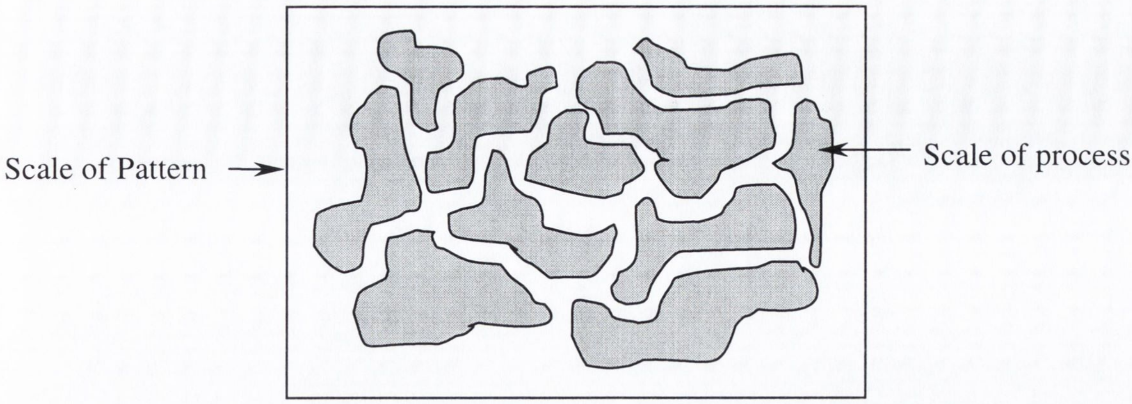

Figure 4.1. A visual description of the relationship between the scale of biological patterns and the processes that cause them.

Allen (1995) considered that different habitats support distinctive macroinvertebrate assemblages influenced by area. The view that increasing areas support increasing species richness is well established and can be explained by the species to area relationship $S = cA^z$ where: S = the number of species; A = area; c = a constant measuring the number of species per unit area and; z = a constant measuring the slope of the line relating S and A (Krebs, 1994). This simply states that as area increases so does species richness. This is a very simplistic, yet effective observation across scales. If a uniform habitat is considered however, the number of species found must at some stage reach a plateau regardless of area, and not until a different habitat is included in the area will the number of species begin to increase again. The relationship is therefore dependent, beyond a certain level, upon the number of habitats included in the sample.

The interaction of the many abiotic and biotic factors present in a water body creates a plethora of habitats at a range of scales. Hildrew & Giller (1994) reviewed work on the spatial and temporal scales of stream habitats and determined five categories. The entire catchment was defined as being in the order of 10^3 m with a persistence of between 10^5 and 10^6 years. In river ecology, segments of the stream were classified with a spatial scale of 10^2 m and temporal scale of between 10^3 and 10^4 years and below this the reach with a spatial scale of 10^1 m and temporally persisting from between 10^1 and 10^2 years. Smaller again was the pool/riffle system on a scale of 10^0 m, and 10^0 and

10^1 years with microhabitats being in the order of 10^{-1} m and persisting for between 10^{-1} and 10^0 years.

A much credited prediction of benthic richness over large geographic areas comes from the River Continuum Concept (Vannote *et al.*, 1980). This predicts that different assemblages of taxa will be found with progression downstream, as the primary food sources change from autochthonous inputs in small tributaries to allochthonous energy sources in larger rivers. Hence taxa richness will increase with progression down stream and therefore with increasing sample area. Foster *et al.* (1992) defined habitats at the macro-scale in terms of different water bodies. They used TWINSPAN to identify ten different types of water body in Ireland based upon assemblages of aquatic Coleoptera (the ten water bodies were: deep rivers; rivers with riffles; puddles; canals and lakes with rich vegetation; ponds and ditches; turloughs; natural minerotrophic fens; base-flushed cutover bogs; peat bogs; and montane flushes). Verdonschot (1992), working in the Netherlands, also identified ten types of open water body by analysing data with Detrended Canonical Correspondence Analysis and Principal Component Analysis. He based the habitat types upon their macroinvertebrate assemblages, defining them as "cenotypes" because of a lack of a definitive boundary between groups and the overlap in the assemblages that they supported. Verdonschot does report however, that the "centroids" (the centre of a cluster of like samples in a detrended canonical correspondence analysis ordination) were characteristic of the ten groups. At a slightly smaller scale, Painter (1999) classified different types of open water found in Wicken Fen (UK) based upon the macroinvertebrate assemblages. Using Coleoptera, Mollusca and Odonata he found clear divisions in the faunal assemblages on two fens, and between large and small water bodies. At the catchment scale the River Continuum Concept (Vannote *et al.,* 1980) proposed the classification of biological responses of rivers in terms of the hydrology and physical responses to the drainage network and its progression downstream and Statzner & Higler (1986) suggested that hydraulic transition zones were important in sectioning stream benthos.

Freshwater fisheries scientists were probably the first to develop the idea of meso-habitats (Bisson *et al.*, 1982; Bovee, 1982; Beschta & Platts, 1986, Harper & Everard, 1998). The classical view of meso-habitats was composed of the pool, riffle and run continuum. The concept has, however, been developed by several authors who have defined meso-habitats much more precisely in terms of substrata material, physical structure, water velocity, faunal assemblages and their regularity along a reach (Armitage, Pardo & Brown, 1995), although the influence of these variables upon faunal assemblages has in fact been realized for some time (Behning 1924; Hynes, 1970a & 1970b).

Table 4.1 lists the meso-habitats defined in the literature by four authors. The meso-habitats at this level of precision were categorized initially from the visual distinctiveness of different areas of the riverbed and substantiated with discrete assemblages of macroinvertebrates (Armitage, Pardo & Brown, 1995; Harper 1995). Harper *et al.* (1995) defined visually distinctive habitats as 'potential' habitats and then, from analysis of the macroinvertebrate assemblages that they supported produced a list of 'functional' habitats. Those with similar assemblages were considered as performing similar biological functions. The distinctiveness of animal assemblages in these studies was identified with standard statistical analysis and multivariate methods.

Table 4.1. Riverine meso-habitats defined in the literature

Brooker (1981)	**Kershner *et al.* (1992)**	**Harper *et al* (1995)**	**Armitage, Pardo & Brown (1995)**
Cascade	Low gradient riffle	Rocks/boulders	*Ranunculus*–fast flow
Riffle	High gradient riffle	Cobbles and pebbles	*Ranunculus*–slow flow
Fast run	Cascade	Gravel	*Nasturtium*
Slow run	Runs	Sand	*Phragmites*
Slack	Glide	Silt	Silt
Pool	Step run	Marginal plants	Sand
Tree roots	Backwater pool	Emergent plants	Gravel–fast flow
Grass roots (*Phalaris*)	Channel confluence pool	Floating-leafed plants	Gravel–slow flow
Ranunculus penicillatus	Corner pool	Submerged broad-leaved plants	
Callitriche spp.	Dam pool	Submerged fine-leaved plants	
Potamogeton natans	Edge water	Mosses	
	Main channel pool	Macroalgae	
	Lateral scour pool	Leaf litter	
	Plunge pool	Woody debris	
	Trench pool	Tree roots	
		Trailing vegetation	

The scale of meso-habitat is convenient for studying differences in macroinvertebrate assemblages within a lake for many reasons. Biological patterns can only be apparent at a scale above the processes that are creating them and the littoral zone of a lake can be viewed as a mosaic of different substrata or meso-habitats. Meso-habitats are nested within the littoral zone of a lake. Tokeshi (1994) stated that the relative ease of taking replicate samples on a patch basis and the different kinds of patchiness available for examination offer practical advantages for studying freshwater communities. It follows that if meso-habitats are viewed as habitat patches they make an ideal unit for studying differences in macroinvertebrate assemblages around the littoral zone of lakes.

The structure of the littoral zone along most lake shores is structurally heterogeneous. This was recognized as long ago as 1918 when Henry Baldwin and George Whipple stated that "Lakes present an infinite variety of physical features, rocky, sandy, swampy margins, in steep and shallow shores, in regular and broken contours." Variations in meso-habitats and macroinvertebrate assemblages, similar to those found along rivers, could be present along the littoral zone of lakes.

4.2. Methods

To investigate potential differences in macroinvertebrate assemblages around the littoral zone of lakes, three series of samples were collected. All samples were collected using a kick/sweep net with a frame of 0.25 x 0.25 m and 1 mm mesh. The net was trawled, with an 'S' type movement, behind feet kicking the substrata for twelve seconds, covering a distance of approximately one meter and in water no deeper than 0.5 m. In all instances, macroinvertebrate samples were preserved in the field in 70% Industrial Methylated Spirits (IMS) and returned to the lab for sorting and identification to the furthest practicable taxonomic level.

The first set of samples were collected during March of 1997. Triplicate samples were taken from predominantly cobble and/or pebble substratum in the eleven intensively studied lakes (Table 2.1). These were taken to investigate if variations in the macroinvertebrate assemblages in a standard, uniform substratum within a lake were greater than variations among lakes and to further investigate the reliability of the standard sampling method in providing an indicative collection of fauna in a uniform substrata. Data are presented in Appendix 1.1 to 1.29.

In September 1996, samples were collected from macrophyte covered and mineral (cobble and/or pebble) substrata from lakes where the two broadly contrasting meso-habitats occurred. Macrophyte stands were easily accessible in 21 of the 29 sample lakes (listed in Table 4.3). This was viewed as being a useful initial step in determining if there were variations in assemblages between different substrata both within and among lakes, as extreme quantitative and qualitative differences in macroinvertebrate communities are found in streams with and without macrophyte growth (Armitage, Pardo & Brown, 1995; Harper, Smith & Barham, 1992; Harper *et al.,* 1995). Taxonomic lists and abundances from the submerged macrophyte samples are shown in Appendix 1.1 to 1.29.

In September 1998, 15 areas of discrete substrata were sampled in Lough Inchiquin. These were identified visually from the shoreline (according to Armitage Pardo & Brown, 1995; Harper, Smith & Barham, 1992), and are listed in Table 4.2. These emulate the meso-habitat concept which has been employed in river studies to determine habitat diversity as described in Chapter 1 (Section 1.6). Each appeared to be visually different from the others with regard to the characteristics of the substrata and the macrophyte community. Substrata particles were categorized by size class (silt < 0.06 mm; sand 0.06 – 4 mm; gravel 4 – 75 mm and cobbles 75 – 300 mm diameter) and the approximate percentage composition of each visually estimated by two independent recorders (Gordon, McMahon & Finlayson, 1992). Macrophyte species were recorded and their density classified into categories of dense, mid-density and sparse. The characteristics of communities were recorded as either filamentous or non-filamentous depending upon leaf structure and the presence of algae was also recorded. During analysis, the abbreviations given in Table 4.2 were used and only the dominant characteristics of the meso-habitat types referred to.

Five replicate macroinvertebrate samples were collected using the standard sampling method, from random points within each meso-habitat. Disturbance of the meso-habitats was kept to a minimum while sampling was undertaken to prevent disruption of areas that were to provide further replicates. Owing to the high animal abundances in samples, they were subsampled prior to sorting. Samples were suspended in four litres of water and three subsamples of 333 ml were sorted to give a total of one quarter of the sample. Abundances were multiplied up to be representative of the whole sample. The remaining three-quarters of the sample were scanned for taxonomic groups that had not been found in the sorted quarter. Taxonomic lists and abundances of macroinvertebrates are given in Appendix 3.

Table 4.2. Visually discrete meso-habitats sampled in Lough Inchiquin in September 1997.

Code	Abbreviation	Habitat description
A	Stone & *Fontinalis*	Pebbles 30%, cobbles 20%, sand 50% & *Fontinalis* (mid-density).
B	Sand & CPOM	Sand & coarse particulate organic matter, sheltered.
C	Boulders & stone	Boulders 20%, cobbles 40%, pebbles 40% & mares tails *(Hippuris vulgaris)* (sparse).
D	Sand & *Littorella*	Sand 60% cobbles 5% & pebbles 15% & *Littorella uniflora,* (mid-density) sheltered by *Phragmites.*
E	Stone & *Littorella.*	Cobble 40%, pebbles 20% & *Littorella uniflora* (mid-density), + other submerged macrophytes (sparse).
F	*Cladophora* & pebbles	*Cladophora* covering pebbles.
G	*Cladophora* & marl	*Cladophora* covering marl & sand.
H	*Phragmites* & sand	Base of *Phragmites* (sparse), algae (sparse) & sand 80%.
I	*Lemna* & grass spp.	*Lemna trisulca* (mid-density) & grass spp. (dense).
J	Cobbles & boulders	Cobbles 60%, boulders 20%, schist 20%, *Fontinalis antipyretica* & *Potamogeton* spp. (sparse).
K	Dense filamentous macrophytes	Filamentous macrophytes, (dense) *Zannichellia palustris* and *Fontinalis antipyretica* covering pebble & marl.
L	Dense non-filamentous macrophytes	Non-filamentous vegetation (dense), *Hippuris vulgaris, Marsupella emarginata* & (?) *Stragnalisor platycarpa*
M	Cobbles & pebbles	Cobbles 60%, pebbles 30% & marl 10%
N	Sand & *Isoetes*	Sand 80% & calcium carbonate covering *Isoetes lacustris*
O	Sand & marl	Sand 80%, marl, coarse particulate organic matter, *Fontinalis antipyretica* & *Elodea canadensis* (sparse)

4.3. Results

4.3.1. Triplicate Samples

There were variations in the mean taxonomic richness (Figure 4.2) and abundance (Figure 4.3) of macroinvertebrates found among the eleven lakes where triplicate samples were collected from predominantly cobble and/or pebble substrata. Differences within lakes were also apparent, but less extreme. Figure 4.4 shows the mean abundances of macroinvertebrates at the taxonomic level of order in the eleven lakes. There are clear differences between the assemblages in each lake. Lough Dan had a very high proportion of Ephemeroptera (all of these were *Leptophlebia vespertina*). Lough Lene had the highest number of Amphipoda (both *Gammarus duebeni* and *Gammarus lacustris* were present) and Lough Owel had a very large abundance of Oligochaeta.

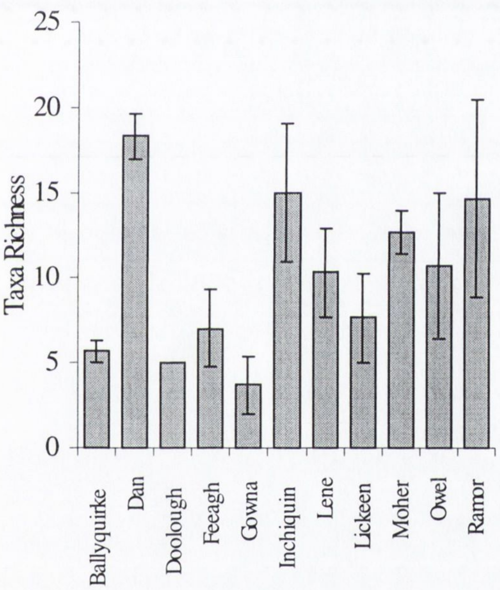

Figure 4.2. Mean taxa richness of replicate samples taken from 11 lakes. Error bars are 95% are *c.l.* ($n = 3$).

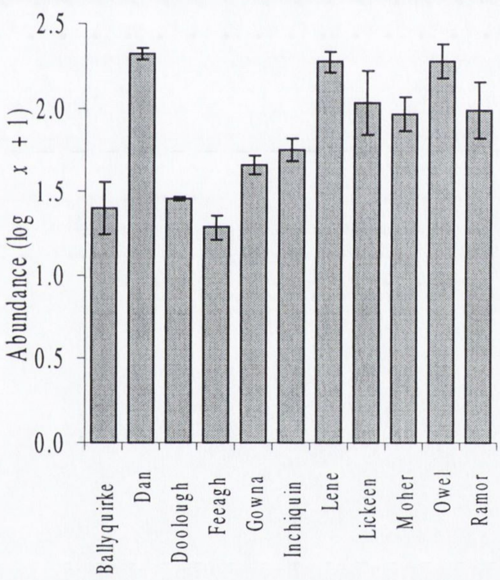

Figure 4.3. Mean abundance of replicate samples taken from 11 lakes Error bars are 95% *c.l.* ($n = 3$).

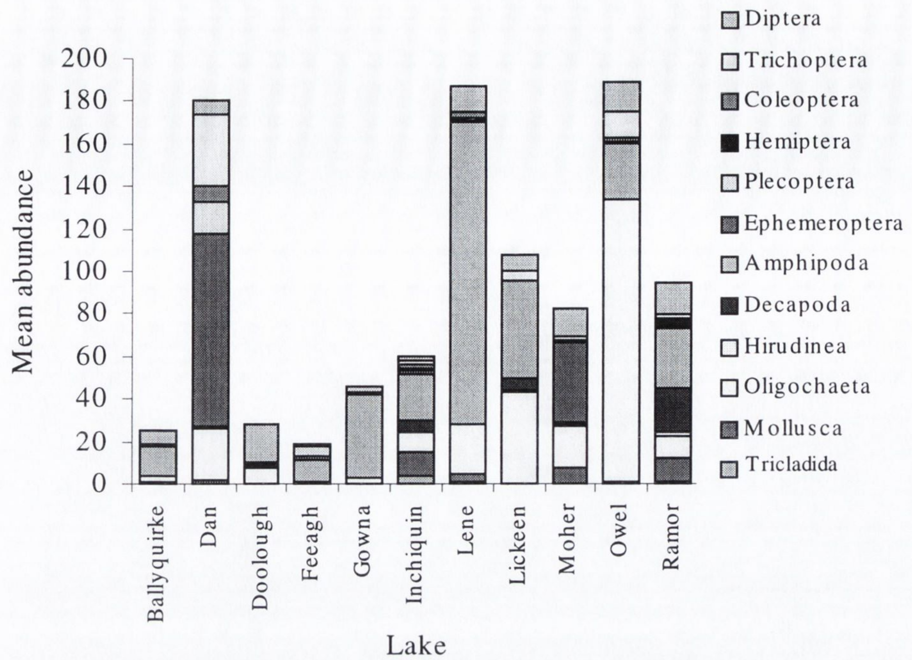

Figure 4.4. Mean abundance of macroinvertebrate orders found in samples from eleven lakes ($n = 3$).

Hierarchical cluster analysis (Figure 4.5) placed the triplicate samples together for all but two lakes (one sample from Lough Lickeen was separated from the other two, as was one sample from Lough Ramor). Multidimensional scaling analysis (Manly, 1986; Kruskal & Wish, 1978) (Figure 4.6) also placed the triplicate samples together or in close proximity in almost all cases. This indicates that in the majority of cases, the three samples from a lake were similar and that the variation in macroinvertebrate assemblages was greater between lakes than it was within a uniform substratum of a lake.

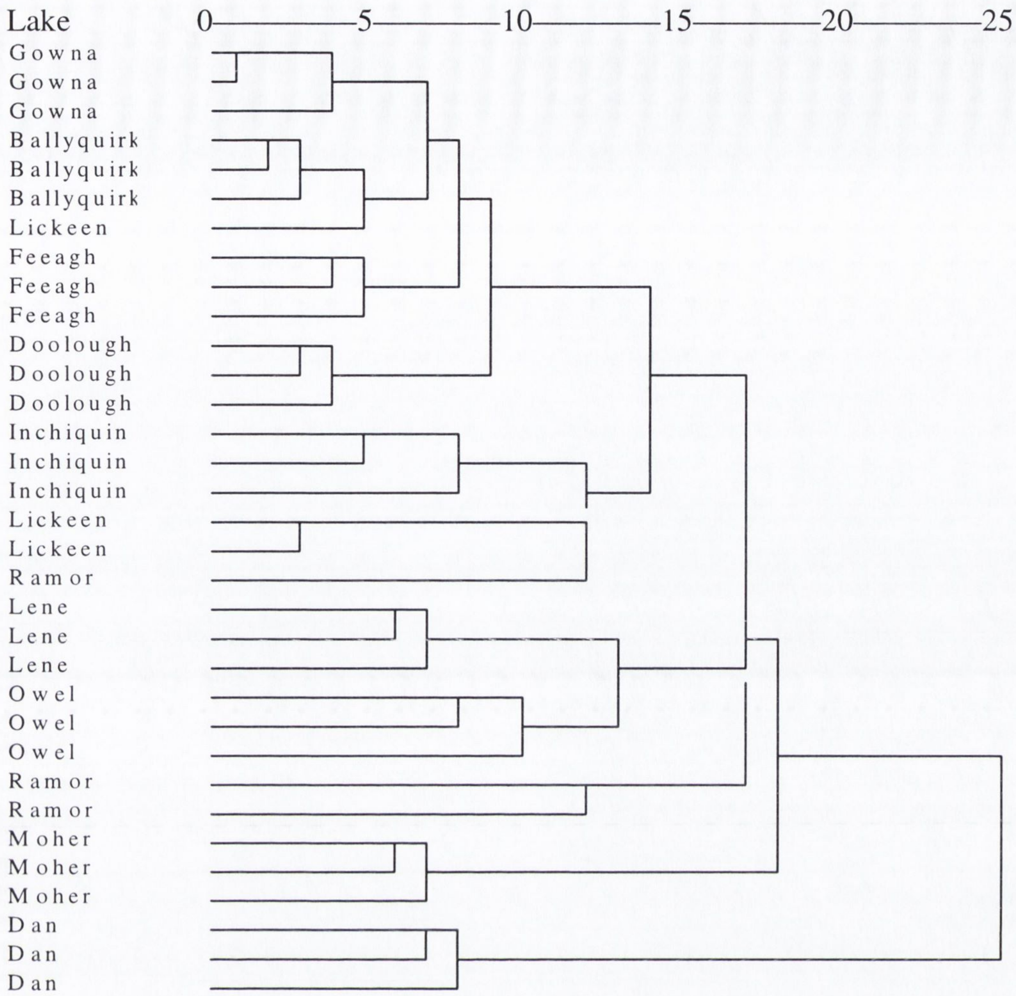

Figure 4.5. Hierarchical cluster analysis of the triplicate samples taken from the eleven intensively studied lakes in March 1997. (Average Euclidean distances between groups) ($n = 33$).

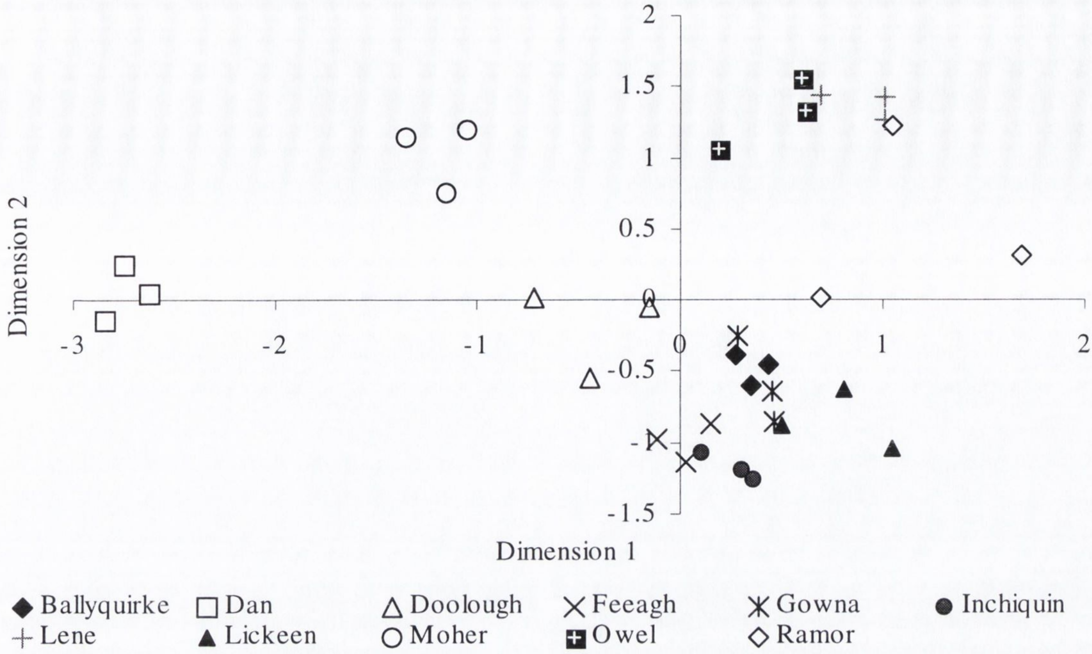

Figure 4.6. Multidimensional Scaling plot of the triplicate samples taken from the eleven intensively studied lakes in March 1997. (Average Euclidean distances between groups) (n = 33).

4.3.2. Macroinvertebrate Samples from Mineral and Macrophyte Covered Substrata from 21 Lakes

Table 4.3 lists the 21 lakes from which macroinvertebrate samples were collected from predominantly mineral and macrophyte substrata and their taxa richness and abundances. Taxa richness data is shown graphically in Figure 4.7 and transformed ($\log x + 1$) abundance data in Figure 4.8.

Overall, there were no significant differences between habitats in terms of abundance or taxa richness (paired two sample t-test, $P > 0.05$ with 20 df.), although there were clearly some localized exceptions to the general trend. Difference in abundance between the two habitats of > 130 animals were found in Lough Ballycullinan, Lough Oughter, Lough Graney, Lough Doolough and Lough Dromore. Differences in taxon richness of > 5 taxa were found in Lough Owel, Lough Egish, Lough Ballycullinan and Lough Dromore.

Table 4.3. The 21 lakes from which macroinvertebrate samples from mineral and macrophyte covered substrata were collected and their respective taxa richness and abundances.

Lake	Taxa Richness/sample		Abundance/sample	
	Mineral	Macrophyte	Mineral	Macrophyte
Inchiquin	26	27	555	576
Owel	16	26	405	486
Egish	20	25	703	980
Ballycullinan	13	23	83	450
Gara South	20	21	141	228
Moher	24	20	148	149
Muckno	16	19	367	174
Dan	19	19	194	121
Ramor	19	18	316	450
Lene	17	17	317	244
Ballyquirke	18	17	126	190
Rea	12	16	42	41
Oughter	11	15	207	592
Graney	18	14	199	65
Mullagh	17	13	913	313
Bray	9	11	200	187
Doolough	9	10	33	100
Lickeen	10	9	168	278
Gowna	9	8	168	243
Dromore	28	7	671	135
Maumwee	7	7	61	34

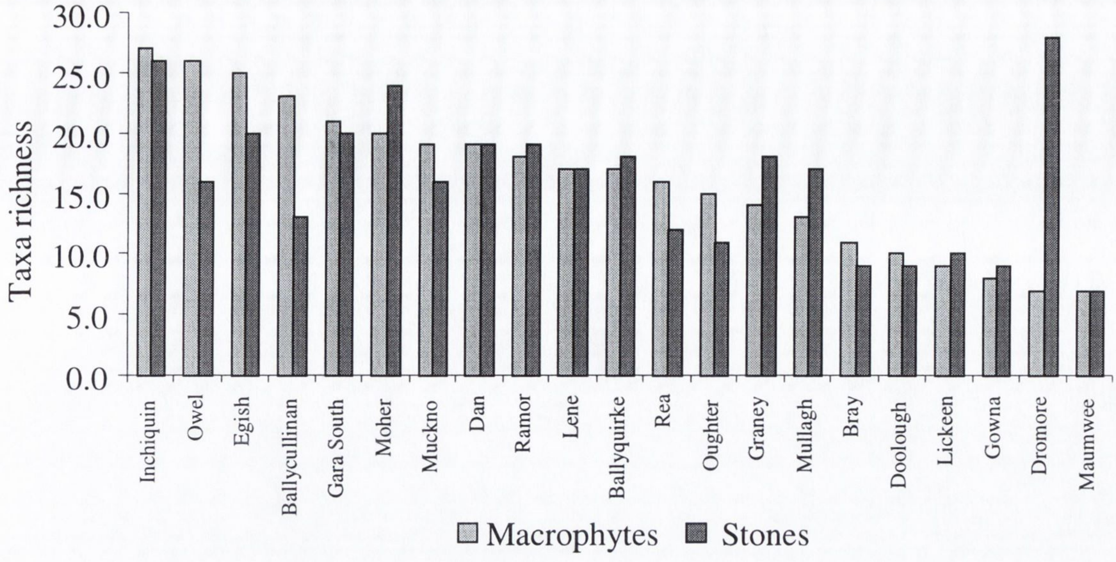

Figure 4.7. Macroinvertebrate taxa richness per sample found in macrophyte and stone (mineral) covered littoral areas of 21 lakes

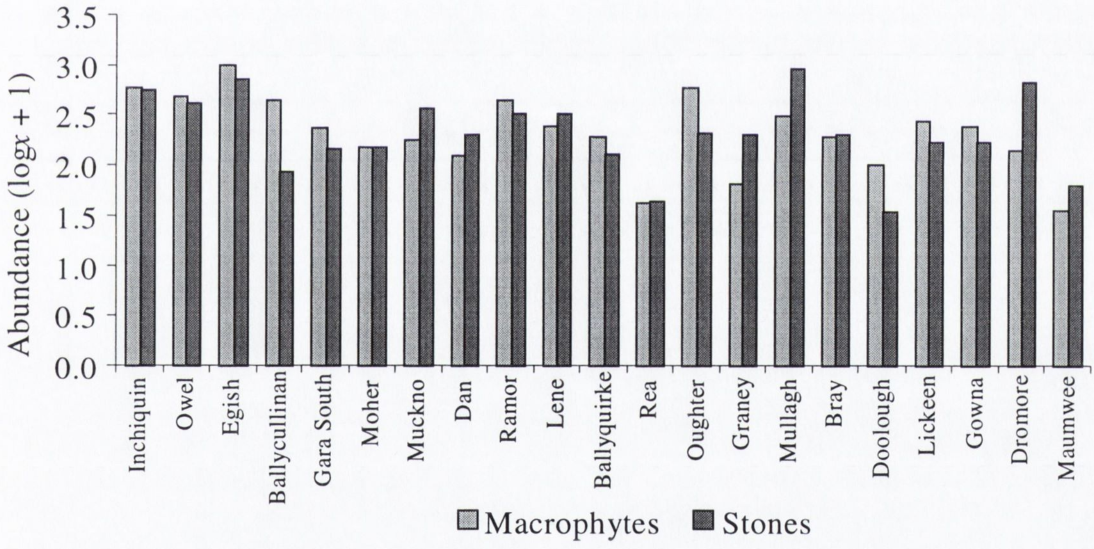

Figure 4.8. Abundance of macroinvertebrates per sample (log x + 1) found in macrophyte and stone (mineral) covered littoral areas of 21 lakes.

To examine the assemblages further and to investigate intra sample similarities, an Hierarchical cluster analysis was performed on log (x + 1) transformed data (to correct for any disproportionate sample variation potentially introduced by using a standard sampling procedure in dissimilar substrata in a number of lakes) (Figure 4.9). In eleven instances, the two samples from a particular lake were clustered together. This is firstly apparent for samples that were separated early on in the divisions. Located at the bottom of the dendrogram the two samples from Egish and the two from Dromore were placed next to one another. Just above these, the two samples from Inchiquin were placed next to each other. At the top of Figure 4.9, the samples from Loughs Bray, Dan and Mullagh were positioned together, and just below these the two samples from Lough Lene. Other samples from the same lake that were placed together include those from Loughs Moher, Graney, Maumwee and Rea. Although they were not placed side by side, samples from Loughs Oughter and Ballyquirke were not divided until the eighth level and those from Doolough until the seventh level. Six pairs of samples were divided before the tenth level (these were samples from: Lough Ballycullinan that were divided at level 23; Lough Owel, at level 18; Lough Muckno, at level 16; Lough Gowna, at level 10; Lough Gara south at level 13 and Lough Lickeen at level 10). Despite these, the majority of divisions imply that the differences in assemblages between lakes were greater than the differences between the habitats within lakes.

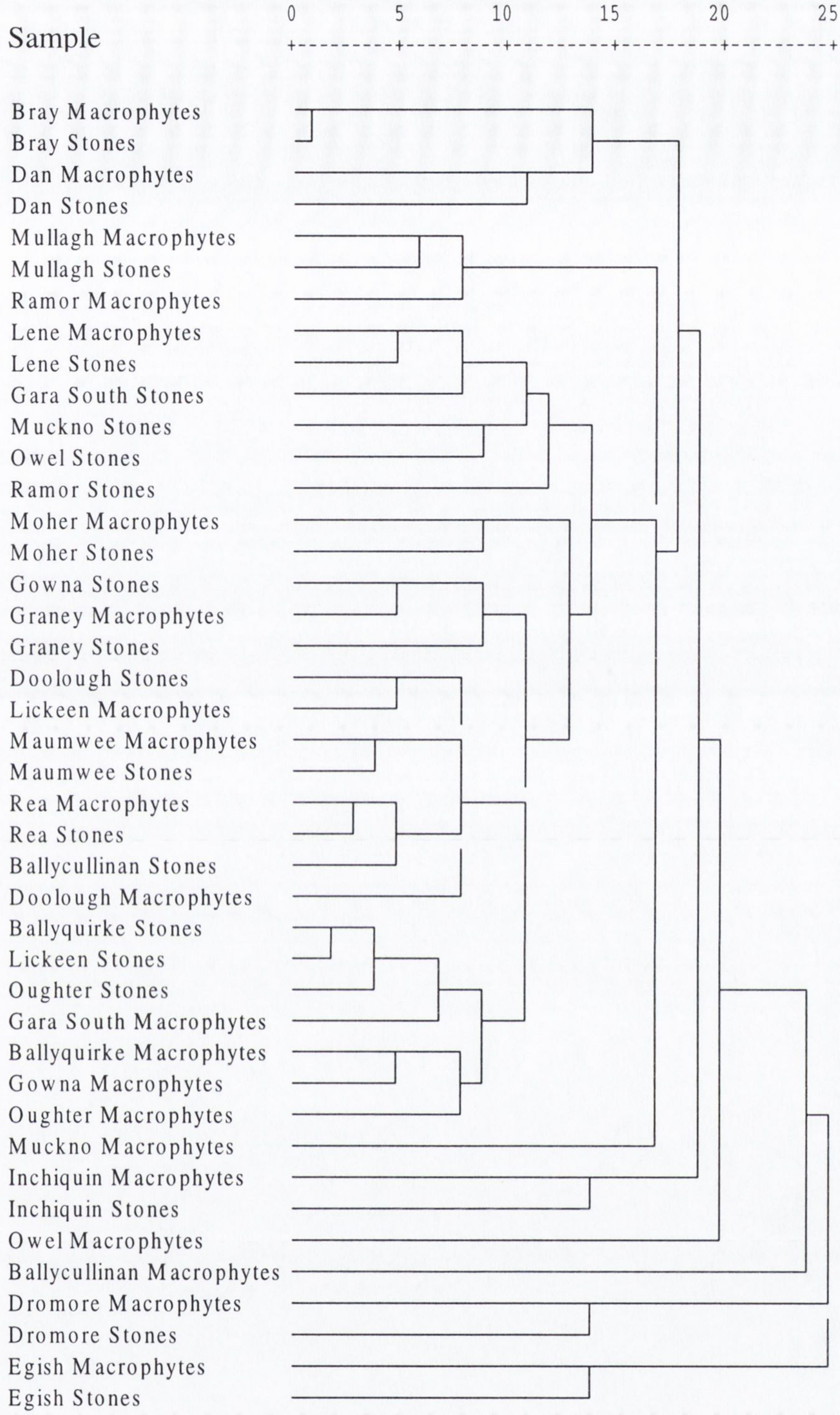

Figure 4.9. Hierarchical cluster analysis of the complimentary macrophyte and inorganic substrate samples (log (x +1) transformed) taken from 21 lakes in September 1996. (Average Euclidean distance between groups) (n = 42).

4.3.3. Replicate Macroinvertebrate Samples from Fifteen Meso-Habitats Found in Lough Inchiquin.

The meso-habitats that were sampled in Lough Inchiquin are listed and described in Table 4.2. Figure 4.10 a) shows the distribution of abundance data for the 75 samples, Figure 4.10 b) the distribution of the log $(x + 1)$ transformed abundance data and Figure 4.10 c) the distribution of the taxa richness data. Before transformation abundance data had a mean of 1463 ± 211 (95% *c.l.*), a median of 1276, $s = 931.2$, $s^2 = 867146$ and a skewness value of 1.73. After transformation, mean = 3.09 ± 0.01 (95% *c.l.*), median = 3.11, $s = 0.27$, $s^2 = 0.07$ and skewness was - 0.30. For tax richness mean = 25.47 ± 1.37 (95% *c.l.*), median = 25, $s = 6.05$, $s^2 = 36.66$ and skewness = - 0.45. In total 112 discernable taxonomic groups were identified in the lake, mostly to species.

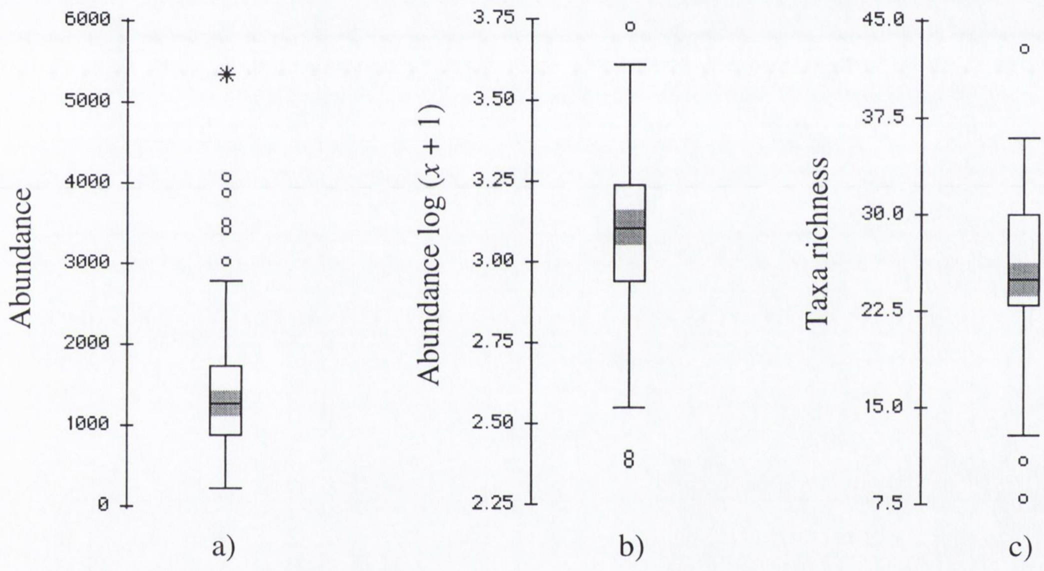

Figure 4.10. The distribution of abundance data: a) before and; b) after log $(x + 1)$ transformation; c) Taxa richness data distribution. For data from the 75 meso-habitat samples collected from Lough Inchiquin. (Centre line = mean, shaded area = 95% *c.l.*, box = upper and lower quartiles, whiskers = main body of data, o = outliers, * = extreme outliers).

Table 4.4, shows the mean macroinvertebrate abundance and taxa richness of the 15 meso-habitats, these values are graphically portrayed in Figure 4.11 and 4.12 respectively. Mean abundance was greatest in *Cladophora* & marl (habitat G) and least in sand & marl (habitat O) while mean taxa richness was greatest in stone & *Fontinalis* (habitat A) and least in sand & coarse particulate organic matter (CPOM) (habitat B).

Table 4.4. Mean macroinvertebrate taxa richness and abundance of the 15 sampled meso-habitats (± 95% *c.l.*, *n* = 5).

Meso-habitat		Taxa richness	Abundance
Code	**Abbreviation**	**Mean ± 95% *c.l.***	**Mean ± 95% *c.l.***
A	Stone & *Fontinalis*	31.4 ± 6.12	1518.0 ± 369.8
B	Sand & CPOM	14.2 ± 4.18	503.8 ± 204.9
C	Boulders & stone	23.8 ± 1.69	1291.0 ± 176.9
D	Sand & *Littorella*	25.2 ± 3.42	1291.8 ± 246.1
E	Stone & *Littorella.*	24.4 ± 1.33	1063.6 ± 167.2
F	*Cladophora* & pebbles	26.0 ± 2.56	1631.8 ± 336.6
G	*Cladophora* & marl	28.0 ± 5.22	4053.6 ± 680.2
H	*Phragmites* & sand	29.4 ± 2.11	2170.8 ± 578.6
I	*Lemna* & grasses	27.6 ± 5.02	862.6 ± 449.2
J	Cobbles & boulders	29.0 ± 2.06	1157.4 ± 190.9
K	Dense filamentous macrophytes.	30.2 ± 1.57	1963.0 ± 668.1
L	Dense non-filamentous macrophytes	26.8 ± 1.57	1652.2 ± 377.2
M	Cobbles & pebbles	23.6 ± 3.37	894.0 ± 148.7
N	Sand & *Isoetes*	27.8 ± 4.27	1460.8 ± 413.0
O	Sand & marl	14.6 ± 2.29	438.6 ± 131.3

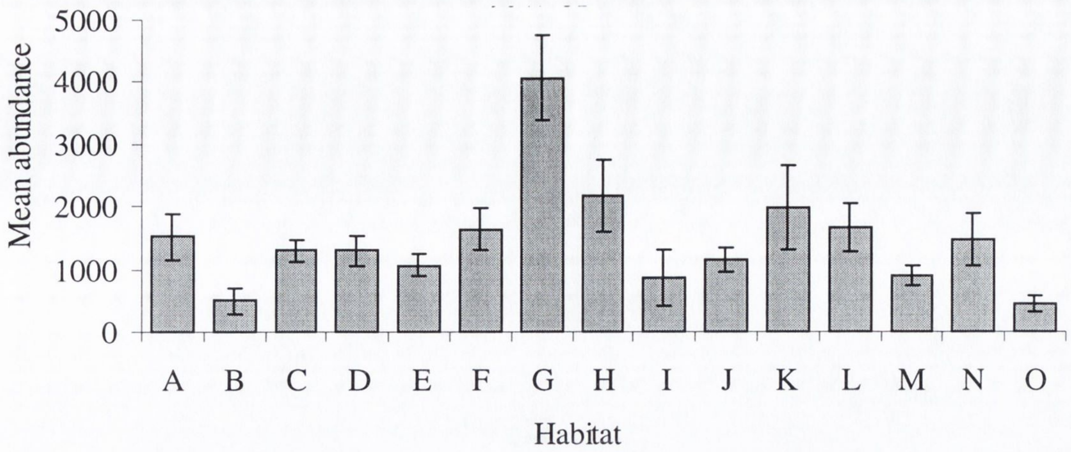

Figure 4.11. Macroinvertebrate abundance of the 15 sampled meso-habitats. (Error bars are 95% *c.l.*, $n = 5$).

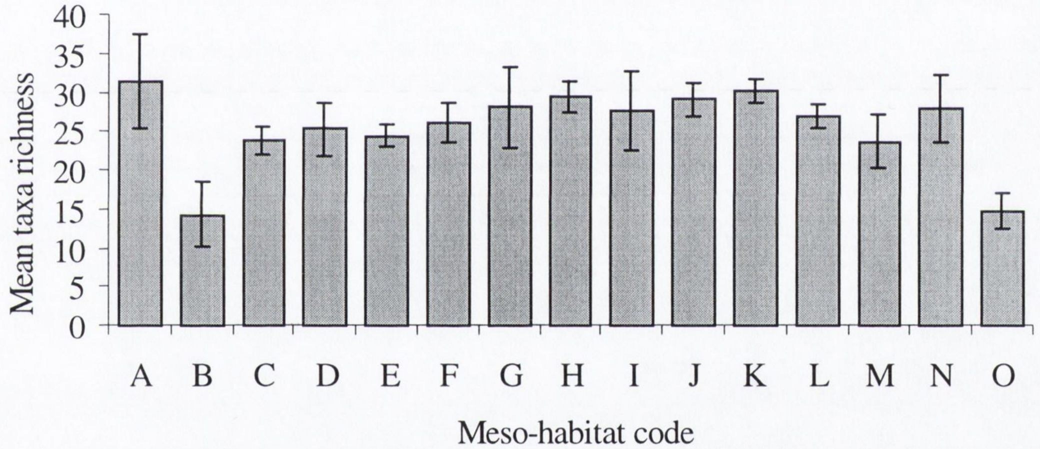

Figure 4.12. Macroinvertebrate taxa richness of the 15 sampled meso-habitats. (Error bars are 95% *c.l.*, $n = 5$).

Analysis of variance showed statistically significant differences among both the mean log $(x + 1)$ transformed macroinvertebrate abundances ($F_{14,60} = 16.63$, $P < 0.001$) and among the mean taxa richness ($F_{14,60} = 8.23$, $P < 0.001$) of the meso-habitats. A Post Hock LSD test showed that there were significant differences between the mean log $(x + 1)$ abundance of most of the meso-habitats.

In only 13 of the comparisons were the abundances of two habitats not significantly different. These are indicated in Table 4.5. Areas of stone & *Fontinalis* contained similar abundances to areas of *Cladophora* & pebble, dense macrophytes and sand & *Isoetes*. Areas of sand covered by CPOM supported similar abundances to sand & marl areas, and abundance in boulders & stones was similar to that of sand & *Littorella,* cobble & boulders, and sand & *Isoetes.* Habitats comprising of sand & *Littorella,* cobble & boulders and sand & *Isoetes* contained similar abundances, as did habitats of stone & *Littorella* and cobble & boulders. Areas of *Cladophora* & pebbles and dense macrophytes contained similar abundances as did *Phragmites* & sand and filamentous macrophytes. *Lemna* & grass species and cobble & pebble also supported abundances that were not significantly different.

The majority of habitats also supported significantly different numbers of taxa. Table 4.5 shows that in only 25 of the 105 comparisons of taxa richness among habitats were significant differences not found. All meso-habitats were shown to have a similar taxa richness with at least one other meso-habitat. Sand & *Littorella*, *Cladophora* & marl, *Lemna* & grass spp. and dense macrophytes showed the highest number of similar abundances, each being similar to five other meso-habitats. In most instances the similarities were expected, for instance sand & *Littorella* areas had a similar taxa richness to areas of stone & *Littorella*, *Cladophora* & pebbles and dense macrophytes, all containing plant growth of some form. Other meso-habitats also had a similar taxa richness to sand & *Littorella*; these were cobbles & pebbles, and boulders & stone areas. While there would appear to be no obvious similarities in the structure of these habitats reference back to the complete descriptions of the habitats (Table 3.1) showed that there were some similarities in physical structure, as the sand & *Littorella* area did contain a low proportion of cobbles and pebbles.

It is, however, important that these differences are not an indication of the identity of taxonomic groups, only the number of taxonomic groups, and so very different assemblages may have been present even though the taxa richness was similar. To investigate differences in the assemblages with regard to taxa and their abundances, multivariate analysis was employed.

Table 4.5. Post hoc Least Squared Difference probabilities for taxa richness (top right of the Table) and log (x + 1) abundance (bottom left) contained in samples from the 15 meso-habitats (significantly different at * = $P < 0.05$ and ** = $P < 0.01$). Values in bold indicate instances where significant differences were not found.

4.3.4. Taxa richness

Abundance (log x + 1)	A Stone & *Font*	B Sand & CPOM	C Bould. & Stone	D Sand & *Litt.*	E Stone & Litt.	F Clad. & Pebb.	G *Clad.* & Marl	H *Phrag.* & Sand	I *Lemna* & Grass	J Cobb. & Bold.	K Fill Macro.	L Dense Macro.	M Cobb. & Pebb.	N Sand & *Isoetes*	O Sand & Marl
A Stone & *Font*		-17.2**	-7.6**	-6.2**	-7.0**	-5.4**	-3.4*	-2.0*	-3.8*	-2.4*	**-1.2**	-4.6**	-7.8**	-3.6*	-16.8**
B Sand & CPOM	-0.5**		9.6**	11.0**	10.2**	11.8**	13.8**	15.2**	13.4**	14.8**	16**	12.6**	9.4**	13.6**	**0.4**
C Bould. & Stone	-0.06*	0.44**		**1.4**	**0.6**	2.2*	4.2**	5.6**	3.8*	5.2**	6.4**	3.0*	**-0.2**	4.0*	-9.2**
D Sand & *Litt.*	-0.07*	0.43**	**-0.01**		**-0.8**	**0.8**	2.8*	4.2**	2.4*	3.8*	5.0**	**1.6**	**-1.6**	2.6*	-10.6**
E Stone & *Litt.*	-0.14**	0.36**	-0.08*	-0.08*		**1.6**	3.6*	5.0**	3.2*	4.6**	5.8**	2.4*	**-0.8**	3.4*	-9.8**
F *Clad.* & Pebb.	**0.03**	0.53**	0.09*	0.10*	0.17**		2.0*	3.4*	**1.6**	3.0*	4.2**	**0.8**	-2.4*	1.8*	-11.4**
G *Clad.* & Marl	0.43**	0.93**	0.49**	0.49**	0.57**	0.40**		**1.4**	**-0.4**	**1.0**	2.2*	**-1.2**	-4.4**	**-0.2**	-13.4**
H *Phrag.* & Sand	0.15**	0.65**	0.21**	0.21**	0.29**	0.12*	-0.28**		-1.8*	**-0.4**	**0.8**	-2.6*	-5.8**	-1.6	-14.8**
I *Lemna* & Grass	-0.28**	0.22**	-0.22**	-0.22**	-0.14*	-0.31**	-0.71**	-0.43**		**1.4**	2.6*	**-0.8**	-4.0*	**0.2**	-13**
J Cobb. & Bold.	-0.11*	0.39**	**-0.05**	**-0.05**	**0.03**	-0.14**	-0.54**	-0.26**	0.17**		**1.2**	-2.2*	-5.4**	-1.2	-14.4**
K Fill Macro.	0.09*	0.59**	0.15**	0.16**	0.24**	0.06*	-0.33**	**-0.05**	0.38**	0.21**		-3.4*	-6.6**	-2.4*	-15.6**
L Dense Macro.	**0.04**	0.54**	0.10*	0.10*	0.18**	**0.01**	-0.39**	-0.11*	0.32**	0.15**	-0.056*		-3.2*	**1.0**	-12.2**
M Cobb. & Pebb.	-0.226**	0.27**	-0.17**	-0.16**	-0.08*	-0.26**	-0.65**	-0.37**	**0.06**	-0.11*	-0.32**	-0.26**		4.2**	-9.0**
N Sand & *Isoetes*	**-0.028**	0.47**	**0.03**	**0.04**	0.11*	-0.06*	-0.46**	-0.17**	0.25**	0.09*	-0.12*	-0.06*	0.20**		-13.2**
O Sand & Marl	-0.544**	**-0.04**	-0.48**	-0.48**	-0.40**	-0.57**	-0.97**	-0.69**	-0.26**	-0.43**	-0.64**	-0.58**	-0.32**	-0.52**	

TWINSPAN produced fourteen distinct groups (Figure 4.13). In the majority of cases replicate samples remained together or were grouped with samples from similarly structured substrata. The only instances where at least four replicate samples did not remain together were samples from *Phragmites* & sand, and sand & *Isoetes* (H and N respectively).

The first division split 35 samples from primarily vegetative from the 40 non-vegetative substrata samples. The five samples from pebbles, cobbles & sand with *Fontinalis* (Samples A 1-5) were split from the remaining non-vegetative samples at the second division of the predominantly mineral substrata. The net spinning trichopteran *Holocentropus dubius* were present in the majority of these samples. Samples containing CPOM (O 1-5 and B 2-5) then split from primarily inorganic substrata samples. These two CPOM habitat types were then divided neatly. The gastropod *Viviparus fasciatus* was found in many of the CPOM, *Fontinalis antipyretica* and *Elodea canadensis* samples (O 1-5).

The remaining 26 samples consisted primarily of boulders, cobbles, pebbles, sand and marl, and most contained specimens of the caseless trichopteran *Tinodes waeneri*. From these samples, M 1-5, consisting of cobbles, pebbles and marl (60%, 30% and 10% respectively) were separated along with sample B 1. The remaining samples containing large inorganic substrata tended to support both the coleopteran *Haliplus confinis* and the case bearing trichopteran *Sericostoma personatum.* Samples J 1-5 (cobbles, boulders, schist and some *Fontinalis antipyretica* and *Potamogeton* species) were then split. These contained large abundances of the gastropod *Valvata macrostoma* and the trichopteran of the Family Leptoceridae, *Mystacides longicornis.*

Of the remaining 15 samples, E 1-5 were clustered together (cobbles, 40%, pebbles, 20% and some *Littorella uniflora*). These contained appreciable numbers of the flatworm *Dugesia polychora.* Meanwhile samples C 1-5 (boulders, 20%, cobbles, 40%, pebbles, 40% and some *Hippuris vulgaris*) and D 1-5 (cobbles, 10%, pebbles, 10%, sand, 80% and some *Littorella uniflora*) were grouped together and contained in a distinctive, although reduced abundance from the previous division, the gastropod *Valvata macrostoma.*

The 35 samples that were divided to the right at the first division consisted primarily of macrophyte habitats. K 1-5 (dense aggregations of filamentous macrophytes) and L 1-5 (dense aggregations non-filamentous macrophytes) were separated from 25 samples containing *Cladophora* algae and reeds. The majority of samples from habitats K and L contained the snail *Physa fontinalis* in relatively high abundances.

Samples from dense vegetation were grouped together after they were separated from two samples of sand with low densities of *Isoetes lacustris* (N 1 & 5) at division *101. Samples containing *Cladophora* were clustered together and then separated depending upon the underlying substrata (*Cladophora* on pebbles and *Cladophora* on marl and sand). Samples G 2, H 3-5 and N 2-4 were grouped together, all of which were from habitats with sand and sparse vegetation.

DECORANA axis 1 and 2 (Figure 4.14) indicated seven distinct clusters. Of these, five were similar to the groups indicated by TWINSPAN. These were the clusters of samples 0 1-4 (sand 80%, marl 20% CPOM with some *Fontinalis antipyretica* & *Elodea canadensis*; G1 & 3-5 (*Cladophora* on marl & sand); I 1-5 and H1 (dense vegetation); M1-5 (cobbles, 60%, pebbles, 30% & marl 10%) and; A 1-5 (*Fontinalis* on pebbles, 30%, cobbles, 20% & sand 50%). The remaining two clusters showed a division between habitats consisting primarily of macrophyte covered substrata and mineral substrata, similar to the initial division made in the TWINSPAN.

Axis 1 and 3 from DECORANA (Figure 4.15) also showed clusters similar to groups indicated by TWINSPAN, although a greater degree of division was apparent than in the plot of axis 1 and 2. Samples from habitats predominating in macrophytes were plotted to the left of the graph and mineral substrata to the right. Furthest to the right all samples from *Fontinalis* covering pebbles, cobbles & sand (A) were again clustered together. Samples from sand 80%, marl 20%, CPOM with low densities of *Fontinalis* & *Elodea* (O 1-4) were also grouped together. Between these two groups were plotted samples from cobbles, pebbles & marl (M1, 2, 4 and 5). The central cluster contained the majority of samples from inorganic substrata (habitats C, D, E and J) and indicated that these samples contained relatively similar macroinvertebrate assemblages. DECORANA axis 2 and 3 together did not show any coherent patterns in the data.

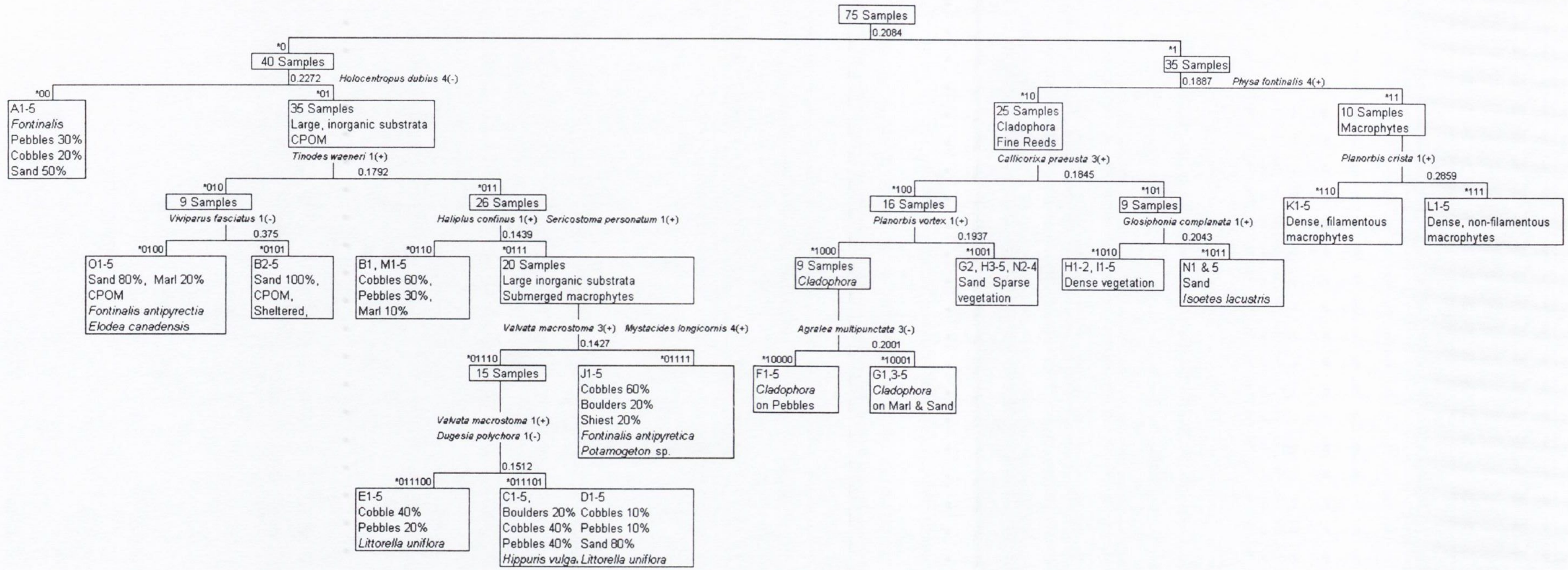

Figure 4.13. TWINSPAN diagram of the five replicate samples from 15 meso-habitats found in Lough Inchiquin. (See Table 4.4 for brief descriptions of the habitats and Table 2.4 for detailed descriptions).

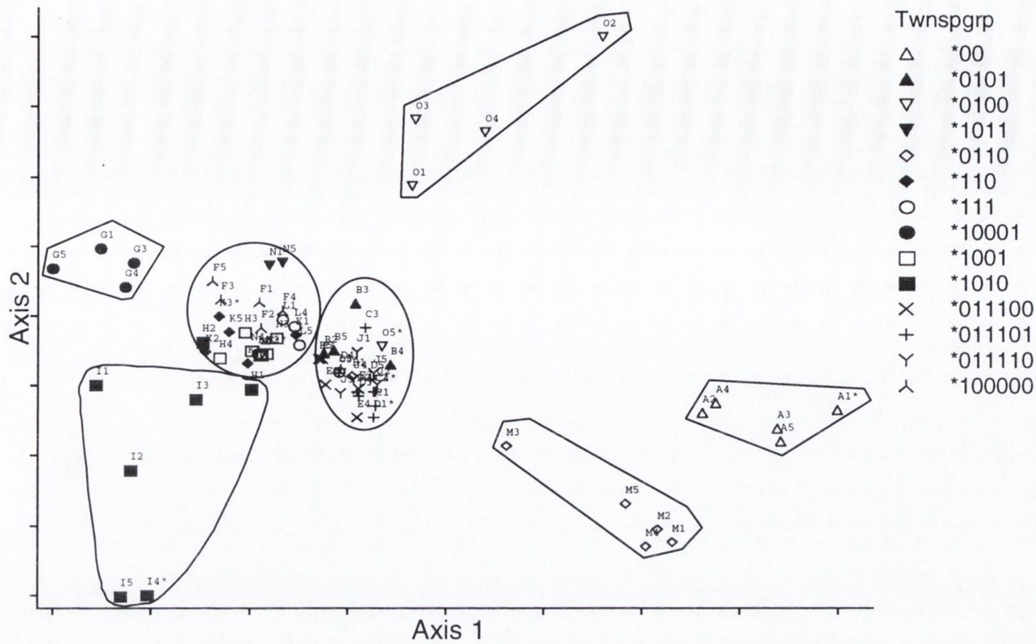

Figure 4.14. DECORANA plot of axis 1 and 2 for the five replicate samples from 15 meso-habitats found in Lough Inchiquin. TWINSPAN groupings indicated by symbol and DECORANA clusters circled. (See Table 4.4 for brief description of habitat codes and Table 2.4 for detailed descriptions).

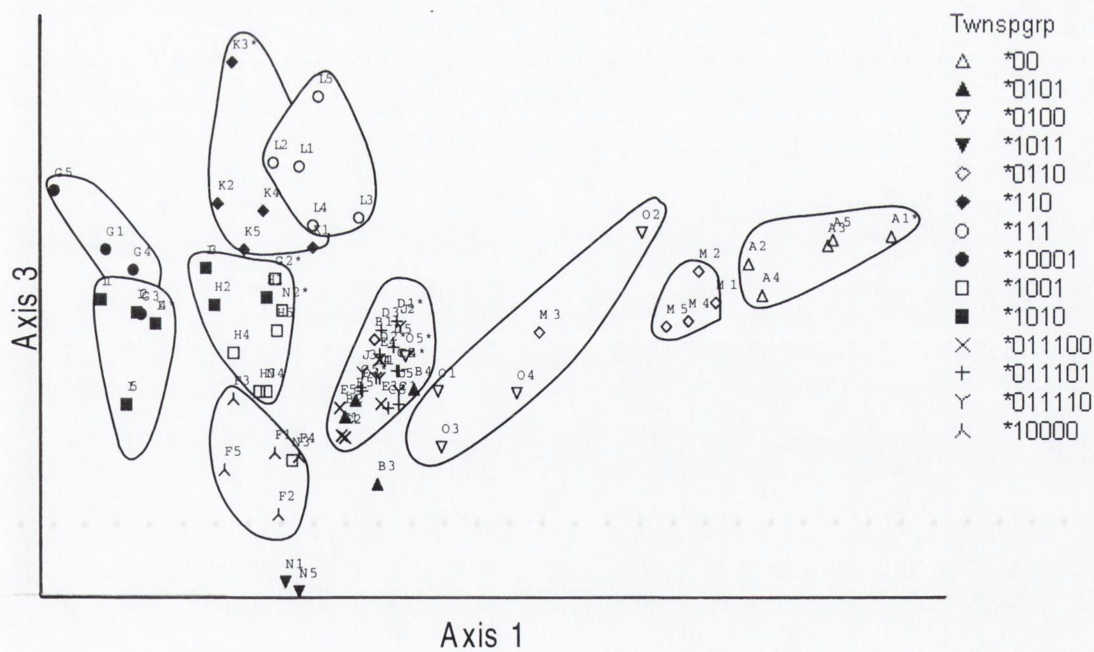

Figure 4.15. DECORANA plot of axis 1 and 3 with the five replicate samples from 15 meso-habitats found in Lough Inchiquin. TWINSPAN groupings indicated by symbol and DECORANA clusters circled. (See Table 4.4 for brief description of habitat codes and Table 2.4 for detailed descriptions).

At the top of Figure 4.15 samples from dense non-filamentous macrophytes were nested into the samples from filamentous macrophytes (habitats L and K, respectively). Below these, several samples from various macrophyte habitats were grouped together, similar to the middle groups *1001, *1010 and *1011 in the TWINSPAN analysis, containing the five replicates from habitat H, two from N, one from I and one from G. Below this, five samples from habitat F were grouped together (*Cladophora* on pebbles). Furthest left in the graph, samples from dense vegetation were grouped (I 1, 2, 4 and 5). Nested within and above this were four samples from habitat G (*Cladophora* on marl & sand).

TWINSPAN and DECORANA axis 1 & 2 and 1 & 3 suggested that of the 15 meso-habitats sampled, several contained similar assemblages of macroinvertebrates although most (8 of 15) did not. Three groupings of biologically dissimilar meso-habitats are indicated in Table 4.6. To compile a list of meso-habitats that showed dissimilar macroinvertebrate assemblages, habitats that were grouped together in at least two of the analysis were amalgamated. This is shown in Table 4.6 and meso-habitats described in Table 4.7.

Table 4.6. Meso-habitats clustered by TWINSPAN and DECORANA axis 1 & 2, and 1 & 3.

TWINSPAN Clusters	**DECORANA Axis 1 & 2 cluster**	**DECORANA Axis 1 & 3 clusters**	**Amalgamated meso-habitats**
A	A	A	A
O	O	O	O
B	–	–	–
M	M	M	M
E, C, D, J	B, C, D, E, J	B, C, D, E, J	B, C, D, E, J
F	F, H, K, L, N	F	F
G	G	G	G
H, I, N	–	H, N	H, N
–	I	I	I
K	–	K	K
L	–	L	L

Table 4.7. Descriptions of biologically dissimilar meso-habitats identified by multivariate analysis.

Amalgamated meso-habitats	Abbreviated name	Meso-habitat descriptions
A	Stone & *Fontinalis*	*Fontinalis* (mid-density), pebbles 30%, cobbles 20% & sand 50%
O	Sand & marl	Sand 80%, marl, CPOM, plus *Fontinalis antipyretica* & *Elodea canadensis* (sparse)
M	Cobbles & pebbles	Cobbles 60%, pebbles 30% & marl 10%
B, C, D, E, J	Predominantly mineral	Boulders, cobbles, pebbles & sand with sparse macrophyte growth
F	*Cladophora* & pebbles	*Cladophora* covering pebbles
G	*Cladophora* & marl	*Cladophora* covering marl & sand
H, N	Predominantly sand	Base of *Phragmites* (sparse), algae (sparse) & sand 80%
I	*Lemna* & Grass spp.	*Lemna trisulca* with dense grasses
K	Dense filamentous macrophytes	Dense filamentous macrophytes, *Zannichellia palustris* and *Fontinalis antipyretica* covering pebble & marl
L	Dense non-filamentous macrophytes	Dense non-filamentous macrophytes, *Hippuris vulgaris, Marsupella emarginata* & (?) *Stragnalisor platycarpa*

Figure 4.16 shows the abundances of the ten most predominant taxonomic groups found in the 15 meso-habitats (values in the histograms have been ordered with regard to the multivariate analysis groupings). Flatworms were present in all of the habitats but appear to have been more prevalent in habitats dominated by macrophytes. This was also the case for crustaceans and molluscs, with the latter being much more prevalent in habitat G (*Cladophora* covering marl & sand). Ephemeroptera were also found in all habitats, although most abundant on cobble & pebble substrata where *Littorella uniflora* was present (habitats D and E).

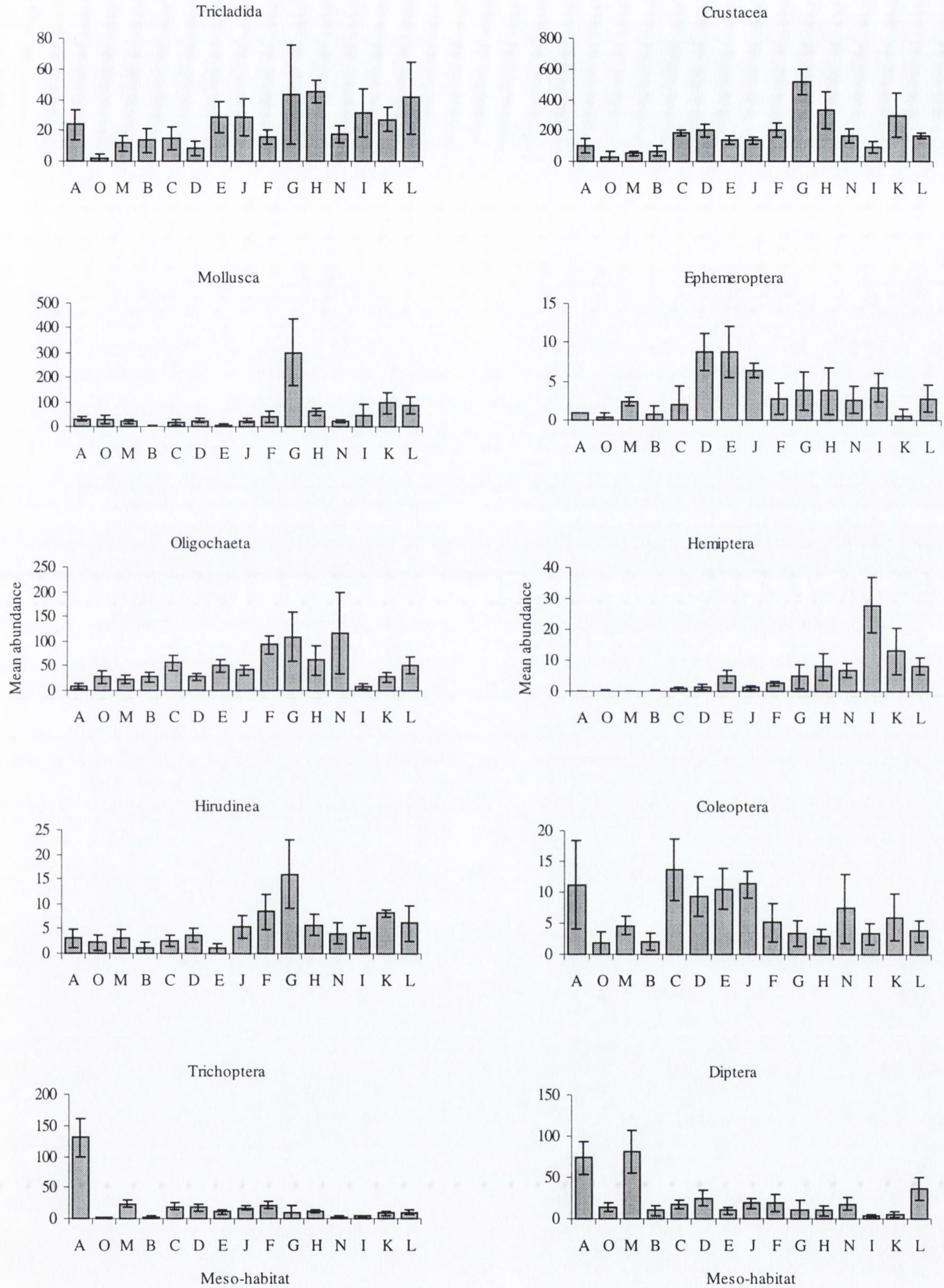

Figure 4.16. Mean abundance (per sample) of the most predominant taxonomic Orders in the 15 meso-habitats sampled in Lough Inchiquin, ordered in according to the multivariate analysis clusters (n = 5) (Error bars are 95% *c.l.*).

Oligochaetes were abundant in most of the habitats and showed mean abundances of less than 10 individuals per sample in only two habitats, *Fontinalis*, pebbles, cobbles & sand, and *Lemna trisulca* with dense grass species (A and I respectively). They were most abundant in *Cladophora* covered substrata (habitats F and G) and habitat N, which comprised mainly sand. Large confidence limits were, however, associated with this mean, indicating that abundance was very variable in the five replicate samples collected in the habitat. Hemipterans were clearly associated with DECORANA clusters that comprised emergent macrophytes and habitats that were clustered to the right in the TWINSPAN analysis, consisting predominantly of macrophytes. Leeches, found in all habitats, showed a slight tendency towards greater abundance among macrophyte covered substrata. They were most abundant in *Cladophora* covering marl & sand (habitat G), possibly because of the high total abundance of macroinvertebrates in this habitat and hence a large number of potential prey taxa (oligochaetes, molluscs and crustaceans). Coleoptera were most common in the habitats made up of large inorganic material with a little macrophyte growth (habitats A, C, D, E and J), while caddis flies were most abundant in habitat A (*Fontinalis* on pebbles, cobbles & sand). Fly larvae were found most among cobbles & pebbles (habitats A and M).

There were significant correlations in mean abundances among certain taxonomic groups (Table 4.8). Forty-six positive and 12 negative correlations were found. Only *Caenis luctuosa* showed no significant correlations to any other taxa. *Valvata macrostoma* and *Helobdella stagnalis* showed the highest numbers of significant correlations (eleven in each case).

Figure 4.7 shows the mean Shannon-Wiener diversity indices for each of the 15 meso-habitats (the histogram has been ordered with regard to the multivariate analysis groups). The highest diversity score of 2.50 was found in *Fontinalis*, pebbles, cobbles & sand (habitat A), and the lowest (1.53) in CPOM on sand (habitat B). Samples of broadly similar substrata showed similarities in diversities. Habitats comprising boulders, cobbles, pebbles and sand (B, C, D and E) and *Cladophora* and reed habitats (F, G, H and N) had similar diversity indices.

Table 4.8. Spearman rank correlations between mean abundance of the most abundant 20 taxa found in the 15 meso-habitats ($n = 5$ in each case, * = $P < 0.05$, ** = $P < 0.01$).

Taxa	*Asellus aquaticus*	Oligochaeta Sum	*Valvata macrostoma*	Chironomidae	*Polycelis nigra/tenuis*	*Crangonyx pseudogracilis*	*Pisidium* sp.	*Bithynia tentaculata*	*Physa fontinalis*	*Tinodes waeneri*	*Oulimnius tuberculatus*	*Polycentropus flavomaculatus*	*Caenis luctuosa*	*Mystacides longicornis*	*Helobdella stagnalis*	*Callicorixa praeusta*	*Haliplus* (larvae)	*Erpobdella octoculata*	*Planorbis contortus*
Asellus aquaticus	–																		
Oligochaeta Sum	**0.67****	–																	
Valvata macrostoma	**0.64****	0.45	–																
Chironomidae	-0.20	-0.10	-0.17	–															
Polycelis nigra/tenuis	0.40	0.32	**0.64****	-0.31	–														
Crangonyx pseudogracilis	0.50*	0.36	**0.77****	-0.35	**0.74****	–													
Pisidium sp.	0.43	-0.02	0.43	-0.33	0.10	0.33	–												
Bithynia tentaculata	0.37	0.08	0.06	0.15	-0.17	-0.05	**0.48***	–											
Physa fontinalis	0.32	0.07	0.17	0.44	0.11	-0.10	-0.19	0.18	–										
Tinodes waeneri	-0.04	0.00	**-0.58***	0.29	**-0.52***	**-0.49***	-0.17	0.38	0.18	–									
Oulimnius tuberculatus	-0.22	-0.21	-	**0.51***	**-0.48***	**-0.59***	-0.29	0.25	0.34	**0.68****	–								
Polycentropus flavomaculatus	-0.20	-0.37	-0.29	**0.81****	-0.22	-0.40	-0.18	0.32	**0.53***	0.40	**0.68****	–							
Caenis luctuosa	0.38	0.22	-0.03	-0.19	0.29	0.30	0.37	0.20	-0.14	0.33	0.19	-0.05	–						
Mystacides longicornis	**0.56***	**0.47***	**0.73****	-0.28	**0.68****	**0.59***	0.16	0.23	0.16	-0.30	-0.38	-0.23	0.12	–					
Helobdella stagnalis	**0.74****	**0.59***	**0.93****	-0.11	**0.57***	**0.71****	0.41	0.24	0.16	-0.30	**-0.51***	-0.22	0.15	**0.81****	–				
Callicorixa praeusta	0.26	0.18	**0.49***	-	**0.62****	**0.55***	0.20	-0.37	0.11	-0.31	**-0.57***	**-0.52***	0.13	0.31	0.35	–			
Haliplus (larvae)	**0.53***	**0.77****	**0.55***	0.10	0.41	**0.53***	0.03	0.11	0.10	0.04	-0.20	-0.23	0.37	**0.59***	**0.71****	0.19	–		
Erpobdella octoculata	0.32	0.12	0.40	-0.03	0.16	0.11	**0.69****	0.42	-0.23	-0.16	-0.21	-0.02	0.26	0.39	**0.49***	-0.11	0.26	–	
Planorbis contortus	**0.58***	0.20	**0.87****	-0.04	0.42	**0.66****	**0.51***	0.18	0.39	-0.36	**-0.47***	-0.10	0.01	**0.49***	**0.78****	**0.47***	0.39	0.23	–
Planorbis albus	0.31	0.01	**0.76****	-0.09	**0.68****	**0.66****	0.12	-0.03	0.36	**-0.53***	-0.41	-0.05	-0.13	**0.69****	**0.65****	0.45	0.31	0.10	**0.75****

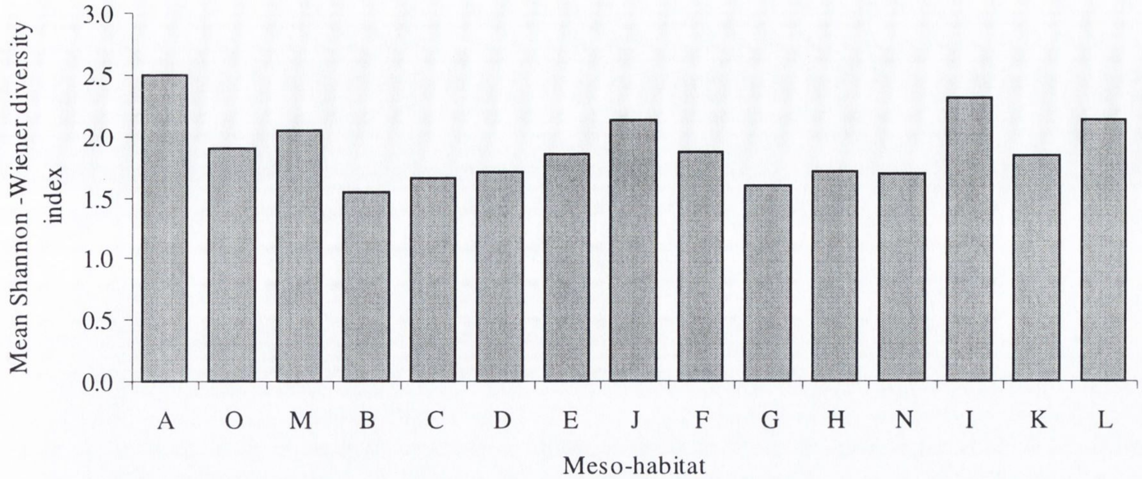

Figure 4.17. Mean Shannon-Wiener diversity index for the 15 meso-habitats sampled in Lough Inchiquin. Order is according to the multivariate analysis clusters ($n = 5$).

Table 4.9 lists the taxa that were found in each of the habitats ordered by the number of habitats in which they were found. Eight taxa occurred in all 15 sampled meso-habitats, these were *Polycelis nigra/tenuis, Bithynia tentaculata,* Oligochaeta, *Erpobdella octoculata, Asellus aquaticus, Crangonyx pseudogracilis, Haliplus* larvae and Chironomidae. Four taxa were found in 14 of the habitats, (*Physa fontinalis, Pisidium* spp., *Helobdella stagnalis* and *Caenis luctuosa*). These taxa were missing from *Lemna* & grasses, Dense non-filamentous macrophytes, sand & CPOM and sand & marl habitats respectively. Seven taxa were found in 13 habitats and five were found in 12 habitats. *Oulimnius tuberculatus* and *Sericostoma personatum* were found in 11 habitats, and Hydracarina and *Sigara dorsalis* in 10 habitats. Five taxa were found in 9 habitats and two in 8 habitats. Thirty-nine taxa were found in only one habitat.

Table 4.9. Macroinvertebrates found in the 15 habitats sampled in Lough Inchiquin.

Phylum/ Class /Order	Family	Taxa/species	Habitats found in	Sum
Isopoda	Asellidae	*Asellus aquaticus*	AOMBCDEJFGHNIKL	15
Diptera	Chironomidae		AOMBCDEJFGHNIKL	15
Tricladida	Planariidae	*Polycelis nigra/tenuis*	AOMBCDEJFGHNIKL	15
Oligochaeta			AOMBCDEJFGHNIKL	15
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	AOMBCDEJFGHNIKL	15
Gastropoda	Bithyniidae	*Bithynia tentaculata*	AOMBCDEJFGHNIKL	15
Hirudinea	Erpobdellidae	*Erpobdella octoculata*	AOMBCDEJFGHNIKL	15
Coleoptera	Haliplidae	*Haliplus* (larvae)	AOMBCDEJFGHNIKL	15
Gastropoda	Physidae	*Physa fontinalis*	AOMBCDEJFGHN KL	14
Gastropoda	Succineidae	*Pisidium* spp.	AOMBCDEJFGHNIK	14
Ephemeroptera	Caenidae	*Caenis luctuosa*	A MBCDEJFGHNIKL	14
Hirudinea	Glossiphoniidae	*Helobdella stagnalis*	AOM CDEJFGHNIKL	14
Trichoptera	Leptoceridae	*Athripsodes aterrimus*	A MBCD JFGHNIKL	13
Gastropoda	Succineidae	*Sphaerium* spp.	AOMBCD JFGHNIK	13
Gastropoda	Planorbidae	*Planorbis albus*	A MB DEJFGHNIKL	13
Gastropoda	Valvatidae	*Valvata macrostoma*	AOM CD JFGHNIKL	13
Tricladida	Dendrocoelidae	*Dendrocoelum lacteum*	A MBCDEJF HNIKL	13
Gastropoda	Planorbidae	*Planorbis contortus*	AOM CD JFGHNIKL	13
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	A MBCDEJFGHN KL	13
Gastropoda	Viviparidae	*Viviparus fasciatus*	AOM DEJFGHNIK	12
Gastropoda	Lymnaeidae	*Lymnaea peregra*	AOM DEJFGH IKL	12
Trichoptera	Leptoceridae	*Mystacides longicornis*	A M C EJFGHNIKL	12
Tricladida	Dugesiidae	*Dugesia polychora*	MBC EJFGHNIKL	12
Hemiptera	Corixidae	*Callicorixa praeusta*	O BCDEJ GHNIKL	12
Coleoptera	Elmidae	*Oulimnius tuberculatus*	AOMBCDEJF N K	11
Trichoptera	Sericostomatidae	*Sericostoma personatum*	O BCDEJFG N KL	11
Hydracarina			A MBCDEJ G KL	10
Hemiptera	Corixidae	*Sigara dorsalis*	CDE FGHNIKL	10
Hirudinea	Glossiphoniidae	*Theromyzon tessulatum*	A M FGHNIKL	9
Diptera	Ceratopogonidae	*Ceratopogonidae*	A B DEJFG NI	9
Hemiptera	Corixidae	Nymphs	C E FGHNIKL	9
Coleoptera	Haliplidae	*Haliplus confinus*	CDEJFGHN K	9
Trichoptera	Psychomyiidae	*Tinodes waeneri*	MBCDEJF N K	9
Amphipoda	Gammaridae	*Gammarus duebeni*	AO EJ HN KL	8
Trichoptera	Hydroptilidae	*Hydroptila* sp.	A CDEJF H K	8
Gastropoda	Neritidae	*Theodoxus fluviatilis*	A M CDEJ K	7
Gastropoda	Planorbidae	*Planorbis vortex*	AO B GHNI	7
Trichoptera	Leptoceridae	*Triaenodes bicolor*	AO GHNIK	7
Arachnidae			MB D F HNI	7
Trichoptera	Polycentropodida	*Polycentropus flavomaculatus*	A M CD J L	6
Trichoptera	Leptoceridae	*Athripsodes cinereus*	A B D JFG	6
Trichoptera	Hydroptilidae	*Agraylea multipunctata*	A C FGHN	6
Gastropoda	Planorbidae	*Planorbis crista*	A J G NI L	6
Gastropoda	Planorbidae	*Segmentina complanata*	JFGHNI	6
Hemiptera	Corixidae	*Sigara distincta*	DEJFG I	6
Hemiptera	Cymatiinae	*Cymatia bonsdorffi*	E GHNIK	6
Trichoptera	Polycentropodida	*Plectrocnemia conspersa*	A M C J G	5
Trichoptera	Polycentropodida	*Holocentropus dubius*	A BC GH	5

Table 4.9. (Continued). Macroinvertebrates found in the 15 habitats sampled in Lough Inchiquin.

Phylum/ Class /Order	Family	Taxa/species	Habitats found in	Sum
Hemiptera	Corixidae	*Corixa panzeri*	GHNI L	5
Coleoptera	Dytiscidae	*Agabus* (larvae)	D HNI L	5
Coleoptera	Hydroporinae	*Potamonectes depressus elegans*	CDEJF	5
Trichoptera	Lepidostomatidae	*Lepidostoma hirtum*	A M J L	4
Hirudinea	Piscicolidae	*Piscicola geometra*	AO J K	4
Gastropoda	Littoridininae	*Potamopyrgus jenkinsi*	AO N L	4
Megaloptera	Sialidae	*Sialis lutaria*	AO B G	4
Gastropoda	Lymnaeidae	*Lymnaea stagnalis*	M NI L	4
Ephemeroptera	Beatidae	*Cloeon dipterum*	NIKL	4
Trichoptera	Limnephilidae	*Limnephilus marmoratus*	OM KL	4
Diptera	Tipulidae		BC GH	4
Coleoptera	Elmidae	*Elmis aenea*	A D L	3
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*	A CD	3
Ephemeroptera	Beatidae	(early instars)	FGH	3
Trichoptera	Polycentropodida	*Holocentropus picicornis*	J H I	3
Gastropoda	Acroloxidae	*Acroloxus lacustris*	H L	2
Hirudinea	Glossiphoniidae	*Boreobdella verrucata*	KL	2
Ephemeroptera	Beatidae	*Centroptilum luteolum*	N L	2
Ephemeroptera	Caenidae	*Caenis horaria*	NI	2
Ephemeroptera	Epehemeridae	*Ephemera danica*	OM	2
Zygoptera	Coenagrionidae	*Ischnura elegans*	H K	2
Neuroptera	Sisyridae	*Sisyra fuscata*	M C	2
Coleoptera	Chrysomelidae	*Macroplea* (larvae)	N K	2
Coleoptera	Hydroporinae	*Hygrotus quinquelineatus*	E I	2
Trichoptera	Limnephilidae	*Limnephilus flavicornis*	B D	2
Trichoptera	Polycentropodida	*Neureclipsis bimaculata*	A	1
Trichoptera	Glossosomatidae	*Agapetus fuscipes*	A	1
Trichoptera	Hydropsychidae	*Hydropsyche pellucidula*	A	1
Ephemeroptera	Beatidae	*Baetis muticus*	A	1
Coleoptera	Gyrinidae	*Gyrinus larvae*	A	1
Trichoptera	Phryganeidae	*Phryganea bipunctata*	A	1
Diptera	Simuliidae		A	1
Gastropoda	Valvatidae	*Valvata cristata*	H	1
Gastropoda	Valvatidae	*Valvata contortus*	G	1
Gastropoda	Valvatidae	*Valvata piscinalis*	L	1
Gastropoda	Bithyniidae	*Bithynia leachi*	J	1
Gastropoda	Planorbidae	*Planorbis planorbis*	L	1
Gastropoda	Planorbidae	*Planorbis carinatus*	N	1
Gastropoda	Succineidae	*Succinea ?(palustris)*	B	1
Hirudinea	Glossiphoniidae	*Glossiphonia heteroclita*	I	1
Ephemeroptera	Beatidae	*Baetis rhodani*	L	1
Ephemeroptera	Beatidae	*Cloeon simile*	I	1
Ephemeroptera	Heptageniidae	*Heptagenia sulphurea*	L	1
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*	D	1
Zygoptera	Coenagrionidae	Early instars	D	1
Hemiptera	Corixidae	*Arctocorisa germari*	K	1
Hemiptera	Corixidae	*Hesperocorixa linnaei*	I	1
Hemiptera	Corixidae	*Sigara falleni*	D	1
Hemiptera	Notonectinae	*Notonecta glauca*	I	1

Table 4.9. (Continued). Macroinvertebrates found in the 15 habitats sampled in Lough Inchiquin.

Phylum/ Class /Order	Family	Taxa/species	Habitats found in	Sum
Coleoptera	Gyrinidae	*Orectochilus villosus*	J	1
Coleoptera	Chrysomelidae	*Macroplea appendiculata*	K	1
Coleoptera	Haliplidae	*Haliplus flavicollis*	K	1
Coleoptera	Noteridae	*Noterus clavicornis*	I	1
Coleoptera	Hydroporinae	*Stictotarsus duidecimpustulatus*	M	1
Coleoptera	Hydroporinae	*Hygrotus ?(inaequalis)*	I	1
Coleoptera	Hydrophilidae	*Hydrophilus* sp.	C	1
Coleoptera	Hydrophilidae	*Helophorus dubius*	C	1
Coleoptera	Hydrophilinae	*Laccobius biguttatus*	I	1
Coleoptera	Hydrophilinae	*Laccobius* (larvae)	I	1
Coleoptera	Hydraenidae	*Hydraena ?(gracilis)*	M	1
Trichoptera	Hydroptilidae	Instars II - IV	F	1
Trichoptera	Limnephilidae	Early Instars	M	1
Trichoptera	Leptoceridae	*Ceraclea nigronervosa*	J	1
Diptera	Tabanidae		H	1

Figure 4.18 shows the cumulative number of taxa that were found in increasing numbers of sampled meso-habitats. The two are highly significantly related to one another ($r = 0.99$, $P < 0.001$). It is clear from this that an increase in the number of meso-habitats that were present relates to an increase in the number of taxa that were found.

The Venn diagrams (Figure 4.19 to 4.23) compare the number of taxa found in habitats that had similar and dissimilar physical features. Figure 4.19 shows the number of taxa that were present in stone & *Fontinalis*, cobble & pebble and predominately stone meso-habitats. Each of these habitats consisted primarily of mineral substratum. Large proportions of the taxa richness of each of the habitats were found in one other, with 32 of the 39 taxa that were found in cobbles & pebbles also being present in predominantly stone substrata. A total of 83 taxonomic groups were found in these habitats, of these only 28 were found in all three.

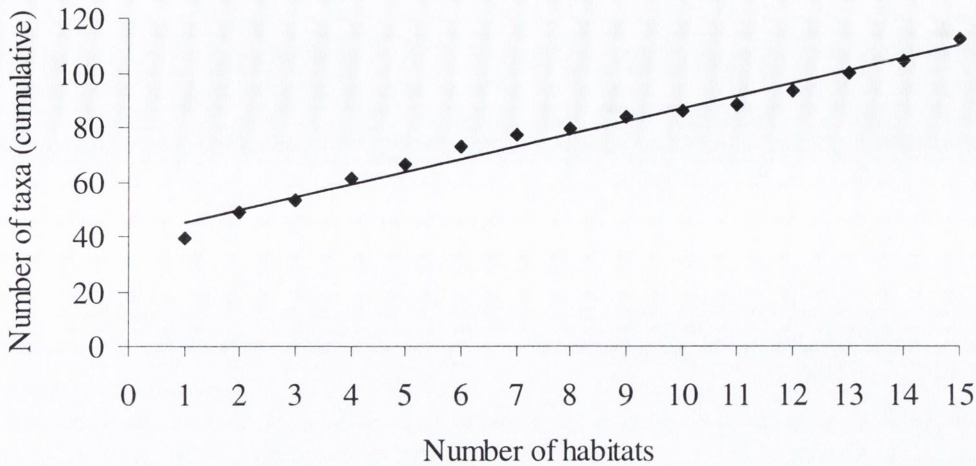

Figure 4.18. The cumulative number of taxa found in increasing numbers of meso-habitats. ($y = 4.6536x + 40.371$, $r = 0.99$).

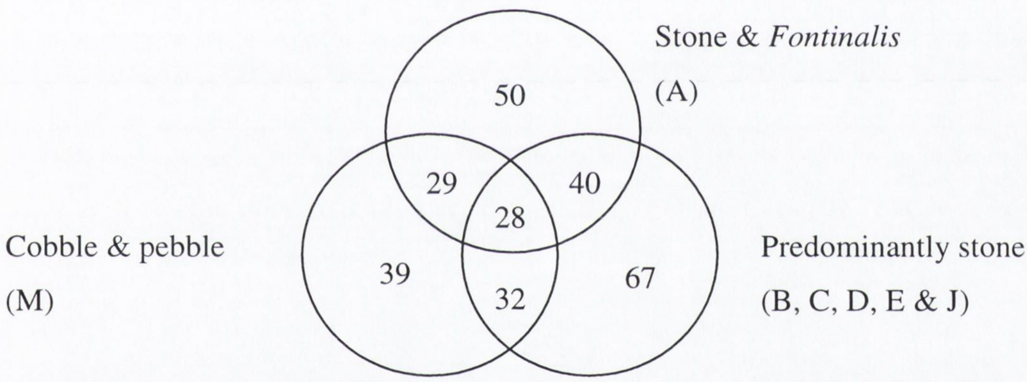

Figure 4.19. Venn diagram of the taxa richness found in stone & *Fontinalis*, cobble & pebble and predominately stone meso-habitats.

Figure 4.20 compares the taxa richness of predominately mineral, dense filamentous macrophytes and dense non-filamentous meso-habitats. A total of 86 taxa were found in these habitats. The predominately mineral habitats were markedly different to macrophyte habitats according to the multivariate analysis many taxa were common to the mineral and one of the macrophyte habitats. A larger proportion were found to be present in both of the macrophyte habitats. Only 26 taxa were found in all three habitat categories. Figure 4.21 compares macrophyte meso-habitats. Of 76 taxa that were found in these habitats, only 23 were found in all three; this is approximately half of the taxa richness found in each of the habitats. Similar numbers of taxa were present in any two of the three habitats.

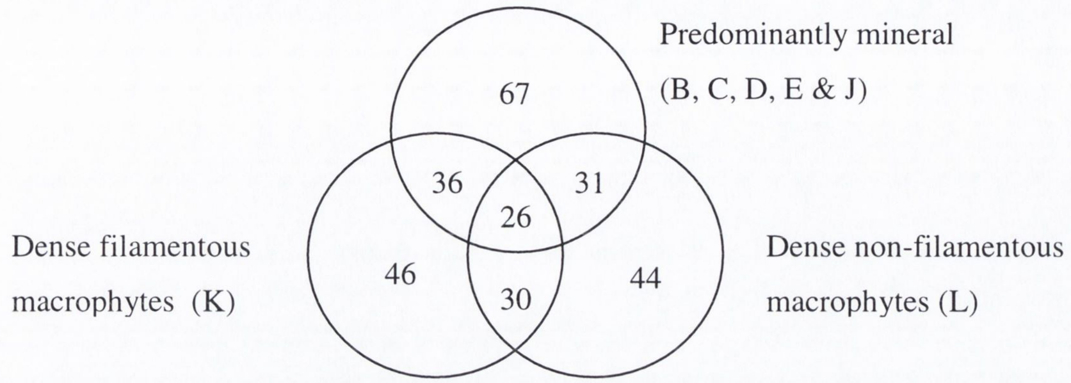

Figure 4.20. Venn diagram of the taxa richness found in predominately mineral, dense filamentous macrophyte and dense non-filamentous macrophyte meso-habitats.

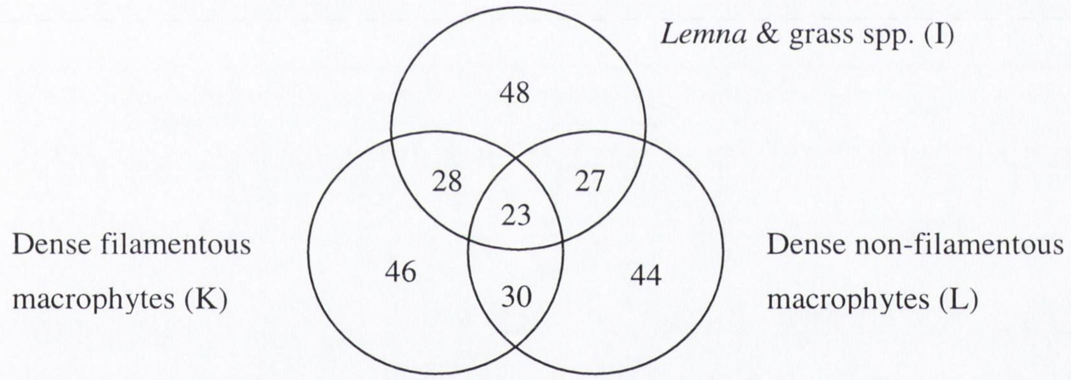

Figure 4.21. Venn diagram of the taxa richness found in *Lemna* & grass, dense filamentous macrophyte and dense non-filamentous macrophyte meso-habitats.

Cladophora & stone and *Cladophora* & marl habitats were clustered close to each other in the multivariate analysis. Figure 4.22 shows that of the 40 taxa found *Cladophora* & stone and 45 found in *Cladophora* & marl, 33 were common to both. A total of 52 taxa were found in these two habitats. Seventy-six taxa were found in total in *Cladophora* & marl, sand & marl and predominantly sand meso-habitats. These are compared in Figure 4.23. The majority of taxa found in sand & marl were also present in the other two habitats and the majority found in *Cladophora* & marl were also present in predominantly sand habitats. Many taxa were found in only one habitat type. These are listed in Table 4.9.

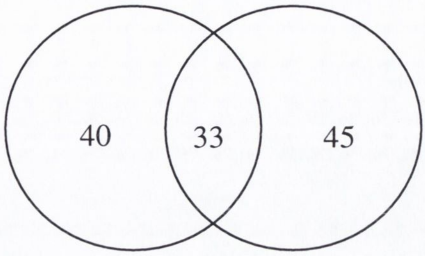

Figure 4.22. Venn diagram of the taxa richness found in *Cladophora* & pebbles, *Cladophora* & marl meso-habitats.

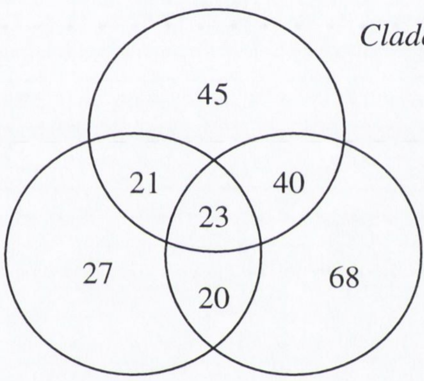

Figure 4.23. Venn diagram of the taxa richness found in *Cladophora* & marl, Sand & marl and predominantly sand meso-habitats.

4.4. Discussion

4.4.5. Uniform Substrata in Lakes

Results from the triplicate samples from uniform substrata in eleven lakes indicated that macroinvertebrate assemblages are indicative of lakes and demonstrate that variations in assemblages are greater among lakes than within a single substratum type. These results also show that the standard sampling method employed would tend to provided samples of littoral macroinvertebrate assemblages from within an apparently homogenous habitat of a lake that were consistent with one another when compared to samples from other substrata within the same lake. This supports the scientific validity of using kick/sweep sampling as a means of sampling macroinvertebrates from the littoral zones of lakes to investigate variations in assemblages among lakes within a single substrate type.

4.4.6. Dissimilar Substrata in Lakes

Samples collected from quite different, mineral and macrophyte habitats among a series of 21 lakes tended to reveal greater differences in macroinvertebrate assemblages among lakes than between different substrata within a lake. There was no statistically significant difference in overall macroinvertebrate abundance or taxa richness between the two habitat types when the two habitat types in 21 lakes were considered. In the Hierarchical cluster analysis, many of the samples were grouped in order of lake rather than habitat. This is somewhat contrary to suggestions in the literature based upon riverine meso-habitats (Armitage, Pardo & Brown, 1995; Harper, Smith & Barham, 1992; Harper *et al.*, 1995), but does suggest that the environmental and chemical differences among lakes influence the macroinvertebrate assemblage to a greater degree than variations in habitat type within a lake. Proportional abundances have often been used in Hierarchical cluster analysis such as this to correct for inequalities in data resulting from using a standard sampling technique in dissimilar substrate types (Giller, Pers. Com.). Such analysis however, resulted in little separation of samples in this instance. Log (x + 1) transformation corrects for disproportional influences of abundance due to sampling in a similar way, however, it additionally reduces the variance of the data, gives less weight to dominant taxa (Armitage, Pardo & Brown, 1995) and in this instance, indicates the greater similarity of samples from within a lake than those from similarly identified substrata in different lakes.

One of the primary objections often cited to using macroinvertebrates in assessing the ecological quality of lakes has been the variability of assemblages found in different substrata, and the need to ensure that samples are taken from similar substrata if comparisons between lakes are to be made (Hunding 1971; Dall, Heegard & Fullerton, 1984; Rasmussen, 1988; Brodersen, Dall & Lindegraad 1998; Harrison & Hildrew, 1998). Although the assessment of the multiple meso-habitat samples from within a single lake indicated clearly that faunal assemblages differed with substrata it was somewhat encouraging for lake assessment methodologies to find that the variability in the assemblages from two markedly different substrata was less than the variability between lakes.

4.4.7. Meso-Habitats in Lough Inchiquin

Among the 15 meso-habitats sampled in Lough Inchiquin, there were significant differences in both abundance and taxa richness between the majority of the habitats. These became apparent in multivariate analysis of the data. Initial divisions of samples agreed with the findings of Armitage, Pardo & Brown (1995), Harper, Smith & Barham (1992) and Harper *et al.* (1995), with marked differences found among the assemblages found in predominantly mineral and macrophyte comminutes, although not necessarily contradictory to the previously discussed analyses of data from 21 lakes, which identified that among lakes differences in assemblages were more marked than they were between two habitat types. In all of the multivariate cases, several clusters of samples were grouped close together. Samples from macrophyte based habitats tended to be placed closer to one another than those taken from inorganic substrata, and different macrophyte communities were found to support different macroinvertebrate assemblages. This agrees with findings of studies that investigated the macroinvertebrate assemblages associated with different macrophyte species (Rook, 1984; Cyr & Downing, 1988; Hanson, 1990; Tokeshi, 1994). Similarly, samples from inorganic substrata were found to be more alike than they were to samples from predominantly macrophyte habitats, and different assemblages were found to associate with particular substrata particle sizes. This agreed with findings from stream studies (Reice, 1974; Doeg, *et al.,* 1989; Smith, Harper & Barham, 1991, Harper *et al.*, 1995).

By collating the habitats that were clustered together in the three multivariate analysis plots, a list of meso-habitats that exhibited similar assemblages was compiled. Only some results of post hoc LSD tests on macroinvertebrate abundance and taxa richness in the habitats supported the groupings. This is not, however, unexpected, as multivariate analysis bases clusters or axis scores upon species and their relative abundances (Norris & Georges, 1993), rather than the total abundance of a sample or its taxa richness. Certain habitats that were clustered by the multivariate analysis showed comparable diversity indices, indicating that the total numbers of individuals in these samples were distributed amongst the number of taxa in a similar way (Fowler & Cohen, 1990). In contrast, however, several samples exhibited comparable diversity indices that were not clustered by multivariate analysis. Again, this may be expected, as diversity indices do not account and compare the abundance of specific taxonomic groups within samples as multivariate analyses do.

At the taxonomic level of order, similarities in abundances agreed with the clusters of the multivariate analysis. An additional insight into the assemblages in the meso-habitats is given in Table 4.9 where the habitats in which taxa were found are shown. The complexity of the assemblages is clear from this, and to describe them in detail from an ecologically meaningful perspective is difficult. It was exactly for this reason that multivariate analysis methods have been applied, and have become popular in community analysis. Their use is now widespread in assessing complex communities because of their ability to simplify very large and complicated data into readily understandable diagrams (Gauch, 1980). Their use in this Chapter has enabled the realization that many visually dissimilar substrata in lakes do support biologically dissimilar macroinvertebrate assemblages and in an attempt to support the divisions and groupings, additional analyses of the data was carried out.

Both the multivariate analysis and Venn diagrams indicated that there were overlaps in assemblages among meso-habitats. Similar results have been found for riverine habitats (Smith, Harper & Barham, 1991; Harper *et al.,* 1995). Ecologically this is not surprising considering the large number of visually discrete areas sampled, the taxa richness of the lake and the high abundances of many of the animals. This was supported by Table 4.9 which shows that of 112 taxa found in Lough Inchiquin, 51 were found in five or more of the sampled meso-habitats. Other taxa, however, were restricted in their distribution. Thirty-nine taxa were found in only one habitat and 10 in only two habitats. An alternative view is that their preference for a substratum was more specific than the nature of the study. As was discussed in the introduction (Section 4.1), the relative scale of a study is imperative if an ecological pattern is to be observed. It may be that macroinvertebrates express habitat preferences at a micro scale as opposed to the meso scale studied here. For instance flow regimes in rivers have been shown to form micro-habitats to which fauna is adapted (Armitage, Pardo &

Brown, 1995; Newall, 1995). This would imply that the expressed differences in the meso-habitats are actually differences in mosaics of microhabitats, therefore defining a meso-habitat as a mosaic of micro-habitats. This is almost certainly true. Nonetheless, the meso-habitats around Lough Inchiquin visually appeared to be uniform in their structure, and the clusters of replicate macroinvertebrate samples in the multivariate analysis supported their biological similarity. This implies that meso-habitats are robust in terms of the assemblages that they support and, as such, in the micro-habitats that they contain.

4.4.8. Temporal Stability and Potential Effects of Anthropogenic Activities upon Meso-Habitat

The robustness of the faunal assemblages found in the meso-habitats implies an associated robustness of biotic and abiotic processes affecting meso-habitats. Even if subjected to local disturbances, meso-habitat robustness may be assumed owing to the distinctive faunal assemblages found in this study and indications of this in the literature (Quinn, Lake & Schreiber, 1998). The longevity of the meso-habitats assessed in this Chapter are, however, not known as there was no temporal variation in the data sets and the temporal stability of meso-habitats in lakes can only be speculated on at this stage. Temporal stability in the absence of anthropogenic impacts would, however, lend weight to their use in indicating ecological quality, with high meso-habitat richness being indicative of high quality. River habitats of a comparable spatial scale (10^0 meters) have been estimated to have a temporal persistence of between 10^{-1} and 10^0 years (Hildrew & Giller, 1994). It is possible that lake meso-habitats may also be stable within these spatial and temporal boundaries. Significant seasonal variations in macroinvertebrate assemblages have been found in the littoral zone of lakes (Reid, Somers & David, 1995; Harrison & Hildrew, 1998). Armitage, Pardo & Brown, (1995) found that the macroinvertebrate assemblages of meso-habitats in rivers remained distinct from one another over the course of a year, even though the degree of separation varied with season. These studies, however, spanned only one year, and it would be of interest to see if samples taken from comparable seasons on consecutive years retained a similarity.

Many factors affect the temporal stability of macrophytes besides seasonal changes and winter die back. Studies have reported changes in macrophyte species richness and abundance owing to anthropogenic impacts. Eutrophication has been cited as a major influence (Jupp & Spencer, 1977; Phillips, Eminson & Moss, 1978; Palmer, 1989; Moss, 1988; Palmer, Bell & Butterfield, 1992) (see Section 1.7). Eutrophic lakes, as opposed to mesotrophic, are likely to have restricted submerged macrophyte communities owing to reductions in light penetration by high phytoplankton standing crops (Harper, 1992). While emergent vegetation may be prolific (Moss 1988), the submerged macrophyte community will tend to have a reduced species richness and an increased abundance (Haslam, 1978; Harper, 1992; United States Environmental Protection Agency, 1995) and biomass (Carpenter & Lodge, 1986), of dominant species. High turbidity can have the same influence upon submerged macrophytes as high phytoplankton abundance, as light penetration of the water column will be reduced. Increased turbidity can result from wave action induced by storms, from soil erosion owing to farming practices including tillage and "poaching" by cattle grazing around the lakeshore, anthropogenic alteration of the lakeshore and removal of both aquatic and riparian vegetation. Mechanized cutting of aquatic macrophytes, as well as aggravating sediments and increasing turbidity, alters macrophyte communities by reducing species richness, and increasing the abundance of dominant species (Nicholson, 1981). Direct herbicidal poisoning of aquatic macrophytes has a similar effect upon the community structure (Nicholson, 1981) and herbicide run off from additions to farmland in a catchment may have comparable impacts. Cattle drinking at the edge of a lake will directly impact meso-habitats as they will disturb and alter the physical structure of the substrata, while their removal would reduce turbidity and allow vegetation to return to the impacted shoreline (Weisner, 1987). Macrophytes also serve to protect the shoreline from wave erosion, and by reducing water movement they can increase deposition rates of material suspended in the water column (Carpenter & Lodge, 1986; Petticrew & Kaliff, 1992). As was shown in Chapter 3, lakes of different trophic state support different macroinvertebrate assemblages. This may be a direct impact, as a consequence of nutrient enrichment and differences in chemical composition of the water or an indirect impact through the food chain. Changes in the composition of macrophyte communities will, however, result from availability of nutrients, and the aquatic macrophyte community structure can also influence the abundance, taxonomic composition and size structure of the littoral macroinvertebrate assemblage of lakes (Hanson, 1990). In support of the temporal stability of meso-habitats Grelsson & Nilsson (1991) found the seed bank at the waters edge of Storvindeln Lake, Sweden, to be significantly correlated with the standing vegetation, indicating that the shore supported a stable macrophyte community.

Meso-habitats comprising large material such as cobbles and boulders may also be temporally stable. These tend to be situated in areas of high wave action, and larger material will only be moved in extremely adverse conditions, while continual deposition and resuspension of finer particulate material associated with these habitats will prevent them from becoming silted up. This will maintain the physical structure of the meso-habitats which will tend to be populated by taxa capable of rapid colonisation following disturbance and those capable of anchoring themselves to large material. Hence, their biological functioning will tend to be stable. The importance of rock surfaces to filter feeding macroinvertebrates has been shown for rivers (Freeman & Wallace, 1984; Huryn & Wallace, 1988; Smith, Harper & Barham, 1991) and riffles (usually comprising cobbles and boulders) have long been associated with high abundances of macroinvertebrates (Pennak & Van Gerpen, 1947; Cummins, 1975; Gore & Judy, 1981). Comparable meso-habitats of large material found in lakes in the work presented here, did not support the highest diversity or abundance of macroinvertebrates but they did contain distinct assemblages.

Finer substrata, such as sands and silts are depositional areas, and are the least stable meso-habitats for two reasons. Temporally they may be expected to continue to accumulate deposited material or develop macrophyte communities. Their persistence in a lake may be a result of direct anthropogenic disturbance or the substrata being too unstable for macrophyte assemblages to become established, which will result in plants being uprooted during storms (Weisner, 1987). Silt substrata are more likely to develop plant communities owing to the high content of organic matter, and macrophytes will tend to slowly ingress into these areas from surrounding macrophyte stands if they are present. During periods of calm weather, silt deposition may occur over any substrata and may change the habitat structure (American Society of Civil Engineering, 1992). Areas of sandy substrata tend to indicate slightly more disturbance by wave action than silt areas, and this will maintain their presence in the littoral zone by reducing both the rate of deposition of organic material and the potential for macrophytes to become established (Weisner, 1991). Although meso-habitats comprising fine particles tend to have low taxa richness and abundances, they are still important components of the littoral zone as they were found to support taxa not found in other meso-habitats and certain taxa (for instance oligochaetes) in high (Botts, 1997).

Meso-habitats are likely to respond to many anthropogenic impacts and could provide a valuable tool in lake management. This is certainly possible on a single lake basis for monitoring anthropogenic effects by simple visual enumeration of their richness. Meso-habitats could also provide a useful unit in restoring degraded stretches of the littoral zone. This is also the case from a conservation perspective; a reduction in the number of meso-habitats within a lake may imply a reduced conservation value. In addition, meso-habitats may also be of use in determining biodiversity as it has been shown in this work that certain taxa are limited in their distribution while others are more widespread. With increasing numbers of meso-habitats, so taxonomic richness increases. Harper & Everard (1998) stated that an assessment of habitat quality should be an indication of biodiversity. Enumeration of the meso-habitat richness around the littoral zone of Lough Inchiquin was indicative of the lake's macroinvertebrate biodiversity.

4.4.9. Inherent Factors for using Meso-habitats in Assessing the Ecological and Conservation Value of Lakes

In this study, meso-habitats have been evaluated in terms of their macroinvertebrate assemblages, which have many desirable qualities for assessing water and ecological quality (discussed in Chapter 1). Meso-habitats will retain these advantages and also gain from the inclusion of information on the structural diversity of the littoral zone. Harper & Everard (1998) reviewed the literature relating to the benefit of riverine meso-habitats in surveying rivers and defined them under four headings, hydrological, geomorphologic, chemical and ecological factors. Many of the findings of Harper & Everard (1998) are relevant to lake assessment:

- Hydrological and Geomorphological factors

Local variations in water movement will create variable micro-environments, both directly and indirectly through erosional and (primarily in lakes) depositional processes and substrate particle size sorting. Water movement also influences macrophyte stands, which will have a feed back effect and reduce water movement, and so increase sedimentation rates. These effects will influence the availability of refugia for invertebrates and fish. Local land use patterns may alter the influx of particulate matter and suspended material may be harmful to fish and plants by clogging gills and blocking out light. Vegetation also protects the bank from erosion by wave action especially during storms.

- Chemical factors

  Wetlands are able to remove pollutants through biological and physical processes and local variations in the redox potential at the sediment surface may be significant in nutrient cycling. Different substrata will undoubtedly vary in redox potential and the degree of aerobic and anaerobic conditions can enable nitrification and denitrification processes to occur simultaneously over small spatial scales. Rates of phosphorus adsorption to the sediment, to suspended material and its subsequent sedimentation may vary and depend upon differences in water movement and macrophyte beds. Concentrations of phytoplankton will affect nutrient availability and the abundance of macroinvertebrate grazers on plants may also influence nutrient dynamics among plants. Shading by riparian vegetation will alter oxygen concentrations and the riparian zone may also be involved in buffering acidification of runoff from afforestation and reduce concentrations of pesticides from agricultural practices (Carpenter & Lodge, 1986).

- Ecological factors

  High abundance and diversity of invertebrates has been attributed to habitat diversity, food supply and stable conditions in chalk streams. Large surface areas provided by plant communities enhance this diversity by providing an intricate physical structure and a larger standing crop of periphyton and microbial biofilm, important food sources for snails, amphibians and fish. Emergent stems are important for emergence of adult insects and provide valuable oviposition sites. Physical habitat variations and vegetation also provide refugia for macroinvertebrates and assist them in evading predators, provides cover for predatory fish, valuable spawning sites for coarse fish, and attachment sites for fish larvae shortly after spawning which may be significant in increasing fish stocks. Gravel substrata in rivers are important as fish spawning sites for salmonids and some coarse fish (Wesche, 1985) and may also be so in lakes. Diverse habitat structure is also important in fulfilling food requirements for different stages of fish development and other vertebrates.

Riparian vegetation provides food resources for higher animal species including birds and bats, and cover for other mammals including otters, and autochthonous input into the littoral zone of lakes. Shade can create local variations in temperature that can effect rates of primary production and development rates of invertebrates, eggs, juvenile salmonids, coarse fish and influences the competitive strength of first year classes of fish.

Sheltered areas can provide refugia for plankton communities and while this is of more importance in rivers, high concentrations of zooplankton and phytoplankton at the downwind end of lakes is often apparent, and areas of shelter at the up wind end of a lake may enhance recolonization rates.

4.5. Conclusions

Meso-habitats have been identified in terms of their macroinvertebrate assemblages in river systems (Brooker 1981; Kershner *et al.*, 1992; Harper 1995; Armitage, Pardo & Brown, 1995) and in this Chapter around the littoral zone of lakes. Meso-habitats include variations in many biological and environmental processes that contribute to the ecology of lakes, and these will operate to different extents depending upon many inter-related factors. While the complexity of assessment of this information is clear, meso-habitats are easily recognisable, and their identification in lakes can be a cost and time efficient contribution for lake assessment and management. The application of meso-habitat assessment in lakes requires an acknowledgement of the limitations of meso-habitat richness for comparing the ecological status, biodiversity or conservation value among lakes. For instance, oligotrophic lakes are considered to have a high conservation value, although invariably such lakes support relatively few, specialized species usually occurring in low abundances (Brodersen, Dall & Lindegraad, 1998). Examples of this in this work include Loughs Maumwee, Easky and Talt, and Pollaphuca Reservoir (Chapter 3, Table 3.5) and although they were not formally surveyed, it is clear from a knowledge gained from frequent visits, that they would also have low meso-habitat richness. A survey of a large sample of lakes may reveal an association between meso-habitat richness and conservation value, and they could be of value if a tiered approach to assessing lakes was taken, with lakes of similar characteristics being compared. The Water Framework Directive (1998) advocates that lake classification should be undertaken in this manner, with lakes grouped into types based upon a range of physical, environmental and biological variables, before being compared against a set of reference conditions that correspond to high ecological status.

5. PATCHINESS WITHIN HABITATS

5.1. Introduction

Investigations of patterns among ecological processes necessitates sampling at a scale smaller than the scale of the pattern (Chapter 4). The scale of meso-habitat has been used to determine differences in macroinvertebrate assemblages along stream courses (Brooker 1981; Kershner *et al.*, 1992; Harper 1995; Armitage, Pardo & Brown, 1995) and in this work (Chapter 4), around the littoral zone of lakes. There appears to be no reference in the literature however, on the distribution of macroinvertebrates within meso-habitats and an assumption that samples provide a characteristic collection of the macroinvertebrates in a meso-habitat. The underlying view that macroinvertebrate distribution is random and the variance at each population density equal to the mean is however, unlikely, as individuals in a natural population are unlikely to occur independently of one another (Taylor, 1961).

Within ecological systems the structure and behaviour of a community varies locally (Downes, Lake & Schreiber, 1993) and organisms by their very nature take up space, use resources and are on some level patchy (Pickett & White, 1985). Rice & Lambshead (1994) defined patchiness as distributions of organisms in space which deviate from randomness in the direction of aggregation rather than regularity. Patches of animals pose a challenge for biologists attempting to measure and understand the factors limiting animal abundances and distributions (Downes, Lake & Schreiber, 1993). Patchy distributions also have implications for analytical methods employing samples of macroinvertebrates as indicators of lake quality, and may undermine the assumption that a sample is representative of the lake and/or meso-habitat (Parsons & Norris, 1996).

The majority of distribution studies of aquatic benthos have been on marine systems, at a range of scales from centimeters to hundreds of meters (Hall, Raffaelli & Thrush, 1994; Dayton, 1994; Rice & Lambshead, 1994; Angel, 1994). Research on distributions of freshwater macroinvertebrates has tended to focus on relatively large spatial variations and associate distributions with variations in substrata, environmental or chemical variables, or a combination of these factors (Death, 1995; Wohl, Wallace & Meyer 1995; Carter, Fend & Kennelly, 1996; Botts, 1997). Community variations however, also occur over relatively small spatial scales (Pickett & White, 1985; Downes, 1990; Hall, Raffaelli & Thrush, 1994). In the benthos of Lake Geneva, Lang (1989) showed that tubificid and lumbriculid worms showed a patchy distribution at a scale less than 1 m^2 and related to "pillow" and "trench" formations that were shown to contain different concentrations of organic material. Minshall & Minshall (1977) working on a foothill stream, found that macroinvertebrates were not normally distributed, and were clumped, and that alterations of the cross sectional pattern of current velocity and streambed composition altered the patterns of distribution. The extent of clumping could, however, not be fully explained with reference to environmental variables.

Downes, Lake & Schreiber, (1993) found that between sites within the same stream order, riffles within the same site and groups of stones (five groups of three stones with surface areas of between 161 and 733 cm^3) within the same riffle, species richness did not vary. Densities however, of 27 of the 35 most abundant taxa, exhibited significant variation over one or more spatial scales and the abundances of 21 taxa varied significantly over small spatial scales (summarized in Table 5.1). This supports the view that there is no one patch size for entire assemblages (Addicott *et al.* 1987; Downes, 1990; Downes, Lake & Schreiber, 1993).

While some work has been done on the spatial distribution of lentic zooplankton (Dumont, 1967; George, 1974; Mitchell & Williams, 1982; Smiley & Tessier, 1998), and phytoplankton (Reynolds, 1994; Neill, 1994), there have been relatively few studies on the distribution patterns of macroinvertebrates in the littoral zone of lakes. Ságová & Adams (1993) investigated aggregation of littoral macroinvertebrates in Trout Lake, Wisconsin, U.S.A., at four spatial scales. At three sites, 3 m x 3 m trellises were placed on the lake bed in water 4.5m deep and within each of the nine 1m^2 areas formed by the trellis, two random core samples of 64 cm^2 were taken. Three tests of distribution (nested analysis of variance, Taylor's power test and Iwao's index of mean crowding and patchiness) indicated that abundances of chironomids, oligochaetes, amphipods, non-predatory and red chironomids were all aggregated at two or more spatial scales (Table 5.2).

Table 5.1. Number of taxa with significant variations in abundances among riffles and groups of stones. (Defined as significant *F* ratios: $P < 0.05$). (After Downes, Lake & Schreiber, 1993).

No. of taxa	**No. of taxa with significant variations in abundance**	
	Among riffles	**Among groups of stones**
4 Ephemeropterans	2	3
2 Plecopterans	2	1
1 Megalopterans	–	1
2 Coleopterans	1	1
6 Dipterans	5	3
6 Trichopterans	4	5

Table 5.2. Aggregation patterns of abundances of taxa at four spatial levels in the littoral zone of Lake Wisconsin, U.S.A. (+ = aggregated; – = random distribution; +/– = uncertainty in distribution pattern). (After Ságová & Adams, 1993).

Taxa	**Among samples (cores) within:**			**Among:**		
	1m^2	**3m^2**	**Sites**	**1m^2**	**3m^2**	**Sites**
Chironomids	+	+/–	–	–	–	+/–
Oligochaetes	–	+	–	–	–	+
Amphipods		+	+	–	–	+
Non-predatory chir.	+	+	+	–	–	+/–
Predatory chir.	+/–	+/–	–	–	–	–
Red chir.	–	–	–	+	+	+/–
Brown chir.	+/–	+/–	+/–	–	–	+/–

Reid, Somers & David (1995) assessed the precision (defined as spatial variation) and repeatability (temporal variation) of littoral macroinvertebrate samples using model II analysis of variance and coefficients of variance (standard deviation/mean). Ten minute kick/sweep net samples were collected from five sites in each of three lakes. They found that spatial differences accounted for 60% of the variation in samples collected twice on the same day and for 46% for samples collected over a three week period. Samples collected four times every 6 to 10 weeks, however, showed greater temporal than spatial variation (26% and 9% respectively), attributable to seasonal changes in abundance. Table 5.3 shows the degree of repeatability and precision found by Reid, Somers & David (1995) for taxonomic groups in samples collected on the same day. High repeatability and precision may be analogous to random distributions of taxa, while low values may be indicative of clumped distributions.

In studies of riverine macroinvertebrates, contagious distributions are common (Minshall & Minshall, 1977) and hence count data has frequently been normalized by log (x + 1) transformation (Sheldon & Haick, 1981; Feminella & Resh, 1990; Norris & Georges, 1993; Scarsbrook & Townsend, 1993). Previously in this work (Chapters 3 and 4) data were also found to be skewed and were normalized by log (x + 1) transformation. This related to distributions among lakes, and among meso-habitats while the distribution of macroinvertebrates within meso-habitats was not fully investigated. Concern about variations in macroinvertebrate assemblages over relatively small spatial scales has been raised with reference to lake classification (Johnes, Moss, & Phillips, 1994), and other authors have noted potential problems for quantitative sampling caused by substratum heterogeneity (Hunding 1971; Dall, Heegard & Fullerton, 1984; and Rasmussen, 1988; Wetzel & Likens, 1991; Harrison & Hildrew, 1998; Brodersen, Dall & Lindegaard, 1998). None of these authors specified spatial scales of distributions that may cause sampling difficulties. In Chapter 4, it was shown that different meso-habitats supported different and often distinct macroinvertebrate assemblages but that within an apparently uniform substratum (meso-habitat), samples were generally similar. This conclusion was, however, based on relatively few samples (5) and the work aimed to assess differences in macroinvertebrate distributions between meso-habitats rather than within a meso-habitat. Variations in the distribution of fauna within meso-habitats may occur as a result of different micro-habitats nested within them (Covich, Palmer & Crowl, 1999) and species may aggregate independent of environmental variables (Minshall & Minshall, 1977; Downes, Lake & Schreiber, 1993; Ságová & Adams, 1993; Reid, Somers & David 1995). This is implicit of behavioural responses promoting aggregations.

Table 5.3. Repeatability (temporal similarity) and precision (spatial similarity) of macroinvertebrate abundances in kick/sweep samples taken on the same day. (Repeatability classified as: high, > 50% of variability explained and site effects larger than temporal effects; moderate, > 20% of variance explained and site effects > temporal effects and; low, 20% of variance explained or site effects < temporal effects. Precision classified as: high, coefficient of variance (CV) < 30%; moderate, CV > 30% but < 40% and; low, CV > 40%). (After Reid, Somers & David, 1995).

Taxa	Repeatability	Precision
Oligochaeta	High	Moderate
Hirudinea	Low	Low
Amphipoda	High	Moderate
Ephemeroptera	Low	Low
Odonata	High	High
Hemiptera	Moderate	High
Trichoptera	Moderate	Low
Coleoptera	High	Low
Diptera (total)	High	High
Ceratopogonidae	Moderate	High
Chironomidae	High	High
Tanyponidae	High	Low
Orthocladiinae	Low	Moderate
Chironominae	High	High
Chironomini	High	High
Tanytarsini	High	High
Pelecypoda	High	Low

It is possible that biotic or abiotic variations in substrata may not be observed during sampling, Dole-Oliver & Marmonier (1992), associated patchy distributions of riverine interstitial macroinvertebrates in gravel bars with areas of upwelling and downwelling of water and such factors could go unnoticed during sampling.

The aim of this study was to assess the spatial distribution of macroinvertebrates within the meso-habitat scale. This was performed for both purely scientific reasons and practical or management reasons. Clumping is of ecological interest as it has implications for the reproduction and survival of species. With regard to management, macroinvertebrate clumping may effect their usefulness in determining ecological quality, as taxa that are highly patchy in their distribution within a habitat may not be a useful inclusion in assessment methodology.

5.2. Statistical Indicators of Distribution Patterns

Work on the spatial distribution of organisms has identified three broad patterns of distribution; regular, random and clumped. These three dispersion patterns are each associated with mathematical models, the positive binomial, the Poisson and the negative binomial models of distribution respectively. For each pattern of distribution, biological examples can be found (Elliott, 1977; Luwig & Reynolds, 1988; Fowler & Cohen, 1990). Each of these statistical frequency distributions have been described in accordance with their variance (s^2) to mean ($\bar{x}$) ratios. For regular patterns $s^2 < \bar{x}$, for random patters $s^2 = \bar{x}$ and for clumped patterns $s^2 > \bar{x}$.

These models, while having distinct mathematical descriptions, in fact represent intervals along a continuum from regular to highly clumped distributions (Luwig & Reynolds, 1988). Chi-Square test (variance to mean ratio) for agreement with a Poisson series (which is an index of dispersion) also indicates contagious and regular distributions (Equation 5.1) (Elliott, 1977). Besides variance to mean ratios, other simple statistical parameters can be used to describe distributions. These include the median, inter-quartile ranges and the skewness of the data. To compare the degree of aggregation among populations, indices of dispersion have also been created. These tend to be based on the ratio of sample variance to the mean (George, 1974), or $\hat{k}$, an estimate of the parameter k, shown in Equation 5.2 (Elliott, 1977). A more accurate value of k can be calculated from the maximum likelihood equation (Equation 5.3)

(Elliott, 1977) where suitable values of $\hat{k}$ are substituted in an iteration until the equation balances.

Equation 5.1

$$\chi^2 = \frac{s^s\,(n-1)}{\bar{x}}$$

Equation 5.2.

$$\hat{k} = \frac{\bar{x}}{s^2 - \bar{x}}$$

Equation 5.3.

$$n \log_e\left(1 + \frac{\bar{x}}{\hat{k}}\right) = \sum\left(\frac{A_{(x)}}{\hat{k} + \bar{x}}\right)$$

k is derived from the negative binomial and it provides an index of clumping if the observed and expected distributions agree (Elliott, 1977). k and $s^2/\bar{x}$ ratio may not be independent of the mean and are therefore often dependent upon the population density and sample size. This may hinder comparisons between populations (Taylor, 1961). In order to overcome this problem a number of indices that describe aggregation relatively well over a range of population densities exist. One, Lloyd's index of mean crowding (Equation 5.4), was originally devised to assess the number of individuals in a population that surround any given individual. Lloyd's index ($\overset{*}{x}$), and it's relation to mean density ($\overset{*}{x}/\bar{x}$), have been used to describe patchiness of zooplankton populations (Green, 1966; George, 1974; Mitchell & Williams, 1982; Irvine, 1987, 1989) and macroinvertebrates (Sheldon & Haick, 1981).

Equation 5.4.

$$\overset{*}{x} = \bar{x} + \left(\frac{s^2}{\bar{x}} - 1\right)$$

5.3. Methods

5.3.1. Macroinvertebrate Samples

To determine the distributions of animals within meso-habitats, twenty replicate samples were collected from each of four areas of uniform substrata in Lough Inchiquin, County Clare. The substrata types were marl and coarse particulate organic matter (CPOM), cobbles & pebbles (30% & 70% respectively) (both sets collected in April, 1997), stands of *Schoenoplectus lacustris*, and stands of *Phragmites* (both sets collected in September, 1997). Samples were collected using a kick/sweep net with frame size of 0.25 x 0.25 m and 1 mm mesh in the same way as described in Chapter 3, Section 3.2.1. Sample locations within each meso-habitat were chosen randomly with x and y co-ordinates taken from a random number table. Care was taken while sampling to limit disturbance to the rest of the meso-habitat and the same position was not sampled twice. Macroinvertebrate samples were preserved in the field in 70% IMS and returned to the lab for sorting and identification to the furthest practicable taxonomic level, usually species. Data are presented in Appendix 4.

5.3.2. Data Analysis

The distribution of the sample data was examined at two scales. Initially the assemblages of the four meso-habitats were compared to see if they were similar. Following this, distributions were assessed independently for each of the meso-habitats. Total abundances and taxa richness were assessed to see if samples contained comparable number of animals, and the frequency distributions of individual species were assessed to see if they exhibited regular, random or clumped distributions.

Distributions were assessed using a variety of models, as any one should not be used independently to justify a particular hypothesis (Elliott, 1977). These were variance to mean ratios, 95% confidence intervals about the mean, skewness, tests for agreement with the Poisson series (Chi-squared variance to mean ratio test (George, 1974; Elliott 1977; Minshall & Minshall, 1977)) and negative binomial series (Chi-squared goodness of fit test (Elliott, 1977)). k from the negative binomial was calculated precisely by the maximum likelihood equation. Lloyd's index of mean crowding ($\overset{*}{x}$) and its relation to mean density were also calculated. Spearman rank correlation (r_s) was used to determine if clumping measures were dependent on mean abundances, as good indicators of distributions should not be influenced by the mean (Elliott, 1977). TWINSPAN and DECORANA were used to identify differences among the four habitats and ensure that the habitats that were being investigated supported dissimilar macroinvertebrate assemblages. Multidimensional scaling (calculated as Average

Euclidean distances between groups) was used to assess variations within the collections of fauna in the 20 samples from each habitat. As similarities in the assemblages were being investigated, as opposed to differences, Hierarchical methods such as cluster analysis and TWINSPAN were not applicable as these methods are designed to divide samples.

5.4. Results

5.4.1. Differences in Assemblages Among the Four Meso-Habitats Sampled in Lough Inchiquin

TWINSPAN (Figure 5.1) and DECORANA (Figure 5.2) analysis of the samples from the four habitats showed that the assemblages were markedly different from each other. In the TWINSPAN analysis, macrophyte and inorganic substrata were split at the first division. The second division of inorganic substrata spilt the 20 cobble & pebble samples from the 20 marl & CPOM samples. Seventeen samples from *Phragmites* stands were separated from the 20 from *Schoenoplectus lacustris* at the second division. Three samples from *Phragmites* were clustered with the samples from *Schoenoplectus lacustris*, suggesting that their assemblages were similar. The DECORANA analysis also grouped samples from like habitats. The groupings of inorganic samples were tighter, showing less variation than those from the macrophyte habitats. Samples from *Phragmites* showed the largest variation. Although there was some overlap, the four groups were distinctive.

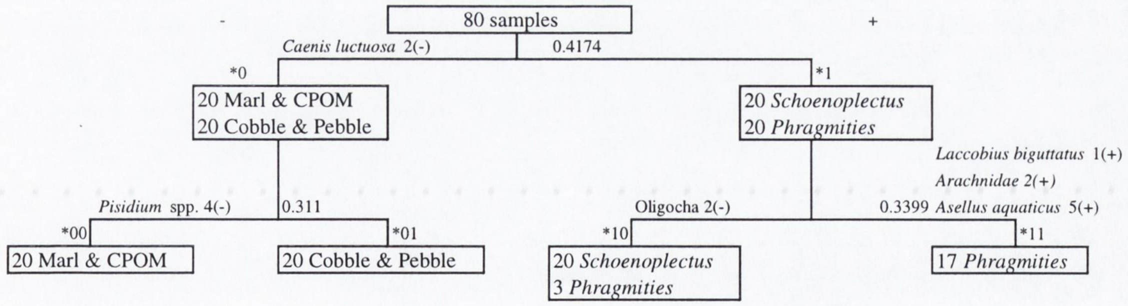

Figure 5.1. TWINSPAN analysis of 20 replicate samples from four meso-habitats found in Lough Inchiquin.

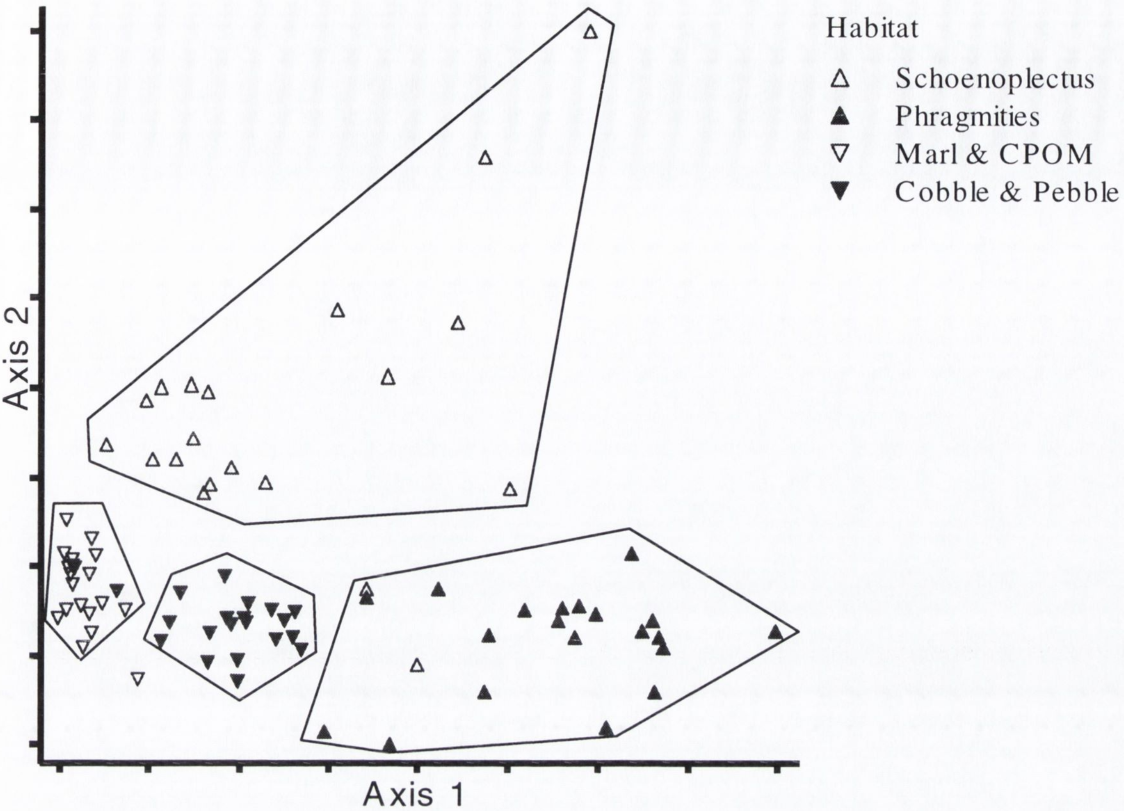

Figure 5.2. DECORANA analysis of 20 replicate samples from four meso-habitats found in Lough Inchiquin.

5.4.2. Taxa Richness and Total Abundance Patterns in the 20 Replicate Samples

Table 5.4 shows summary statistics of the taxa richness data from the four habitats. These statistics indicate that taxa richness in two cases (for cobbles & pebbles and *Schoenoplectus*) were approximately randomly distributed because skewness was low and means and medians were similar. Sample variance in the case of marl & CPOM was smaller than the mean, suggesting a uniform distribution while the sample variance in *Phragmites* was greater than the mean suggesting a clumped distribution. The distribution of taxa richness data for the four habitats is shown in Figure 5.3. Chi-squared tests (variance to mean ratios) indicated that taxa richness in the 20 samples from cobble & pebble substrata and *Schoenoplectus lacustris* stands conformed to the Poisson series, indicating random distributions (cobble & pebble, $\chi^2_{19} = 11.53$; *Schoenoplectus lacustris,* $\chi^2_{19} = 13.45$; $P > 0.05$ in both cases). In marl & CPOM, $\chi^2_{19} = 5.63$ ($P < 0.05$) indicating that taxa richness was regularly distributed. The distribution of taxa from *Phragmites* stands also did not conform to the Poisson series with χ^2_{19} = 35.75 (P < 0.05), indicating a clumped distribution.

Table 5.4. Summary statistics for taxa richness data from four meso-habitats in Lough Inchiquin.

Summary statistics	**Habitat**			
	Marl & CPOM	**Cobble & pebble**	***Phragmites***	***Schoenoplectus***
n	20	20	20	20
Mean (± 95% *c.l.*)	12.8 ± 0.85	14.9 ± 1.32	13.0 ± 0.82	10.2 ± 1.18
Median	13	15	14	9.5
Variance	3.78	9.04	23.52	6.14
Skewness	- 0.30	0.05	-0.69	- 0.42

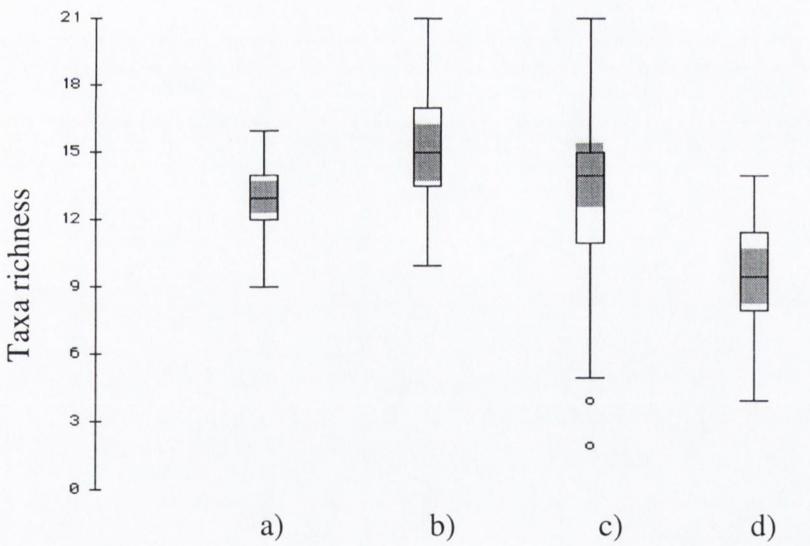

Figure 5.3. Distribution of taxa richness data for a) Marl & CPOM, b) Cobbles & pebbles, c) *Phragmites* and d) *Schoenoplectus* habitats. (Centre line = mean, shaded area = 95% *c.l.*, box = upper and lower quartiles, whiskers = main body of data, o = outliers) (n = 20 in each case).

Table 5.5 shows summary statistics for the abundance data of the four habitats. In all four habitats, median values were similar to mean values and skewness values were low. Variances were much greater than means however, indicating that the data were not normally distributed. This was confirmed by Chi-squared test (variance to mean ratio) for agreement with a Poisson series. For all four habitats, agreement with a Poisson series was rejected ($P < 0.01$) and high values of χ^2 indicated that macroinvertebrates were clumped (marl & CPOM, $\chi^2_{19} = 1254$; cobbles & pebbles, $\chi^2_{19} = 1668$; *Phragmites* $\chi^2_{19} = 314$ and; *Schoenoplectus* $\chi^2_{19} = 728$). Comparisons of the observed and expected frequencies predicted by the negative binomial model using χ^2 goodness of fit, for the marl and CPOM substrata, revealed that the two were significantly dissimilar, although only just so ($P < 0.05$ $\chi^2_{23} = 38.57$, critical $\chi^2 = 35.17$). This was also the case for the cobble and pebble substrata ($P < 0.05$ $\chi^2_{22} = 37.68$, critical $\chi^2 = 33.92$). In *Schoenoplectus lacustris* stands and *Phragmites* stands observed and negative binomial distributions were similar ($P > 0.05$, $\chi^2_{24} = 27.95$ and $P > 0.05$, $\chi^2_{13} = 16.60$ respectively). Data distributions are shown in Figure 5.4.

Table 5.5. Summary statistics for abundance data from four meso-habitats in Lough Inchiquin.

Summary statistics	**Habitat**			
	Marl & CPOM	**Cobbles & pebbles**	***Phragmites***	***Schoenoplectus***
n	20	20	20	20
Mean (± 95% *c.l.*)	833 ± 102	590 ± 100	84 ± 7	112 ± 29
Median	840	551	78	108
Variance	55014	51786	1388	4290
Skewness	-0.17	0.64	0.05	0.57

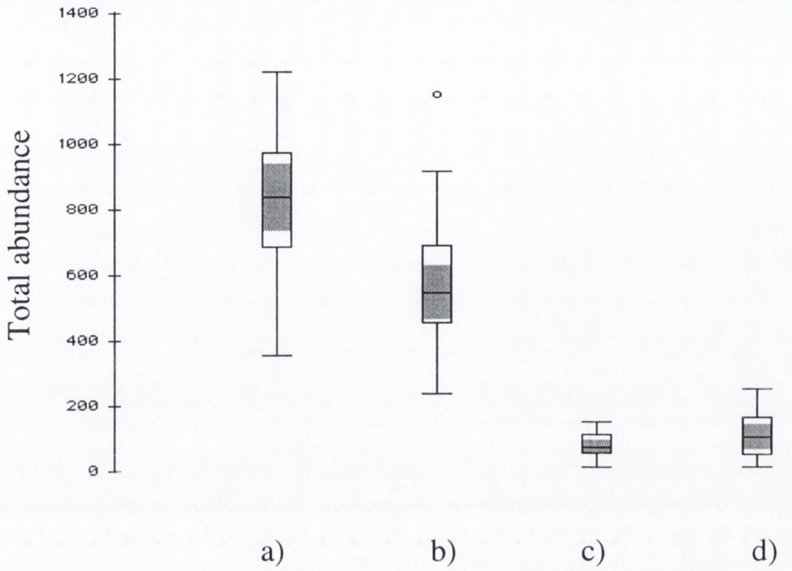

Figure 5.4. Distribution of abundance data for a) Marl & CPOM, b) Cobbles & pebbles, c) *Phragmites* and d) *Schoenoplectus* habitats. (Centre line = mean, shaded area = 95% *c.l.*, box = upper and lower quartiles, whiskers = main body of data, o = outliers) (n = 20 in each case).

5.4.3. The Distribution of Taxa Within a Marl and Coarse Particulate Organic Matter Meso-Habitat in Lough Inchiquin

Thirty taxa were found in the marl and CPOM habitat. The proportional abundance contained in each of the 20 replicates at the taxonomic level of Order is shown in Figure 5.5. Proportional abundances of taxa appeared to differ among samples. Each sample did, however, contain representatives of most macroinvertebrates at the taxonomic level of Order.

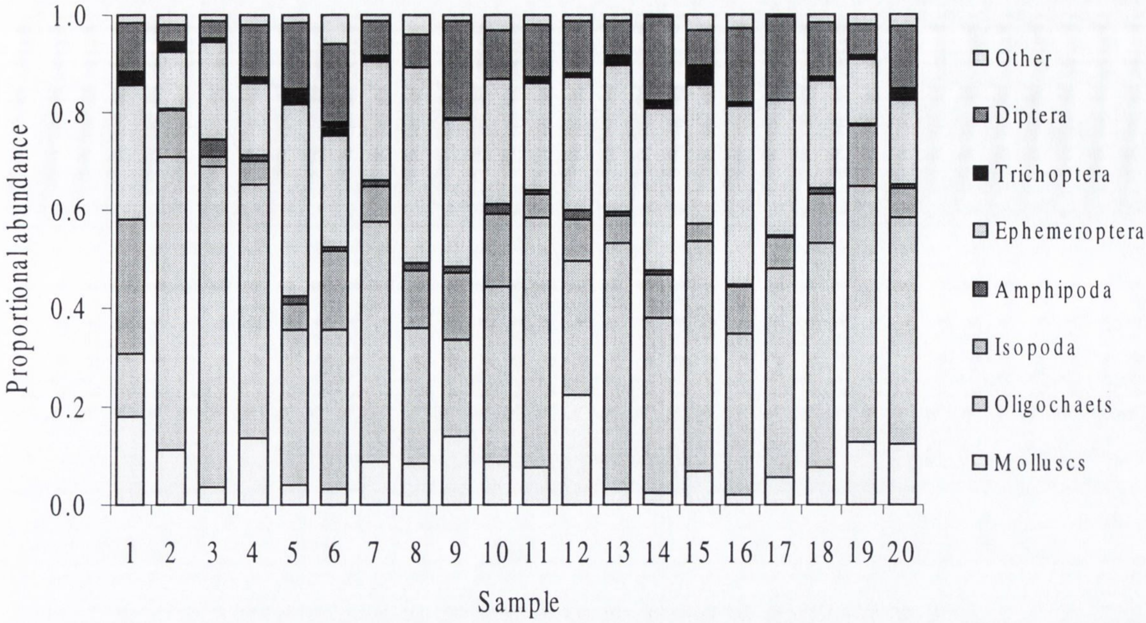

Figure 5.5. The proportional abundance of macroinvertebrates Orders found in the 20 replicate samples collected from marl and CPOM substratum. (Orders that contributed less than one percent of the total abundance were grouped and classified as "other.").

Of the thirty taxa found in the marl and CPOM substrata, 13 were found in more than 5 samples (Table 5.6). The most prolific taxa were oligochaetes, found in all 20 samples and with the largest mean abundance. The mayfly *Caenis luctuosa*, the isopod, *Asellus aquaticus,* the pea mussel *Pisidium* spp. and Chironomidae fly larvae were also found in all 20 replicates in high abundances. For all but one species (*Sericostoma personatum)*, sample variance was greater than the mean, with variance to mean ratios > 1. Only *Erpobdella octoculata* and *Sericostoma personatum* conformed to Poisson series ($P >$ 0.05, df. = 19). For both of these taxa variance to mean ratios were low.

Table 5.6. Measures of abundance distribution for taxa found in five or more samples from marl and CPOM covered substratum. Count = the number of samples in which taxa were present. Chi-squared test (variance to mean ratio) calculated for: agreement with a Poisson series, * = significant contagion at $P > 0.05$ and; agreement with a negative binomial series with df. degrees of freedom, * = $P > 0.05$.

Taxa	Count	s^2	$\bar{x} \pm 95$ % *c.l.*	$s^2/\bar{x}$	No. of counts within 95% *c.l.*	Skewness	Poisson	Negative binomial			k	$\overset{*}{x}$	$\overset{*}{x}/\bar{x}$
							χ^2	df	χ^2	Grouped by			
Polycelis nigra/tenuis	17	55.2	7.3 ± 3.26	7.6	5	2.03	144*	4	0.24*	5	1.07	13.86	1.90
Bithynia tentaculata	14	14.7	3.5 ± 1.68	4.2	7	1.15	80*	4	18.48	–	–	6.70	1.91
Pisidium spp.	20	3370.3	70.8 ± 25.4	47.6	5	1.27	904*	5	5.90*	8	1.79	117.40	1.66
Oligochaeta	20	23708.0	339.2 ± 67.4	69.9	6	0.33	1328*	9	22.63	50	–	408.09	1.20
Helobdella stagnalis	17	14.7	4.25 ± 1.68	3.5	7	1.58	66*	6	21.14	–	–	6.71	1.58
Erpobdella octoculata	15	3.5	2.1 ± 0.82	1.7	4	0.55	31	3	6.39*	–	12.85	2.75	1.31
Asellus aquaticus	20	4312.6	79.2 ± 28.7	54.5	11	2.93	1035*	5	9.17*	20	2.47	132.65	1.67
Gammarus lacustris	19	46.2	7.65 ± 2.98	6.0	8	2.61	115*	2	2.86*	5	2.25	12.69	1.66
Caenis luctuosa	20	4691.4	206 ± 30.0	22.8	8	0.17	433*	14	22.13*	20	9.31	227.77	1.11
Athripsodes cinereus	18	79.0	11.25 ± 3.90	7.0	6	0.71	134*	3	3.36*	–	1.34	17.28	1.54
Sericostoma personatum	5	0.3	0.3 ± 0.25	1.0	2	1.84	21	0	–	–	–	0.39	1.29
Chironomidae	20	2262.7	88.2 ± 1.22	25.7	10	0.40	487*	7	7.33*	20	3.46	112.85	1.28
Ceratopogonidae	13	7.8	3.1 ± 20.8	2.5	4	0.42	48*	5	42.94	–	–	4.61	1.49

Erpobdella octoculata also conformed to the negative binomial however, and as high values of k and low skewness indicates, it was not strongly clumped. Elliott (1977) stated that agreement with a Poisson series does not prove randomness, but indicates that the hypothesis of randomness is not disproved. This may explain the agreement with both distribution models. In all other cases, χ^2 tests for agreement with a Poisson indicated clumped distributions. Including *Erpobdella octoculata,* the distribution of 8 of the 13 taxa agreed significantly ($P > 0.05$) with the negative binomial.

Speraman rank correlation showed that sample variance and Lloyds index of mean crowding ($\overset{*}{x}$) were associated with the mean ($r_s = 0.93$ and 0.98 respectively; $P < 0.01$, $n = 13$). k and $\overset{*}{x}/\bar{x}$ were independent of the mean ($r_s = 0.26$ and 0.29 respectively; $P >$ 0.05, $n = 8$ and 13 respectively). This indicates that both k and $\overset{*}{x}/\bar{x}$ were good measures of the degree of clumping. Lloyds index divided by mean abundance showed that *Bithynia tentaculata* and *Polycelis nigra/tenuis* were most clumped. These taxa were found in 14 and 17 samples respectively. k was smallest for Ceratopogonidae followed by *Polycelis nigra/tenuis* and *Athripsodes cinereus.* k was greatest for *Erpobdella octoculata, Caenis luctuosa,* Oligochaeta and Chironomidae respectively, all of which had low $\overset{*}{x}/\bar{x}$ values indicating that they were least clumped.

Skewness was also independent of the mean (r_s = - 0.34; $P > 0.05$, $n = 13$) and correlated with $\overset{*}{x}/\bar{x}$ ($r_s = 0.75$; $P < 0.01$, $n = 13$.). Taxa that were most skewed were *Asellus aquaticus*, *Gammarus lacustris* and *Polycelis nigra/tenuis*, while *Caenis luctuosa*, oligochaetes and chironomids attained the lowest skewness values indicating a more normal distribution. To summarise the ordering of the clumping Table 5.7 lists taxa depending upon the summed rank order of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. For taxa where k was not a valid indicator of clumping (because agreement with the negative binomial was not found) the average rank for the other two measures was taken and applied in the ordering of k. Taxa appearing at the top of the table showed the greatest degree of clumping and those at the bottom the most random distributions.

In a Multidimensional scaling analysis (Figure 5.6) most samples clustered relatively close together, or in a continuum, indicating that they contained generally similar collections of macroinvertebrates. Only sample 1 appeared to be separate from the main cluster, suggesting that the assemblage in this sample was somewhat different from the others. Reference back to Figure 5.5 shows that this sample contained a relatively larger proportional abundance of isopoda, and fewer oligochaetes than the other samples.

Table 5.7. Taxa found in 5 or more samples (excluding those which conformed to a Poisson series) from marl and CPOM substratum ordered by the summed ranks of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. Where k was not applicable, the average rank of $\overset{*}{x}/\bar{x}$ and skewness was used in place of k. Most clumped taxa appear at the top of the table.

Taxa
Polycelis nigra/tenuis
Asellus aquaticus
Gammarus lacustris
Athripsodes cinereus
Pisidium spp.
Helobdella stagnalis
Bithynia tentaculata
Ceratopogonidae
Erpobdella octoculata
Chironomidae
Caenis luctuosa
Oligochaeta

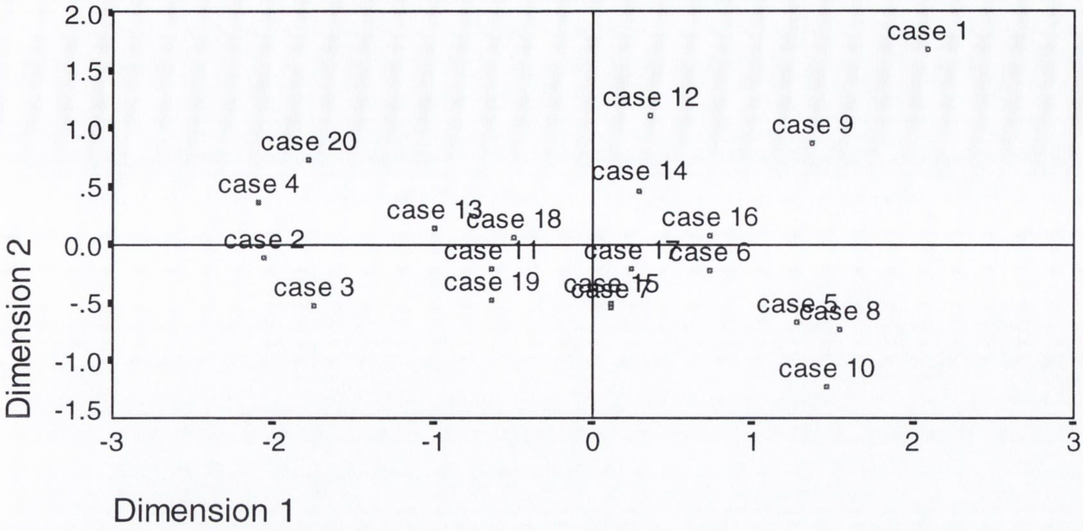

Figure 5.6. Multidimensional scaling dimensions 1 and 2 of samples from marl and CPOM covered substrata. Distance measure used was average Euclidean distance between groups, $n = 20$.

5.4.4. The Distribution of Taxa Within a Cobble and Pebble Meso-Habitat in Lough Inchiquin

Forty-one distinctive taxonomic groups were found in the stone and pebble substrata. The proportional abundance by Order of animals in the 20 replicate samples is shown in Figure 5.7. Samples contained representatives of most taxonomic orders, although proportionally differences among samples were apparent. The most prevalent taxa were oligochaetes, isopods and ephemeropterans.

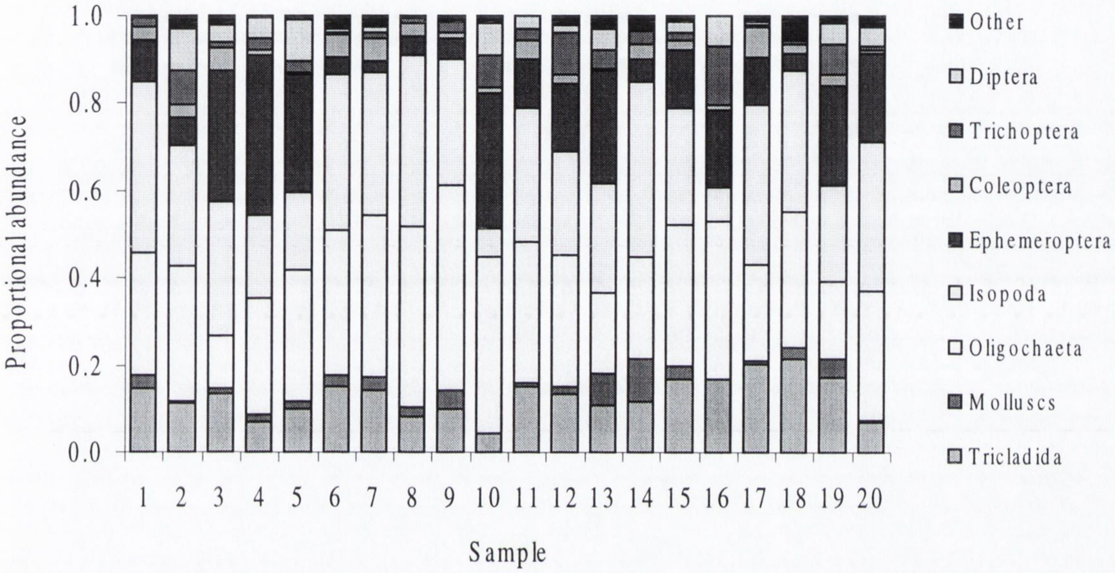

Figure 5.7. The proportional abundance of macroinvertebrates per Order found in the 20 replicate samples collected from cobble and pebble substratum. (Orders that contributed less than one percent to the total abundance were grouped and classified as "other").

Table 5.8 shows distribution measures for taxa occurring in five or more samples from a cobble and pebbles substratum. Sample variance was strongly associated with the mean (r_s = 0.97, P < 0.05, n = 21) as was Lloyd's index (r_s = 0.97, P < 0.01, n = 21). k was independent of x (r_s = 0.44, P > 0.05, n = 11), however $\overset{*}{x}/\bar{x}$ was not (r_s = - 0.74, P < 0.01, n = 21). The data contained four obvious outliers, however even with their removal $\overset{*}{x}/\bar{x}$ was still dependent on $\bar{x}$, although less significantly (r_s = - 0.58, P < 0.05, n = 21). For all taxa, variance was greater than mean abundance, suggesting negative binomial distributions. Test for

Table 5.8. Measures of abundance distribution for taxa found in five or more samples from a cobble & pebble substratum. Count = the number of samples in which taxa were present. Chi-squared test (variance to mean ratio) calculated for: agreement with a Poisson series, * = significant contagion at $P > 0.05$ and; agreement with a negative binomial series with df. degrees of freedom, * = $P > 0.05$

Taxa	Count	s^2	$\bar{x} \pm 95$ % c.l	$s^2/\bar{x}$	No. of counts within 95% cl	Skewness	Poisson	Negative binomial			k	$\overset{*}{x}$	$\overset{*}{x}/\bar{x}$
							χ^2	df	χ^2	Grouped by			
Dugesia polychroa	6	10.9	1.8 ± 1.45	6.1	0	2.05	115*	1	6.6	–	–	6.86	3.81
Polycelis nigra/tenuis	20	955.8	70.0 ± 13.55	13.7	5	0.19	259*	9	22.5	10	–	82.65	1.18
Dendrocoelum lacteum	8	3.4	1.3 ± 0.81	2.6	2	0.86	49*	2	12.1	–	–	2.9	2.23
Theodoxus fluviatilis	18	16.8	5.9 ± 1.79	2.9	3	0.25	54*	7	18.9	–	–	7.72	1.32
Bithynia tentaculata	12	65.1	4.0 ± 3.53	16.3	8	3.60	309*	2	4.7*	–	0.35	19.26	4.82
Lymnaea peregra	5	1.0	0.5 ± 0.44	2.2	0	2.79	42*	1	0.1*	–	0.35	1.67	3.70
Pisidium spp.	7	7.0	1.6 ± 1.16	4.5	2	1.68	86*	1	2.9*	–	0.22	5.06	3.27
Sphaerium spp.	6	0.9	0.5 ± 0.41	1.8	0	3.07	38*	1	3.4*	–	7.19	1.43	3.18
Oligochaeta	20	6569.4	175.2 ± 35.52	37.5	5	0.57	712*	11	12.2*	20	5.03	211.7	1.21
Helobdella stagnalis	7	9.1	1.9 ± 1.32	4.9	1	1.38	93*	1	5.6	–	–	5.76	3.11
Erpobdella octoculata	7	3.5	1.3 ± 0.82	2.8	1	0.90	53*	1	15.4	–	–	3.02	2.41
Asellus aquaticus	20	3731.3	152.2 ± 26.77	24.5	9	0.36	466*	9	15.9*	20	5.99	175.72	1.15
Crangonyx pseudogracilis	12	16.5	4.1 ± 1.78	4.1	3	0.33	77*	3	9.9	–	–	7.12	1.76
Gammarus duebeni	5	1.0	0.5 ± 0.44	2.2	0	2.79	42*	2	0.1*	–	0.35	1.67	3.70
Caenis luctuosa	20	10304.8	104.2 ± 44.49	98.9	6	1.14	1879*	5	8.8*	20	1.08	202.09	1.94
Ephemera danica	11	6.5	1.8 ± 1.12	3.6	6	1.61	68*	3	5.5*	–	0.57	4.4	2.45
Oulimnius tuberculatus	20	98.5	14.2 ± 4.35	6.9	6	1.31	132*	4	2.3*	5	2.98	20.14	1.42
Tinodes waeneri	14	465.6	15.8 ± 9.46	29.5	5	1.94	560*	3	1.1*	10	0.38	44.27	2.80
Sericostoma personatum	18	8.4	4.1 ± 1.27	2.1	11	1.20	39*	6	20.8	–	–	5.15	1.26
Paraponyx stratiotata	5	0.9	0.4 ± 0.41	2.2	15	3.27	42*	1	4.7	–	–	1.61	4.03
Chironomidae	15	719.3	22.8 ± 11.75	31.5	6	1.81	599*	3	9.7	10	–	53.35	2.34

agreement with a Poisson series was rejected in all instances ($P < 0.05$) and indicated clumped distributions. The distribution of eleven taxa conformed significantly to predicted negative binomial frequencies and relatively few samples contained abundances of taxa that fell within the 95% confidence intervals about the mean.

Oligochaeta, *Asellus aquaticus, Caenis luctuosa, Polycelis nigra/tenuis* and *Oulimnius tuberculatus* were found in all 20 replicates with mean abundances of 175.2, 152.2, 104.2, 70.0 and 14.2 respectively. The number of samples a taxon was found in was inversely related to $\overset{*}{x}/\bar{x}$ (r_s = - 0.84, $P < 0.01$, n = 21) and the above mentioned taxa had low values of $\overset{*}{x}/\bar{x}$ indicating that their distributions were less clumped. *Bithynia tentaculata, Paraponyx stratiotata, Dugesia polychroa, Lymnaea peregra, Gammarus duebeni, Pisidium* spp., *Sphaerium* spp. and *Helobdella stagnalis* all had $\overset{*}{x}/\bar{x}$ values greater than 3 and with the exception of *Bithynia tentaculata*, were found in fewer than 8 samples. k was inversely related to $\overset{*}{x}/\bar{x}$ (Speraman rank correlation, r_s = - 0.75, P < 0.05, n = 11) and was lowest for *Pisidium* spp., *Bithynia tentaculata, Lymnaea peregra, Gammarus duebeni* and *Tinodes waeneri* (all below 0.4). Skewness was related to $\overset{*}{x}/\bar{x}$ (r_s = 0.89, $P < 0.01$, n = 21) and to $\bar{x}$ (r_s = -0.59, $P < 0.01$, n = 21), although with the removal of four outliers it was independent of $\bar{x}$ (r_s = -0.42, $P < 0.01$, n = 17). Skewness was greatest for *Bithynia tentaculata, Paraponyx stratiotata, Sphaerium* spp., *Lymnaea peregra* and *Gammarus duebeni*. The summed ranks of values of $\overset{*}{x}/\bar{x}$, k and skewness indicated that *Bithynia tentaculata, Dugesia polychroa, Gammarus duebeni* and *Lymnaea peregra* were most clumped in the cobble and pebble substratum, and *Polycelis nigra/tenuis, Asellus aquaticus*, Oligochaeta, *Sericostoma personatum* and *Theodoxus fluviatilis* were least clumped (Table 5.9).

Multidimensional scaling (Figure 5.8) indicated that the majority of samples from cobble & pebble substratum were clustered relatively together, with few outliers. Only four samples (3, 4, 5 and 10) appeared removed from the rest, indicating that the majority of samples contained similar assemblages.

Table 5.9. The thirteen taxa found in more than 5 samples from cobble & pebble substratum ordered by the summed ranks of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. Where k was not applicable, the average rank of $\overset{*}{x}/\bar{x}$ and skewness was used in place of k. Most clumped taxa appear at the top of the table.

Taxa
Paraponyx stratiotata
Bithynia tentaculata
Gammarus duebeni
Dugesia polychroa
Lymnaea peregra
Pisidium spp.
Tinodes waeneri
Chironomidae
Helobdella stagnalis
Sphaerium spp.
Ephemera danica
Erpobdella octoculata
Caenis luctuosa
Oulimnius tuberculatus
Dendrocoelum lacteum
Sericostoma personatum
Crangonyx pseudogracilis
Oligochaeta
Theodoxus fluviatilis
Asellus aquaticus
Polycelis nigra/tenuis

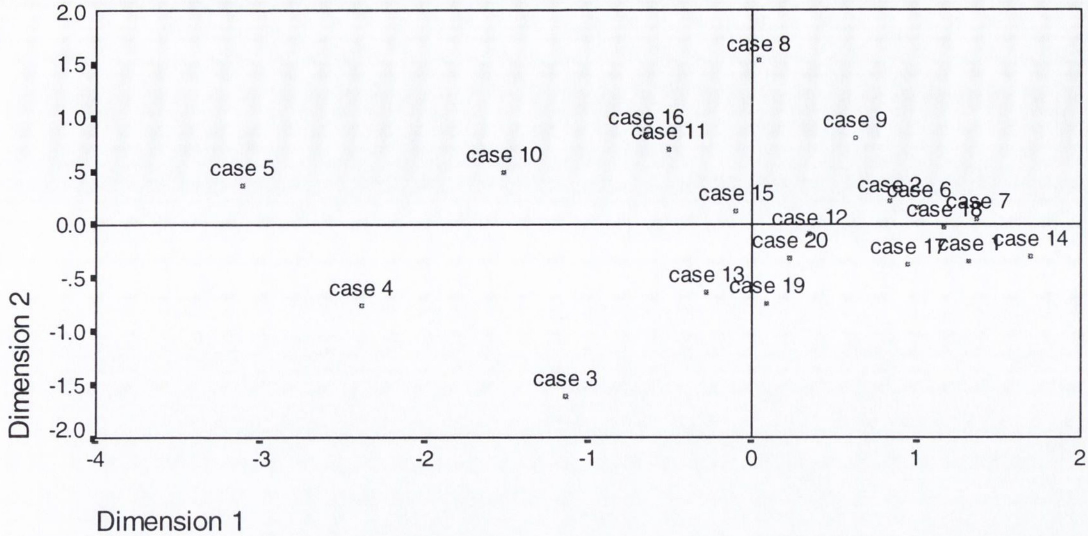

Figure 5.8. Multidimensional scaling dimensions 1 and 2 of samples from cobble & pebble substratum. Distance measure used was average Euclidean distance between groups, $n = 20$.

5.4.5. The Distribution of Taxa Within a *Phragmites* Meso-Habitat in Lough Inchiquin

Fifty distinctive taxonomic groups of macroinvertebrates were found in stands of *Phragmites*. Proportional abundance, at the taxonomic level of Order, found in the 20 replicate samples is shown in Figure 5.9. The most abundant Order in the samples was Isopoda. At the taxonomic level of Order, many samples appeared to contained proportionally similar collections of animals, noticeably samples 1 to 9, while samples 17 to 20 are prominent due to the dominance of Isopoda and the low abundance of other taxa.

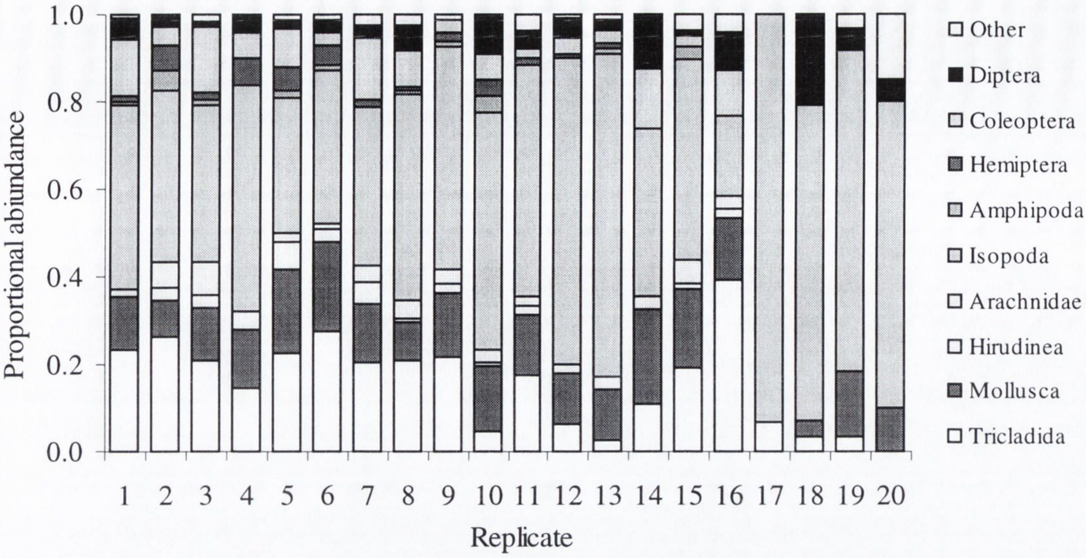

Figure 5.9. The proportional abundance of macroinvertebrates per Order found in the 20 replicate samples collected from *Phragmites* stands.

Indicators of distributions for the twenty taxa found in five or more samples are given in Table 5.10. $\overset{*}{x}$ was related to $\bar{x}$ ($r_s = 0.94$, $P < 0.01$, $n = 20$) and in all instances variance was greater than, and associated with, mean abundance ($r_s = 0.97$, $P < 0.01$, $n = 20$). The distributions of five taxa agreed with a Poisson series (*Lymnaea peregra, Theromyzon tessulatum, Crangonyx pseudogracilis* Corixidae nymphs and Tipulidae, where $P > 0.05$) while for the rest, values of χ^2 indicated clumped distributions. In most cases, this was confirmed by agreement with negative binomial distributions. The distributions of Corixidae nymphs and *Theromyzon tessulatum* however, agreed with both the Poisson series and the negative binomial. For Corixidae nymphs the variance and mean were also quite similar ($s^2/\bar{x} = 1.7$) however, the skewness of the data and $\overset{*}{x}/\bar{x}$ were high and the value of *k* very low, indicating that their distribution was aggregated. Their absence from 12 of the 20 samples supports this view. In the case of *Theromyzon tessulatum* the ratio of variance to mean was also close to 1 ($s^2/\bar{x} = 1.5$) suggesting a more normal distribution. Skewness and $\overset{*}{x}/\bar{x}$ were also relatively low and *k* was very high, indicating a more uniform distribution.

Table 5.10. Measures of abundance distribution for taxa found in five or more samples from *Phragmites* stands. Count = the number of samples in which taxa were present. Chi-squared test (variance to mean ratio) calculated for: agreement with a Poisson series, * = significant contagion at $P > 0.05$ and; agreement with a negative binomial series with df. degrees of freedom, * = $P > 0.05$

Taxa	Count	s^2	$\bar{x} \pm 95$ % c.l	$s^2/\bar{x}$	No. of counts within 95% *c.l.*	Skewness	Poisson	Negative binomial			k	$\overset{*}{x}$	$\overset{*}{x}/\bar{x}$
							χ^2	df	χ^2	Grouped by			
Dugesia polychroa	7	1.6	0.8 ± 0.55	2.1	3	1.60	40*	1	2.70*	–	0.48	1.84	2.45
Polycelis nigra/tenuis	19	122.6	13.3 ± 4.85	9.2	5	0.52	175*	4	7.40*	5	1.10	21.52	1.62
Dendrocoelum lacteum	5	0.9	0.5 ± 0.41	1.8	0	1.66	34*	1	4.40	–	–	1.29	2.58
Valvata macrostoma	8	2.4	0.9 ± 0.68	2.7	5	1.87	51*	1	2.94*	–	0.47	2.58	2.86
Viviparus fasciatus	17	19.8	6.3 ± 1.95	3.1	6	0.37	60*	7	13.2*	–	2.08	8.44	1.34
Physa fontinalis	7	1.2	0.7 ± 0.48	1.8	3	1.88	35*	1	2.83*	–	8.29	1.48	2.27
Lymnaea peregra	5	0.6	0.4 ± 0.33	1.4	0	1.60	27	0	–		–	0.82	2.05
Planorbis vortex	9	12.6	2.1 ± 1.56	6.0	5	1.65	114*	2	1.72*	–	0.28	7.11	3.39
Oligochaeta	6	1.4	0.6 ± 0.52	2.6	4	3.09	49*	1	0.24*	–	0.41	2.13	3.87
Helobdella stagnalis	7	2.1	0.9 ± 0.64	2.5	2	1.86	48*	1	1.80*	–	0.40	2.36	2.78
Theromyzon tessulatum	7	0.9	0.6 ± 0.41	1.5	3	1.37	28	1	3.52*	–	20.47	1.07	1.79
Arachnidae	13	3.6	2.1 ± 0.83	1.8	2	0.28	34*	3	8.40	–	–	2.82	1.38
Asellus aquaticus	20	365.9	40.2 ± 8.38	9.1	13	0.78	173*	5	6.25*	10	5.33	48.30	1.20
Crangonyx pseudogracilis	10	1.5	0.9 ± 0.53	1.6	6	1.40	31	1	5.88	–	–	1.53	1.70
Corixidae (nymphs)	8	1.0	0.6 ± 0.44	1.7	6	2.37	31	1	1.74*	–	-10.64	1.25	2.08
Cymatia bonsdorffi	5	3.4	0.8 ± 0.81	4.3	17	2.53	82*	2	2.17*	–	0.17	4.09	5.11
Haliplus confinus	12	6.31	1.9 ± 1.10	3.3	8	1.68	63*	5	3.85	–	–	4.22	2.22
Laccobius biguttatus	13	10.53	3 ± 1.42	3.5	4	0.78	67*	6	9.18*	–	0.73	5.51	1.84
Chironomidae	15	7.99	3.25 ± 1.24	2.5	4	0.35	47*	6	9.52*	–	1.43	4.71	1.45
Tipulidae	5	0.45	0.35 ± 0.29	1.3	0	1.78	24	0	–		2.59	0.64	1.82

$\overset{*}{x}/\bar{x}$ was not independent of the mean (r_s = - 0.48, P < 0.05, n = 20). With the removal of three outliers it was (r_s = - 0.16, P < 0.05, n = 17). It was also inversely related to the number of samples taxa were found in (r_s = - 0.67, P < 0.01, n = 20), indicating that taxa found in fewer samples were clumped to a greater degree. $\overset{*}{x}/\bar{x}$ was greatest for *Cymatia bonsdorffi, Oligochaeta, Planorbis vortex, Valvata macrostoma*, *Helobdella stagnalis* and *Dendrocoelum lacteum*. k was independent of the mean (r_s = 0.11, P > 0.05, n = 15) and inversely related to $\overset{*}{x}/\bar{x}$ (r_s = - 0.70, P < 0.05, n = 15). Values of k were low for Corixidae nymphs, *Cymatia bonsdorffi, Planorbis vortex and Dendrocoelum lacteum* indicating a greater degree of clumping. k was largest for *Physa fontinalis, Asellus aquaticus,* and Tipulidae, indicating a less clumped distribution. Skewness was inversely related to the mean (r_s = - 0.63, P < 0.05, n = 20), but with the removal of three outliers it was independent (r_s = - 0.46, P < 0.05, n = 17). It was also positively related to $\overset{*}{x}/\bar{x}$ (r_s = 0.83, P < 0.01, n = 20). It too indicated that Oligochaeta, *Cymatia bonsdorffi*, Corixidae (nymphs), *Physa fontinalis, Valvata macrostoma* and *Helobdella stagnalis* were not normally or randomly distributed. Table 5.11 lists taxa found in more than five samples in order of the sum of the rank order of 1/k, $\overset{*}{x}/\bar{x}$ and skewness.

Multidimensional scaling (Figure 5.10) showed that samples from *Phragmites* stands tended to fall, broadly, into three clusters. The largest cluster contained samples 17, 18, 20, 11, 14, 3, 2, 6 and 15 (bottom left of the plot). Samples 5, 1, 7, 8, 9 and 4 appeared to be separated from these (top right) and 10, 19 and 13 separate again (bottom right). This suggests that there may have been three apparently distinct assemblages in the *Phragmites* habitat, with certain 'intermediate' samples (*e.g.* samples 19 and 15) forming a continuum, or being transitional, between the distinct assemblages. There were only two extreme outliers (samples 16 and 12).

Table 5.11. The thirteen taxa found in more than 5 samples from *Phragmites* stands ordered by the summed ranks of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. Where k was not applicable, the average rank of $\overset{*}{x}/\bar{x}$ and skewness was used in place of k. Most clumped taxa appear at the top of the table.

Taxa
Cymatia bonsdorffi
Oligochaeta
Corixidae (nymphs)
Valvata macrostoma
Helobdella stagnalis
Planorbis vortex
Dendrocoelum lacteum
Haliplus confinus
Dugesia polychroa
Physa fontinalis
Laccobius biguttatus
Polycelis nigra/tenuis
Chironomidae
Viviparus fasciatus
Arachnidae
Asellus aquaticus

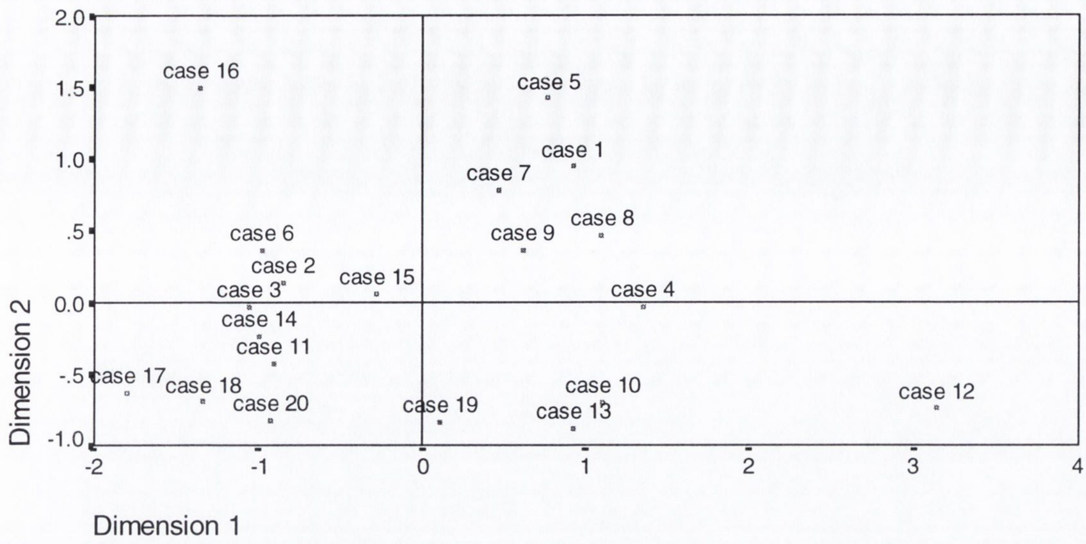

Figure 5.10. Multidimensional scaling dimensions 1 and 2 of samples *Phragmites* stands. Distance measure used was average Euclidean distance between groups, $n = 20$.

5.4.6. The Distribution of Taxa Within a *Schoenoplectus lacustris* Meso-Habitat in Lough Inchiquin

Figure 5.11 shows the proportional abundance of macroinvertebrate Orders found in the 20 samples from *Schoenoplectus* stands. Each sample contained representatives of most Orders, however the majority of samples do not appear to have contained proportionally similar collections of macroinvertebrates.

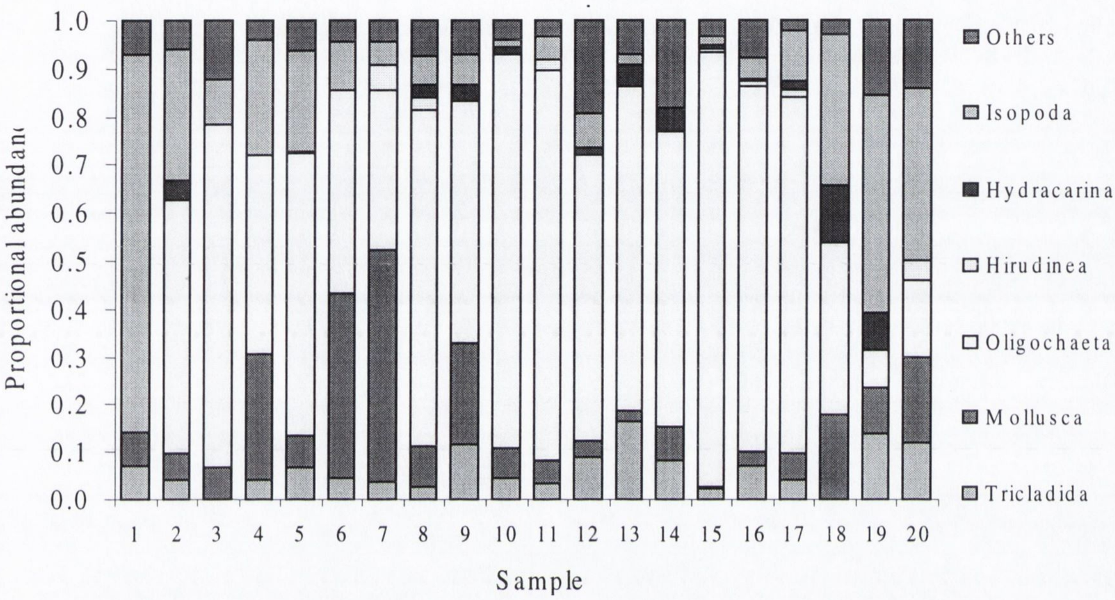

Figure 5.11. The proportional abundance of macroinvertebrates per Order found in the 20 replicate samples collected from *Schoenoplectus lacustris* stands.

Of 35 taxa found in stands of *Schoenoplectus lacustris* Table 5.12 shows measures of distribution for eleven that were present in 5 or more samples. Sample variance was greater than the mean for all but two species, *Caenis luctuosa* and *Haliplus confinus*. The distributions of both of these conformed to a Poisson series ($P > 0.05$) as did the distributions of *Dugesia polychroa, Helobdella stagnalis* and *Theromyzon tessulatum* ($P > 0.05$), where in each case the variance to mean ratio was low. Seven taxa abundances agreed with negative binomial series ($P > 0.05$), however in two instances this was for taxa which also agreed to a Poisson series (*Dugesia polychroa* and *Helobdella stagnalis*).

Table 5.12. Measures of abundance distribution for taxa found in five or more samples from *Schoenoplectus lacustris* stands. Count = the number of samples in which taxa were present. Chi-squared test (variance to mean ratio) calculated for: agreement with a Poisson series, * = significant contagion at $P > 0.05$ and; agreement with a negative binomial series with df. degrees of freedom, * = $P > 0.05$

Taxa	Count	s^2	$\bar{x} \pm 95$ % c.l.	$s^2/\bar{x}$	No. of counts within 95% c.l.	Skewness	Poisson χ^2	Negative binomial df	Negative binomial χ^2	Negative binomial Grouped by	k	$\overset{*}{x}$	$\overset{*}{x}/\bar{x}$
Dugesia polychroa	12	1.0	0.9 ± 0.43	1.1	17	1.78	22	2	3.69*	–	-1.17	1.00	2.15
Polycelis nigra/tenuis	18	11.8	4.9 ± 1.50	2.4	8	0.61	45.7*	7	8.14*	–	2.99	6.30	1.29
Valvata macrostoma	10	6.8	1.8 ± 1.14	3.8	3	1.85	72*	2	3.80	–	–	4.58	2.54
Viviparus fasciatus	18	108.1	8.0 ± 4.56	13.6	8	2.07	258*	2	1.76	–	–	20.54	2.58
Acroloxus lacustris	10	10.1	2.0 ± 1.39	5.1	6	1.81	96*	2	2.74	–	–	6.05	3.03
Oligochaeta	19	4119.7	72.4 ± 28.13	56.9	6	1.09	1081*	5	4.30*	10	1.00	128.30	1.77
Helobdella stagnalis	6	0.8	0.5 ± 0.39	1.6	0	1.75	30	1	3.10*	–	5.80	1.08	2.16
Theromyzon tessulatum	5	0.6	0.4 ± 0.33	1.4	0	1.60	27	0	–	–	–	0.82	2.05
Hydracarina	13	4.6	2.0 ± 0.94	2.3	3	1.29	45*	3	1.37*	–	1.21	3.30	1.69
Asellus aquaticus	19	73.0	11.4 ± 3.74	6.4	6	0.97	122*	3	1.03*	5	1.85	16.80	1.47
Caenis luctuosa	5	0.2	0.3 ± 0.19	0.8	0	1.25	15	0	–	–	–	0.04	0.16
Haliplus confinus	7	0.2	0.4 ± 0.21	0.7	0	0.68	13	0	–	–	–	0.03	0.10
Chironomidae	20	9.42	5.05 ± 1.34	1.9	4	0.03	35*	7	11.12*	–	4.91	5.92	1.17

Abundance variance of *Dugesia polychroa* was almost equal to the mean. It was found in more than half of the samples (12) and a high number of sample abundances fell within the 95% confidence intervals about the mean. These factors suggest that *Dugesia polychroa* were randomly distributed even though values of skewness, k and $\overset{*}{x}/\bar{x}$ indicated clumping. *Helobdella stagnalis* had a higher variance to mean ratio and the value of k, and the low number of sample abundances falling within the 95% confidence intervals suggest that its distribution was clumped. For both of these taxa, and the others that conform to Poisson series, mean abundances were low and, with the exception of *Dugesia polychroa* were found in less than 7 samples. It is likely that for *Dugesia polychroa* and *Helobdella stagnalis* the sample size failed in establishing their distribution in this habitat.

For the taxa shown in Table 5.12 Both sample variance and $\overset{*}{x}$ were associated with the mean ($r_s = 0.96$ and 0.95 respectively, $P < 0.01$ and $n = 13$ in both cases). k and $\overset{*}{x}/\bar{x}$ were independent of the mean ($r_s = 0.21$ and 0.17 respectively, $P > 0.05$ in both cases and $n = 7$ and 13 respectively).

Acroloxus lacustris, *Viviparus fasciatus* and *Valvata macrostoma* had values of $\overset{*}{x}/\bar{x}$ greater than 2 and the highest values of skewness, indicating their more clumped distributions. (Skewness was independent of the mean, $r_s = 0.21$, $P > 0.05$, $n = 13$, and related to $\overset{*}{x}/\bar{x}$, $r_s = 0.89$, $P < 0.01$, $n = 13$). Large values of k were found for *Chironomidae, Polycelis nigra/tenuis* and *Asellus aquaticus*, the distributions of which were less skewed than other taxa, indicating that they were more normally distributed. Table 5.13 shows the order of taxa depending upon the sum of the rank orders of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. Taxa that conformed to Poisson series have not been included in this table.

In a multidimensional scaling plot (Figure 5.12), samples 15, 11, 10, 16 and 17 were separate from the rest. Samples 6 and 7 also appeared to be somewhat different to the others. Samples did also appear to have formed a continuum, with intermediary samples between the extremes. This suggests that the assemblage tended to be constant across the meso-habitat but that slight differences in taxonomic richness and abundances in samples occurred along a gradient.

Table 5.13. Taxa found in more than 5 samples from *Schoenoplectus lacustris* stands, that did not conform to Poisson series, ordered by the summed ranks of $1/k$, $\overset{*}{x}/\bar{x}$ and skewness. Where k was not applicable, average rank of $\overset{*}{x}/\bar{x}$ and skewness was used in place of k. Most clumped taxa appear at the top of the table.

Taxa
Acroloxus lacustris
Viviparus fasciatus
Valvata macrostoma
Oligochaeta
Hydracarina
Asellus aquaticus
Polycelis nigra/tenuis
Chironomidae

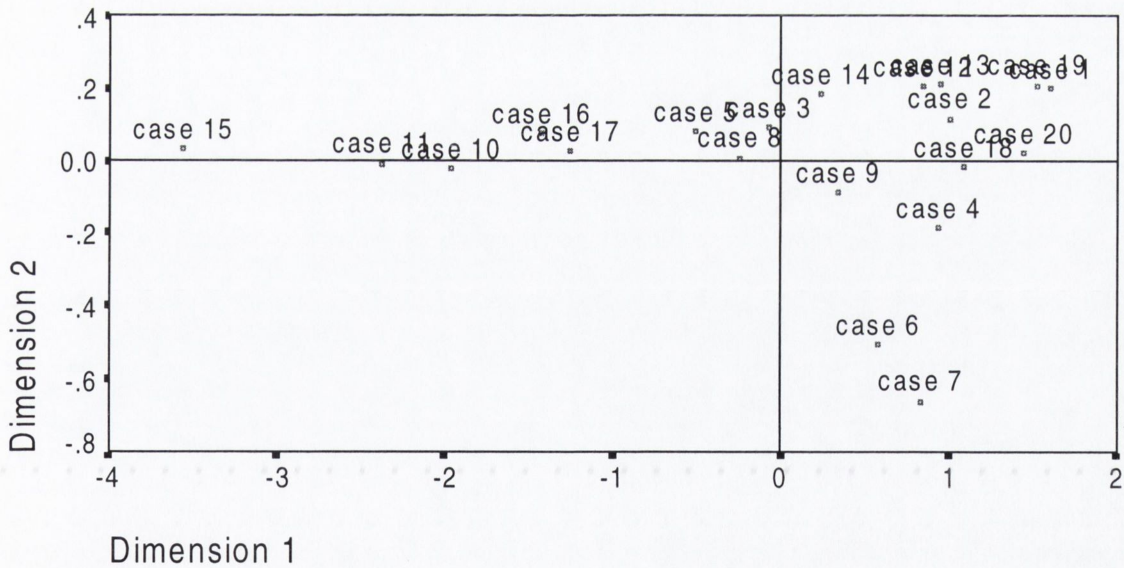

Figure 5.12. Multidimensional scaling dimensions 1 and 2 for samples from *Schoenoplectus* stands. Distance measure used was average Euclidean distance between groups, $n = 20$.

5.5. Discussion

From the results of this study it is apparent that many macroinvertebrates found in the four lake meso-habitats were clumped in their distributions. Macroinvertebrate assemblages were also found to be dissimilar among the meso-habitats and this supports the results presented in Chapter 4; that heterogeneous areas of substrata harbour different assemblages of macroinvertebrates.

The homogeneity of different meso-habitats and the distinctiveness of macroinvertebrate assemblages is dependent upon the scale or resolution at which they are viewed. Brodserson, Dall & Lindegaard, (1998) viewed the littoral zone as a heterogeneous set of micro-habitats that are separate components of apparently homogenous meso-habitats. Kotliar & Wiens (1990) proposed a conceptual, hierarchical model of patch structure. This is shown in Figure 5.13. For each organism, the "grain" is restricted to scales greater than the perception limits, with grain defined as the smallest scale at which an organism will exhibit a behavioural response (either preference or aversion) to patch structure. At small scales, an organism may perceive its environment as homogenous, and with little response to any structure that may exist. "Extent" was defined by Kotliar & Wiens (1990) as the largest scale at which an organism responds to patch structure. This model is organism-defined as opposed to observer-defined. The hierarchy of the micro-habitat, meso-habitat and lake as a whole may also be viewed from a sampling perspective (Figure 5.13), with the perception limits defined as the size of the samples taken. If the scale of samples is less than the scale of the grain, the samples may be significantly different from one another. If, on the other hand samples comprise several micro-habitats then the resolution of the sampling method may be too coarse for appreciable differences in animal distributions to be noticed.

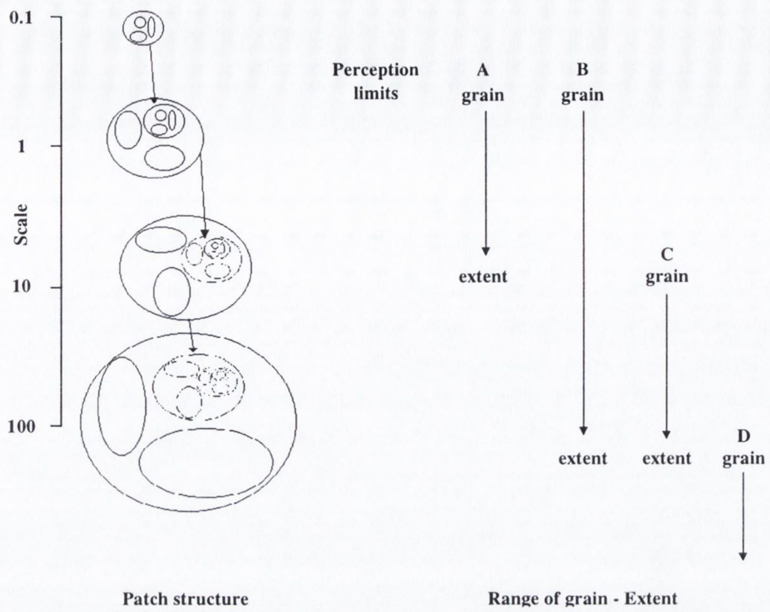

Figure 5.13. Hierarchical patch structure and grain – extent ranges for four organisms (A – D) with four nested levels within the patch hierarchy (Kotliar & Wiens, 1990).

It is clear that sample size is not independent of the pattern and detection of spatial distribution. With increasing sample size, the apparent dispersion of a clumped population can change from random to clumped and to regular, and the three distributions can overlap. Clumped distributions can result from randomly distributed patches with regularly distributed individuals in each patch (Elliott, 1977). This means that animal distributions can be clumped at more than one scale. If a species is clumped in its environment then the clumps also have a distribution, which may be regular, random or clumped.

The size of species clumps or patches can be detected by taking replicate samples of increasing area and plotting variance against sample size. The approximate clump size is distinguished at the point of highest variance (Elliott, 1977). It was not possible from the data collected here to determine the size of the species patches. Agreement with negative binomial distributions, however, suggests that the kick/sweep samples were generally smaller than either clumps of organisms, or clumps of organism aggregation.

To establish if contagion was occurring at different spatial scales, and to establish the size of species patches it would have been necessary to collect samples of different sizes, and with high replication.

The negative binomial is probably the most useful model of clumped distributions as it provides a good empirical description and can be applied to a wide range of clumped distributions. Agreement with the negative binomial or Poisson series should not, however, be the sole basis for justifying a particular hypothesis of distribution as no test can prove randomness, and agreement with a Poisson series simply means that the hypothesis of randomness is not disproved (Elliott, 1977). By applying both tests, the clumped distribution of many taxa can be verified. In this study, Lloyd's index of mean crowding gave a relative measure of the extent of clumping. In certain instances, agreement was found with both the negative binomial and the Poisson series; for *Erpobdella octoculata* in marl and CPOM, *Theromyzon tessulatum* and Corixidae (nymphs) in *Phragmites* stands, and *Dugesia polychroa* and *Helobdella stagnalis* in *Schoenoplectus lacustris* stands. It is probable in these instances that the samples were not of an appropriate scale to adequately explain the distributions and samples covering a smaller spatial area would be needed to resolve the issue.

Table 5.14 summarizes the associations between measures of clumping and means, assessed by Spearman Rank correlation. The Spearman Rank correlation was used as the measures were derived variables, and their statistical distributions unknown. The use of parametric methods would have been invalid. As may be expected, in all habitats sample variance (s^2) was associated with mean abundance, as was Lloyd's index of mean crowding ($\overset{*}{x}$). Contrary to Taylor (1961), k was found to be independent of the mean in all habitats. Lloyd's index, ($\overset{*}{x}/\bar{x}$) and skewness were only independent of the mean in marl & CPOM and *Schoenoplectus* stands. This is of interest as $\overset{*}{x}/\bar{x}$ is designed to be independent of the mean. The dependence may have been a random occurrence of the statistical distribution of $\overset{*}{x}/\bar{x}$, for which there will be a probability of data indicating dependence when, in fact, there is none. It may not therefore, have been a true result of animal distributions. Alternatively, it may indicate a behavioural response of macroinvertebrates, as an increased density provides more opportunity for clumping to occur and additionally, if animals were to exhibit preferences for micro-habitats then it is likely that aggregation would be augmented in these localities, by high abundances. Data sets comprising means and the calculated measures of clumping $\overset{*}{x}/\bar{x}$ and skewness for taxa in cobbles & pebbles contained four outliers, and in *Phragmites* stands three outliers. These were removed to investigate if significant relationships with the means remained (Table 5.14). Significance was not found in the correlations between means and $\overset{*}{x}/\bar{x}$ in the case of *Phragmites* stands, and was reduced in the case of cobbles & pebbles. Correlations between $\bar{x}$ and skewness in these two habitats was also not found when outliers were removed. This suggests that the dependence was a result of the statistical distributions of the clumping measures. Because of this, and support by reference in the literature to *k*, $\overset{*}{x}/\bar{x}$ and skewness being independent of the mean, they were believed to be good indicators of the degree of aggregation and were used to rank taxa in order of their degree of clumping.

Table 5.14. Associations between means and measures of clumping assessed by Spearman Rank correlations (– = no significant association at $P > 0.05$; + = significant association at $P < 0.05$; ++ = significant association at $P < 0.01$). Indicators in parenthesis are significances with the removal of four outliers in the case of cobbles & pebbles and three in the case of *Phragmites* stands.

Measure	**Marl & CPOM**	**Cobbles & pebbles**	***Phragmites* stands**	***Schoenoplectus* stands**
s^2	++	++	++	++
k	–	–	–	–
$\overset{*}{x}$	++	++	++	++
$\overset{*}{x}/\bar{x}$	–	++ (+)	+ (–)	–
Skewness	–	++ (–)	++ (–)	–

While different species aggregated to different extents within a meso-habitat, they did not show the same degree of clumping among the different habitats. This agrees with Elliott's (1977) suggestion that different species tend to show different contagious distributions within the same habitat, and the dispersion pattern of one species may vary within a small area of substrata. Among different meso-habitats, the distribution of environmental variables that a species responds to may differ at the micro-habitat scale (Milner, 1987; Malmqvist *et al.*, 1991) and this may cause the distribution of a species to alter among meso-habitats. For example, in a cobble meso-habitat a large proportion of the micro-habitats will provide shelter from wave action. This may be favorable to taxa such as the case bearing caddis *Sericostoma personatum*. A meso-habitat consisting primarily of sand however, will contain fewer micro-habitat shelters from wave action and therefore the distribution of *Sericostoma personatum* would be expected to differ. For this organism the cobble meso-habitat is, therefore, a more heterogeneous one than the sand meso-habitat.

While there were differences in taxa distributions, at the taxonomic level of Order the majority of replicate samples contained representatives of most taxa, and the most abundant taxa appeared to have similar proportional abundances among replicates. Multidimensional scaling (MDS) was used in the analysis of samples from individual meso-habitats to determine if samples were markedly different. By using average Euclidean distances between groups, more weight was given to abundant taxa (Norris & Georges, 1993). As the extent of clumping was not constant for species and certain taxa appeared in only a few samples and in low abundances, it would not have been useful to assess dissimilarities of samples with equal weighting given to rare taxa and more abundant taxa. This is based upon the view that monitoring programs should rely on frequently occurring taxa, as rare taxa are unlikely to add useful information to a score and it is not justified to base an assumption of quality on an absence (Hellawell, 1986).

The similarity of samples from meso-habitats indicated by the MDS is important, as it shows that samples containing taxa with clumped distributions were similar with regard to the more abundant taxa, and some degree of confidence can be placed upon the samples to provide a reliable collection of fauna. Unfortunately, the degree of reliance cannot be quantified, although the robustness of both the samples and MDS analysis is implied in the results.

To maximize the efficiency of sampling in monitoring programmes a substratum should be chosen within which taxa are distributed as uniformly as possible. Of the habitats assessed here, cobble & pebble substrata and *Schoenoplectus lacustris* stands were shown to have a random distribution of total number of macroinvertebrates and of taxa but not of number of individuals, while for marl & CPOM a uniform distribution of individuals was also apparent. These three habitats would therefore provide reliable sampling sites. This does not however, take in to consideration the taxa richness of the habitats, which should also be a consideration in monitoring. This would indicate marl & CPOM and cobble & pebble substrata as sites least prone to difficulties of assessment arising from spatial pattern.

The total abundance of macroinvertebrates can also be a useful indicator in monitoring, as increased abundance is indicative of heightened productivity, and usually a higher nutrient loading (Chapter 3). Total abundances in the four meso-habitats were clumped, and in *Schoenoplectus lacustris* and *Phragmites* stands total abundance distributions agreed with the negative binomial. These findings are comparable with those of Downes, Lake & Schreiber (1993), who showed that while taxonomic richness among riffles at the same site in a river were comparable, abundances differed.

The clumped distribution of macroinvertebrates will therefore require monitoring programmes which rely upon indicator organisms to have samples large enough to ensure that all representative of dominant taxa, or at least those included in the assessment metric, are collected or for sufficient replicates to be taken. This will increase the processing time of samples with possible resource implications. The problem is likely to be more sever in scientific studies of ecosystem processes if they require the full compliment of taxa present in a habitat to be collected.

6. LITTORAL MACROINVERTEBRATES AND MESO-HABITATS: IMPLICATIONS OF THEIR USE IN RAPID ASSESSMENT METHODOLOGIES AND SCIENTIFIC STUDIES

6.1. Macroinvertebrate Distributions Among Lakes and their Potential use in Rapid Analysis of Ecological Status

With a notable exception (Johnes, Moss & Phillips, 1994, 1996) the view that ecological assessment should classify lakes along ecological continuum seems to have been either largely forgotten or ignored (Allott & Monteith, 1999). Most anthropogenic impacts could be viewed as continua from low to high impact, and the majority probably a function of geomorphology and land use of the catchment. To simplify the classification of lakes and simultaneously incorporate the continuum view of lakes is difficult. Pragmatically categorization of lakes based on catchment geomorphologies and other conservative attributes is probably required in order to make comparisons among lakes within similar typologies. This view of comparisons among lakes with similar fundamental attributes and baseline reference conditions is part of the philosophy of the European Councils' forthcoming Water Framework Directive (European Union Environment Council, 1998).

In this study, macroinvertebrate assemblages in lakes were found to be related to a number of chemical and environmental attributes. It is clear from this work (Chapter 3) that the 28 study lakes could be arranged into "Groups," based on the macroinvertebrate assemblage that they supported. Within these Groups there were similar ecological, chemical and environmental conditions. The identification of such groups could be usefully developed through further investigations of a larger sample of lakes, also encompassing a rang of hydromorphological and physicochemical characteristics. A larger number of lakes sampled from each of the Groups would enable better estimates of variability within them and the establishment of an index of reference lakes, typical of each of the Groups.

6.2. Meso-habitats in Lakes

Further development of assessment of ecological quality of lakes might include the use of meso-habitats to determine ecological quality (Lewis & Williams, 1984; Allen, 1995; Harper, Smith & Barham, 1992; Armitage, Pardo & Brown, 1995). A simple count of the visually discrete units of habitat, including for example, various stone substratum types, plant growth (emergent and submerged), overhanging plants, trees and roots, wave washed margins and depositional areas may provide useful information, and could be easily done.

The number of lakes sampled and the time limitations of this project did not allow all lakes to be assessed in terms of their meso-habitat composition. Lough Inchiquin was chosen to investigate the existence of meso-habitats in lakes because of its rich macroinvertebrate fauna. Differing macroinvertebrate assemblages were found in the 15 areas of visually distinct substrata or meso-habitats, providing proof that around the littoral zone, faunal communities are not constant. This is relevant to the use of macroinvertebrates for lake monitoring, particularly if such monitoring was to be based on single samples. Although the study indicated that meso-habitats were secondary to chemical conditions as determinants of macroinvertebrate assemblages, the habitat chosen for sampling should nevertheless be standardized to reduce "noise" in data sets created by sampling different habitats.

6.3. Meso-habitats: a Panacea for Lake Monitoring?

In Chapter 1, the apparent convergence of many methods claiming to evaluate lakes in terms of water quality, ecological quality and conservation value that were based upon the same principles and data was discussed. It may appear that a similar set of conclusions have been drawn in this work, and that a "meso-habitat" approach to lake assessment provides the panacea for lake monitoring and management. Initially, as meso-habitats contain distinct macro-invertebrate assemblages which indeed are used as descriptions of the meso-habitat and which are related to chemical variables, they are useful in determining water quality. As they encompass many aspects of the environment (Harper & Everard, 1998), meso-habitats are suggested as a useful unit for assessing ecological quality and conservation value. It is their use that is important however, and it should not be forgotten that they are only one of a suite of rapid analysis tools with which to evaluate lake ecosystems. Meso-habitats may not be a definitive determinant of ecological quality and how they are evaluated, both scientifically and philosophically, is important. The only true way to determine the ecological status of a lake is to conduct extensive biological and chemical analysis, which is costly. Rapid lake assessment methods are required to provide a balanced, objective and affordable analysis of ecological state. They should be viewed from an impartial perspective, and the flaws that will be inherent in any method should be realized. This includes an understating of the measured variables, the results, potential for miss-classification (or robustness of a score) and the degree of resolution among lakes (how coarse or fine distinctions between classifications are). Such understandings of a method should ensure that improper management decisions are not made through inappropriate application of monitoring and investigation.

The potential of using meso-habitats to compare the ecological or conservational value of lakes has not been assessed here, only their existence and the implications to management goals in one lake. As noted in Chapter 4, it may be that their best application would be within a lake over time, and among lake comparisons may not be reliable as some lakes may naturally possess a low number of meso-habitats, and a lake in its "natural state" can only be perceived as "good". For example, small sheltered lakes with high inputs of particulate matter, would result in very little open shoreline, with the majority of the littoral zone given over to macrophyte stands. Lake shape may also be influential. A lake with a contorted shoreline may provide more areas suitable for macrophyte growth than a more uniform or round lake, while a lake with a long reach in the direction of the prevailing wind would allow for a larger influence of wave action. The surrounding topography will also be influential. For instance, a flat landscape would allow a greater exposure to wind than a mountainous landscape, while the proportion of terrestrial vegetation will contribute to the allochthonous input to a lake. Additionally, as water quality seems to be the primary influence over macroinvertebrate assemblages, meso-habitats may be more indicative of potential rather than actual ecological quality. They may indeed be more applicable in the evaluation of potential "conservation value" rather than ecological status as defined by adherence to, or departure from reference conditions of high quality.

6.4. Macroinvertebrate Distribution Within Meso-Habitats: Consequences for Rapid Analysis Methodologies and Scientific Studies

A disregard of the clumping of animals, owing to micro-habitat, breeding or behaviour, could lead to errors in estimating diversity if methods presume random distributions (Norris & Georges, 1993). It is, therefore, important to be aware of distribution patterns and this is applicable for both scientific studies trying to assess the effect of a disturbance and for monitoring programmes. For scientific investigations into disturbances it is important to determine whether the spatial patterns that are observed are a consequence of the impact or if they are a result of natural animal distributions. To increase the confidence that a result reflects an overall state, scientific investigations can include control samples, taken either simultaneously from a different and yet comparable site or to sample pre and post-impact. Sufficient replication of samples strengthens statistical analysis. The most effective monitoring programme will aim to include controls and replication. This is, however, often not practical owing to time restraints and the large number of water bodies to be monitored. In which case it is important to minimize variability and increase the reliability of samples for monitoring programmes, as often only single samples are collected. This is needed to ensure that samples provide a representative collection of the macroinvertebrate fauna present in a substratum. To achieve this requires consideration of the distribution of taxa within the meso-habitat types to be sampled.

The abundance of macroinvertebrates in samples from meso-habitats was not normally or randomly distributed (Chapter 5). It is important to know the distributions of macroinvertebrates in the sampling habitat chosen as samples in a monitoring programme will not always provide a collection of macroinvertebrates that resembles the community structure of all habitats. This is also important for specific scientific studies. Both scientific studies and rapid analysis methods need to appreciate natural variations in animal distributions and ensure, through correct experimental design and statistical application, that findings are not an artifact of clumped distributions. Knowledge of distributions is also important for statistical analysis, as normal data distributions are required for parametric statistical tests. These tend to be stronger than their non-parametric counterparts. A knowledge of underlying distributions enables application (if necessary) of sensible data transformations and the subsequent use of parametric statistical methods.

The distribution patterns of taxa (Chapters 4 & 5) are not necessarily temporally constant. They will change among seasons (Chapter 3, Section 3.4.2), and may also differ among years. Reid, Somers & David, (1995) found that the repeatability of macroinvertebrate samples taken every six weeks from the littoral zone of lakes was low, and that samples incorporated considerable temporal variation owing to seasonal changes in assemblages. Samples to monitor anthropogenic impacts should, therefore, be collected over short time periods to ensure that natural temporal variations in assemblages are not misconstrued as the result of external impacts. This stretches the resources of agencies employed to run monitoring programmes, as they are often expected to provide information on large numbers of lakes. In Ireland there are 5327 lakes indicated on the 1:126,720-map range (Allott *et al.,* 1998). To collect samples from even a small proportion of these within a short period may not be feasible. Knowledge gained from frequent fieldwork suggests that it may be possible to sample up to ten lakes per day if sampling procedures are not time consuming and lakes are close together. A more realistic figure may be eight lakes per day. This figure would enable five independent surveyors to assess 280 lakes per week and 1680 lakes in six weeks. This figure is estimated for an extremely intensive working period for Ireland, and there is still an extensive deficit in the number of lakes assessed, although even in an extensive monitoring programme it would probably not be necessary to monitor all of the lakes in a country. Finland, for instance, has over 180,000 lakes. In this case focus should be placed on a range of lakes to include those which are known to be heavily impacted, those at risk from common pressures of eutrophication or acidification, and those deemed to be of high ecological value worth conserving and which may provide important reference information.

The limitation of resources and expectation of monitoring agencies to provide valid information on the ecological and water quality of lakes brings into question the number of samples a monitoring programme should use. For scientific investigations, these restraints are not so poignant, as such studies tend to be smaller in their range and have specific hypotheses to test. This allows sampling to be designed to ensure adequate replication of samples for satisfactory statistical testing. Limitations on extensive monitoring programmes, however, may advocate the use of single samples with an assumption that sampling is done in uniform meso-habitats in which a rich faunal collection is anticipated, and that the distribution of taxa is expected to be random. There are implications from this. Not all lakes contain the same meso-habitats and, therefore, if for example a cobble and pebble meso-habitat were chosen as the standard sampling substratum and it did not occur in a lake, an alternative substrata would have to be sampled. This may to some extent reduce meaningful comparisons, although it has been shown here that differences in the assemblages of markedly different habitats (cobble/pebble and macrophyte habitats) were less within a lake than the differences between lakes. It has also been shown that a single sample from all habitats may not always contain a representative collection of fauna if the distribution of taxa or abundance is not random (Chapter 5). With no replication of samples this could go unnoticed, and could result in a lake being misclassified by the omission of important taxa from the sample. Alternatively, larger samples could be taken in an attempt to ensure that all taxa were collected, which would require more time to sort and process. Results from Chapter 4 suggested that replicate samples from a uniform meso-habitat are comparable to one another and differences in assemblages among lakes tend to be greater than differences within lakes, at least with respect to abundant taxa. In Chapter 5, replicate samples from meso-habitats were also shown to be similar when assessed by Multidimensional scaling, which places greater weighting upon more abundant taxa. This suggests that rapid analysis should rely upon only common taxa. Additionally, the problem of samples not containing a truly representative collection of the taxa in a meso-habitat maybe overcome if acceptable limits on taxa which are to be included are placed in the methodology.

Sampling single meso-habitats may also result in a loss of information of taxa richness of a lake. It was apparent from the results presented in Chapter 4 that few species were found in all meso-habitats. This may not be of great significance unless the total richness of macroinvertebrates in a lake needs to be known. Results of this work indicate that if a single habitat type needs to be chosen for macroinvertebrate sampling in order to provide the most useful indications of ecological quality a course, primarily inorganic habitat such as pebbles/ cobbles would be best. A well designed rapid analysis programme for lakes must take into consideration limitations of sampling, and not require that all meso-habitats be sampled. Indeed such sampling would be wasteful of time and resources, as the amount of information gained would not offset the time taken in sampling, sorting and identification of taxa (Parsons & Norris, 1996). In addition, the majority of abundant taxa are likely to be found in most meso-habitats (Chapter 4) and if all meso-habitats in each lake were sampled the resulting data would again, not be strictly comparable. The reasons for this are twofold. Firstly, not all lakes contain the same collection of meso-habitats and secondly, impacts may not have the same effect upon the assemblages of different meso-habitats. The problem of lakes not containing the same collection of meso-habitats brings in to question the choice of a single, standard sampling habitat, as it may not be present in all lakes. It may therefore, be more realistic from a practical view point, to identify a small range of standard sampling habitats a few of which may be expected to exist in all lakes. Either a selection or one of these could be sampled. The comparability of samples from different habitats is, however, then an issue. It may be possible to calculate conversion factors to allow for this and enable scores from different habitats to be compared, although from work undertaken here, this is purely speculative at this stage.

6.5. Toward A Comprehensive Rapid Analysis Methodology of Lake Ecological Quality

The above discussion suggests that sampling more than a standardized meso-habitat would result in complications in assessing the ecological and water quality of lakes, and confound the results of a monitoring programme. Meso-habitat richness could however, add valuable information to a rapid analysis methodology for determining the ecological state of a lake (Chapter 4). Although the enumeration of meso-habitats is simple, it is not an easy task to incorporate this and macroinvertebrate data into a monitoring programme. A comprehensive score could, however, be achieved if a tiered use of the information were used. Initially, identification and enumeration of macroinvertebrates from a standardized sample and from a standard meso-habitat (for instance a stone and/or cobble substratum) could be used to "type" a lake into a group of lakes with comparable attributes (as in the lake Groups determined in Chapter 3). This would ensure that comparisons were only made among lakes with similar physicochemical composition. A set of "reference lakes" (lakes chosen to be deemed good examples of the different lake groups) could be used as standards for comparison with other lakes. The richness of meso-habitats in a lake could then be assessed by counting them. It may be that a standard collection of meso-habitats exists in lakes, enabling a list of meso-habitats likely to be encountered in most lakes to be compiled which could then be "ticked off" a list during field assessment. It may be impractical to assess the diversity of the littoral zone for the entire circumference of a lake owing to restraints on time and access. It would therefore be necessary to determine how much of a lake shore needs to be viewed to achieve a significant measure of the meso-habitat richness. For example, a survey of 200 m on either side of an access point may be acceptable. This requires further research. Meso-habitat richness could indicate the "potential" ecological quality of a lake. By comparison of diversity of macroinvertebrates in standard samples with relevant reference lakes, an indication of the "expected" meso-habitat ecological status could be determined. This could then be used at the second tier of lake ranking, and the two scores presented together in results, for instance 2_4, or 3_2, with the first number indicating the lake group and the subscript indicating meso-habitat diversity. This proposed scheme, based mainly on the results presented in this work, attempts to integrate both biological diversity of macroinvertebrate fauna and the biological and physical diversity of the littoral zone to assess ecological quality in a manner that will be both cost and time efficient. This could enable the valuable inclusion of the meso-habitat concept to the assessment and classification of the ecological quality of lakes. A large scale study of this assessment method would reveal its potential and enable its further development.

6.6. Conclusions

The distribution of littoral macroinvertebrates is not uniform either among or within lakes. Their distribution is related to many lake parameters and differences in the structure of the littoral zone which support different assemblages. There does seem to be potential in using macroinvertebrates and their assemblages in rapid assessment of ecological quality. The ecological interactions are not, however, simple to evaluate and the variables that influence macroinvertebrate distributions are not easily quantified. It should also be noted that distributions of macroinvertebrates among lakes is in itself worthy of recording for several reasons. The continued recording of macroinvertebrate presence among lakes will allow for greater understanding of their biogeography. This will enable species distribution maps to be compiled to determine their ecological boundaries in latitude and longitude, identify those in greater need of conservation efforts, and indicate peculiarities in species distributions worthy of further investigation. Species distributions are *de facto* linked with environmental conditions, although the knowledge of limiting environmental conditions is, generally poor. Even so, the macroinvertebrate assemblages in lakes provides a "fingerprint" of the lake and subsequent departures in the assemblage from this fingerprint would testify towards changes in a lake's ecology, be it natural or caused by anthropogenic activities. Although macroinvertebrate distributions among lakes can contribute to lake ecological assessment, the potential for other biotic, chemical and environmental variables to provide equally valid information to an appropriate key of the ecological quality of lakes should not be ignored. It appears that knowledge of macroinvertebrate distribution is not well enough refined at this stage to rely on them as the only indicator and to do so, with the volume of information available from other lake biota and environmental variables would of course be somewhat "short sighted".

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7.1 Taxonomic Keys Used for Identification of Macroinvertebrates

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Appendix 1.1. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Ballycullinan.

Date			10/04/96	10/06/96	08/07/96	09/09/96	09/09/96	13/01/97	08/04/97	02/06/97
Habitat			Stones	Stones	Stones	Stones	Plants	Stone	Stone	Stone
Group	Family	Species								
Tricladida	Dugesiidae	*Dugesia lugubris*		4	2	1			6	4
		Dugesia polychora					20	40		
	Planariidae	*Planaria torva*						3		5
		Polycelis nigra/tenuis	8		1	1			16	14
	Dendrocoelidae	*Dendrocoelum lacteum*				3		10	4	2
	Viviparidae	*Viviparus fasciatus*	2						3	
Gastropoda	Valvatidae	*Valvata cristata*			19		8			
		Valvata macrostoma	35					5		
	Bithyniidae	*Bithynia tentaculata*	3	2	52	5	255			21
	Physidae	*Physa fontinalis*		4	11		26	1		
		Lymnaea peregra	11	7	10	2	8		7	
	Planorbidae	*Planorbis albus*					29	1	1	
		Planorbis laevis								4
		Segmentina complanata		1	11		21	1		
		Succinea putris				1	10			
Lamellibranchiata		*Sphaerium* sp.			13		4			2
Oligochaeta	Tubificidae	*Limnodrilus* sp.				2	2	-	-	-
	Naididae	*Nais simplex*			1			-	-	-
		Stylaria lacustris		1	277	56	13	-	-	-
		Dero digitata		1				-	-	-
	Lumbricidae	*Lumbriculus variegatus*		12	2	1	7	-	-	-
		immature Tubificidae with hair chaetae		2	1	1		-	-	-
		Oligochaeta Sum		16	281	60	22	17	6	45
Hirudinea	Glossiphoniidae	*Helobdella stagnalis*		1	2		1			
		Hemiclepsis marginata			2					1
	Erpobdellidae	*Erpobdella testacea*					1		1	
		Dina lineata							1	
Hydracarina			3				1			25
Ostracoda							1			
Isopoda	Asellidae	*Asellus aquaticus*	624	234	125	5	14	68	65	347
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	11		2		4	1	2	1
Ephemeroptera	Caenidae	*Caenis horaria*				1		1	15	
		Caenis luctuosa	3						3	
	Leptophlebiidae	*Leptophlebia vespertina*							3	
Hemiptera	Notonectinae	*Notonceta* (nymphs)								2
Coleoptera	Haliplidae	*Haliplus confinus*	2				5			1
		Haliplus (larvae)	2			1	1			
	Noteridae	*Noterus crassicornis*					3			
	Hydroporinae	*Porhydrus lineatus*				1	12			
		Hyphydrus ovatus					2		11	
		Hygrotus quinquelineatus					1			1
		Hygrotus inaequalis				1				
		Hydroporus pubescens	2							
	Hydrophilinae	*Laccobius biguttatus*								2
Trichoptera	Psychomyiidae	*Tinodes waeneri*			1				1	
	Limnephilidae	*Limnephilus marmoratus*	8		2			7		1
	Leptoceridae	*Athripsodes cinereus*		1						
		Triaenodes bicolor		1						
Diptera	Chironomidae	*Corynoneura* sp.					1	-	-	-
		Cricotopus/Orthocladius sp.	3		7			-	-	-
		Dicrotendipes sp.			4			-	-	-
		Glyptotendipes sp.		3	1	1		-	-	-
		Microtendipes sp.		1	1			-	-	-
		Psectrocladius sp.			4			-	-	-
		Tanytarsus sp.			1			-	-	-
		Chironomidae Sum	3	4	18	1	1	24	99	17
	Ceratopogonidae			1						

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.2. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Ballyquirke.

Date				12/04/96	08/05/96	12/06/96	11/07/96	14/08/96	12/09/96	12/09/96	16/10/96	15/01/97	11/03/97	11/03/97	11/03/97	10/04/97	05/05/97	04/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species															
Tricladida	Dugesiidae		*Dugesia polychora*						1	1								
	Planariidae		*Planaria torva*									1						2
			Polycelis nigra/tenuis						1			7		1			8	14
Gastropoda	Valvatidae		*Valvata cristata*						1									
			Valvata piscinalis					2										
	Littoridininae		*Potamopyrgus jenkinsi*	3		10	15	1	2	39								
	Bithyniidae		*Bithynia tentaculata*						1									
	Lymnaeidae		*Lymnaea peregra*	3														
	Planorbidae		*Planorbis albus*															10
			Planorbis carinatus					1		1								
	Ancylidae		*Succinea putris*						1									
Lamellibranchiata			*Pisidium* sp.				2	1	3	3							1	
			Sphaerium sp.			2	1		1	1								
Oligochaeta	Tubificidae		*Limnodrilus* sp.		1	12	8		7	4			-	-	-	-	-	-
			Peloscolex ferox			2							-	-	-	-	-	-
			Aulodrilus pluriseta							1			-	-	-	-	-	-
	Naididae		*Nais barbata*		4								-	-	-	-	-	-
			Nais communis		7								-	-	-	-	-	-
			Nais elinguis	1	4								-	-	-	-	-	-
			Nais simplex		6								-	-	-	-	-	-
			Stylaria lacustris		4		4	1	11	7			-	-	-	-	-	-
	Enchytraeidae		Enchytraeidae spp.								5		-	-	-	-	-	-
	Lumbricidae		*Lumbriculus variegatus*	2	2				4	1			-	-	-	-	-	-
			Stylodrilus heringianus			25	6						-	-	-	-	-	-
			Lumbricidae spp.			2							-	-	-	-	-	-
			immature Tubificidae with hair chaetae			3			1	3			-	-	-	-	-	-
			Oligochaeta Sum	3	28	44	18	1	23	16	5	36	4	4	1	40	64	25
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*			1												
			Helobdella stagnalis				3		1									
	Erpobdellidae		*Dina lineata*							2								
Hydracarina					5	2		1										
Mysidacea			*Mysis relicta*					1										
Isopoda	Asellidae		*Asellus aquaticus*	3	3	16	6	6	14	20		9	1			10	22	171
Amphipoda	Crangammaridae		*Crangonyx pseudogracilis*	6	11			1										8
	Gammaridae		*Gammarus duebeni*	10	84	+	+		7	66	+	53	6	15	9	4	36	61
			Gammarus lacustris	32												5		
			Gammaridae (juveniles)			67	27				13		2	6	3			

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.2. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Ballyquirke.

Date				12/04/96	08/05/96	12/06/96	11/07/96	14/08/96	12/09/96	12/09/96	16/10/96	15/01/97	11/03/97	11/03/97	11/03/97	10/04/97	05/05/97	04/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species															
Ephemeroptera	Siphlonuridae		*Siphlonurus armatus*													1		
	Beatidae		*Centroptilum luteolum*		2			5										
			Cloeon simile															2
	Heptageniidae		*Heptagenia fuscogrisea*							1		1						
	Caenidae		*Caenis horaria*					1									1	
			Caenis luctuosa		42	3	3		49	10		38				40	5	8
Hemiptera	Corixidae		*Callicorixa praeusta*							1								
			Sigara falleni		2		1	19		1	1	3				2		
			Corixidae (nymphs)		4	31	1	8				3			1			30
	Micronectinae		*Micronecta poweri*			34	7											139
Coleoptera	Gyrinidae		*Gyrinus* spp.					1										
	Haliplidae		*Haliplus confinus*														2	
	Hydroporinae		*Hygrotus quinquelineatus*	3														
			Potamonectes depressus elegans		1													
			Hydroporinae (larvae)			1												
	Elmidae		*Esolus parallelepipedus*					1										
			Oulimnius tuberculatus		8	10	8		5	4		1				2		9
Trichoptera	Polycentropodidae		*Polycentropus flavomaculatus*					1								2		
			Cyrnus trimaculatus						1									1
	Psychomyiidae		*Tinodes unicolor*															1
			Tinodes waeneri															11
	Limnephilidae		*Limnephilus lunatus*													1		
			Limnephilus marmoratus		1													
			Limnephilidae (early Instars)										1			1		
			Anabolia nervosa													6		
	Goeridae		*Goera pilosa*							1								
	Lepidostomatidae		*Lepidostoma hirtum*									1						
	Leptoceridae		*Athripsodes cinereus*						1	1								
			Mystacides azurea									1						
			Mystacides (early instars)					1										

Appendix 1.2. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Ballyquirke.

Date				12/04/96	08/05/96	12/06/96	11/07/96	14/08/96	12/09/96	12/09/96	16/10/96	15/01/97	11/03/97	11/03/97	11/03/97	10/04/97	05/05/97	04/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species															
Diptera	Tipulidae		*Tipulidae* spp.									1		1				
	Chironomidae		*Chironomus* sp.				20					-	-	-	-	-	-	-
			Cladotanytarsus sp.	4	4	56	20		1			-	-	-	-	-	-	-
			Corynoneura sp.		3	8						-	-	-	-	-	-	-
			Cricotopus/Orthocladius sp.	4	1	16			2	2		-	-	-	-	-	-	-
			Cryptochironomus sp.		1				2	2		-	-	-	-	-	-	-
			Endochironomus sp.							14		-	-	-	-	-	-	-
			Glyptotendipes sp.				180	23	6	2		-	-	-	-	-	-	-
			Microtendipes sp.						1			-	-	-	-	-	-	-
			Paratanytarsus sp.	4					1			-	-	-	-	-	-	-
			Pentaneurini					1				-	-	-	-	-	-	-
			Polypedilum sp.			16	20					-	-	-	-	-	-	-
			Psectrocladius sp.	1				2				-	-	-	-	-	-	-
			Synorthocladius sp.		1					2		-	-	-	-	-	-	-
			Tanytarsus sp.	1	1							-	-	-	-	-	-	-
			Chironomidae pupae		2			2										
			Chironomidae Sum	14	13	96	240	28	13	22		7	5	9	6	19	8	13
	Ceratopogonidae				1	1										2		

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.3. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Bray.

Date Habitat Group	Family	Subfamily	Species	25/04/96 Stones	25/06/96 Stones	25/07/96 Plants	24/09/96 Plants	24/09/96 Plants	27/01/97 Stones	18/04/97 Stones	17/06/97 Stones
Tricladida	Planariidae		*Phagocata vitta*						1		
Oligochaeta	Enchytraeidae		*Enchytraeidae* spp.	-	-	-	88		-	-	-
	Lumbricidae		*Lumbriculus variegatus*	-	-	-	24	31	-	-	-
			Oligochaeta Sum	99	18	7	112	31	3	74	68
Hydracarina			*Hydracarina* spp.								2
Ephemeroptera	Leptophlebiidae		*Leptophlebia marginata*		147	2					
			Leptophlebia vespertina	3			2	1	198	95	2
Plecoptera	Nemouridae		*Amphinemura sulcicollis*								1
			Nemoura avicularis			1					
	Chloroperlidae		*Siphonoperla torrentium*	42	7						
			Plecoptera (early instars)				2	1	1	3	
Coleoptera	Hydroporinae		*Coelambus impressopunctatus*	3							
			Coelambus nigrolineatus							3	
			Hydroporinae (larvae)		1						
	Elmidae		*Esolus parallelepipedus*			21					
			Oulimnius tuberculatus	6	3	406	20	80		31	
Trichoptera	Polycentropodidae		*Plectrocnemia conspersa*	16			8	11		3	
			Polycentropus flavomaculatus		6	1				9	
			Polycentropus kingi		4	1	7	27			
			Cyrnus trimaculatus					1		1	
	Psychomyiidae		*Tinodes maculicornis*					7			
			Tinodes waeneri	22			38	21		43	
	Limnephilidae		*Drusus annulatus*			1					
			Limnephilidae (early Instars)				1				
			Potamophylax latipennis		3						
			Potamophylax roundipennis	3							
			Micropterna lateralis			2					
			Mystacides azurea			2					
	Sericostomatidae		*Sericostoma personatum*		1			1			
Diptera	Chironomidae		*Corynoneura* sp.		-	-	9	1	-	-	-
			Diamesa sp.		-	-		1	-	-	-
			Polypedilum sp.	1	-	-			-	-	-
			Psectrocladius sp.		-	-		4	-	-	-
			Tanytarsus sp.		-	-	1		-	-	-
			Chironomidae Sum	1	5	5	10	6	19	4	3

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.4. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Bunny.

Date				10/04/96	10/06/96	08/07/96	09/09/96	13/01/97	08/04/97	02/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family	Subfamily	Species							
Tricladida	Dugesiidae		*Dugesia lugubris*		1					
	Planariidae		*Polycelis nigra/tenuis*		1					1
Gastropoda	Bithyniidae		*Bithynia tentaculata*			10				1
Lamellibranchiata			Sphaerium sp.		1	5				4
Oligochaeta	Tubificidae		*Limnodrilus sp.*		34	4		-	-	-
			Uncinais uncinata		4			-	-	-
			Stylaria lacustris			1	1	-	-	-
	Lumbricidae		*Lumbriculus variegatus*		4	4		-	-	-
			Lumbricidae spp.	1				-	-	-
			immature Tubificidae with hair chaetae	11	14	4		-	-	-
			Oligochaeta Sum	12	56	13	1	47	58	32
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*							1
	Hirudidae		*Haemopis sanguisuga*		1					
	Erpobdellidae		*Erpobdella octoculata/testacea*		2	2				
Hydracarina							1			1
Isopoda	Asellidae		*Asellus aquaticus*		8	14		1		7
			Asellus meridianus			4				
Amphipoda	Gammaridae		*Gammarus duebeni*	115	+	+				
			Gammarus lacustris	50						
			Gammaridae (juveniles)		8	10				
Ephemeroptera	Beatidae		*Centroptilum luteolum*						1	
	Caenidae		*Caenis luctuosa*		2	6		1	1	1
	Leptophlebiidae		*Leptophlebia marginata*					1		
			Leptophlebia vespertina	1				1		
Zygoptera	Coenagrioniidae		*Enallagma cyathigerum*		1					
Coleoptera	Gyrinidae		*Gyrinus* spp.			1				
	Hydroporinae		*Hydroporus* (larvae)						1	
			Potamonectes depressus elegans	3					1	
			Hydroporinae (larvae)			1				
	Elmidae		*Oulimnius tuberculatus*						1	
	Limnephilidae		*Limnephilus vittatus*	6						
			Limnephilidae (early Instars)					1		
	Leptoceridae		*Athripsodes cinereus*		2	1				
Diptera	Tipulidae		*Tipulidae* spp.	2						
	Chironomidae		*Cladotanytarsus* sp.		2	2		-	-	-
			Cricotopus/Orthocladius sp.	24		4	1	-	-	-
			Cyphomella sp.		4			-	-	-
			Dicrotendipes sp.				3	-	-	-
			Endochironomus sp.			1		-	-	-
			Microtendipes sp.			1		-	-	-
			Pentaneurini			3		-	-	-
			Polypedilum sp.		14	1		-	-	-
			Stempellinella sp.				1	-	-	-
			Tanytarsus sp.		4	11		-	-	-
			Chironomidae pupae	2		9		-	-	-
			Chironomidae Sum	26	24	32	5	3	9	12
	Ceratopogonidae		Ceratopogonidae spp.			2			1	

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.5. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Cullaun.

Date Habitat Group	Family	Subfamily	Species	10/04/96 Stones	10/06/96 Stones	08/07/96 Stones	09/09/96 Stones	13/01/97 Stone	08/04/97 Stone	02/06/97 Stone
Tricladida	Dugesiidae		*Dugesia lugubris*					1	2	2
			Dugesia polychora							
	Planariidae		*Polycelis nigra/tenuis*	45	15	7	40	37	25	12
	Dendrocoelidae		*Dendrocoelum lacteum*		2	2		3	2	1
Gastropoda	Viviparidae		*Viviparus fasciatus*						2	
	Bithyniidae		*Bithynia tentaculata*			6	5		1	
	Lymnaeidae		*Lymnaea peregra*				1			
Lamellibranchiata			*Sphaerium* sp.	2						
Oligochaeta	Tubificidae		*Limnodrilus* sp.		60	17	4	-	-	-
			Aulodrilus pluriseta		3			-	-	-
	Naididae		*Nais simplex*			2		-	-	-
			Stylaria lacustris		3	5	32	-	-	-
	Enchytraeidae		Enchytraeidae spp.		30	3	8	-	-	-
	Lumbricidae		*Lumbriculus variegatus*		6	5	16	-	-	-
			immature Tubificidae with hair chaetae		8	5		-	-	-
			Oligochaeta Sum	16	110	37	60	57	444	32
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*			1				
			Helobdella stagnalis		4	4	6		2	1
	Erpobdellidae		*Erpobdella testacea*							1
			Erpobdella octoculata/testacea		1	2				
			Dina lineata				1			
Hydracarina			*Hydracarina spp.*					1		2
Isopoda	Asellidae		*Asellus aquaticus*	43	186	354	75	112	35	169
Amphipoda	Crangammaridae		*Crangonyx pseudogracilis*					5	1	
			Gammaridae (juveniles)			5				
Ephemeroptera	Beatidae		*Centroptilum luteolum*	5						
			Cloeon dipterum	2				1		
			Cloeon simile	67				5	1	
	Caenidae		*Caenis luctuosa*	51	8	5	5	88	63	6
	Leptophlebiidae		*Leptophlebia vespertina*	57				2	4	
Coleoptera	Haliplidae		*Haliplus flavicollis*		1					
			Haliplus (larvae)				1			
	Hydroporinae		*Hydroporus pubescens*	5						
			Potamonectes depressus elegans					1		
			Oulimnius tuberculatus			5	1	6	1	1
Trichoptera	Polycentropodidae		*Plectrocnemia conspersa*					1		
			Polycentropus flavomaculatus		3	2				
			Polycentropus kingi		1					
	Psychomyiidae		*Tinodes waeneri*		11	9		12	5	12
	Ecnomidae		*Ecnomus tenellus*		1					
	Limnephilidae		*Limnephilus fuscinervis*	2						
			Limnephilus lunatus		1					
			Limnephilus marmoratus					1		
			Limnephilidae (early Instars)					1		
			Anabolia nervosa	1						
	Leptoceridae		*Athripsodes cinereus*			1	1			
			Mystacides azurea	2						
	Sericostomatidae		*Sericostoma personatum*	2			2	1		
Diptera	Tipulidae				1				1	1
	Chironomidae		*Cladotanytarsus* sp.		5	5	1	-	-	-
			Cricotopus/Orthocladius sp.	28		15	1	-	-	-
			Cryptochironomus sp.			1	1	-	-	-
			Dicrotendipes sp.			1	1	-	-	-
			Microtendipes sp.		10	6		-	-	-
			Paratendipes sp.	4		4	1	-	-	-
			Pentaneurini	4		1		-	-	-
			Polypedilum sp.		1			-	-	-
			Potthastia gaedii					-	-	-
			Psectrocladius sp.	4				-	-	-
			Synorthocladius sp.		1		1	-	-	-
			Tanytarsus sp.			11	1	-	-	-
			Chironomidae pupae		1			-	-	-
			Chironomidae Sum	40	18	44	7	7	63	3
	Ceratopogonidae					3			1	
	Tabanidae			2						

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.6. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Dan.

Date				25/04/96	22/05/96	25/06/96	25/07/96	27/08/96	24/09/96	24/09/96	25/10/96	27/01/97	14/03/97	14/03/97	14/03/97	18/04/97	08/05/97	17/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Plants (s)	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family	Subfamily	Species															
Tricladida	Planariidae		*Polycelis nigra/tenuis*									3			1	1	1	
Lamellibranchiata			*Pisidium* sp.							1	1							
			Sphaerium sp.		1										3			
Oligochaeta	Tubificidae		*Psammoryctides barbatus*								1	-	-	-	-	-	-	-
			Limnodrilus sp.		11	4					2	-	-	-	-	-	-	-
			Peloscolex ferox	1	1		8					-	-	-	-	-	-	-
	Naididae		*Nais communis*		9							-	-	-	-	-	-	-
			Stylaria lacustris	1	5			4	1	7		-	-	-	-	-	-	-
	Enchytraeidae		Enchytraeidae spp.		3	14		1			2	-	-	-	-	-	-	-
	Lumbricidae		*Lumbriculus variegatus*			120	1		2	1	8	-	-	-	-	-	-	-
			Stylodrilus heringianus	2	33							-	-	-	-	-	-	-
			immature Tubificidae with hair chaetae		25	12	7					-	-	-	-	-	-	-
			Oligochaeta Sum	4	87	150	16	5	3	8	13	25	15	33	26	41	32	36
Hirudinea	Glossiphoniidae		*Helobdella stagnalis*			1												
	Erpobdellidae		*Erpobdella testacea*											2				
Hydracarina						1	4			1			3	3	1	3	1	7
Isopoda	Asellidae		Asellus aquaticus								52							
Amphipoda	Gammaridae		Gammaridae (juveniles)								1							
Ephemeroptera	Siphlonuridae		*Siphlonurus lacustris*			1												
	Beatidae		*Cloeon simile*		1													
	Leptophlebiidae		*Leptophlebia marginata*														14	
			Leptophlebia vespertina	186	9	2			23	9		103	112	73	88	32		
Plecoptera	Nemouridae		*Nemoura avicularis*											1		1		
	Perlidae		*Perla bipunctata*										4	5	3			
	Chloroperlidae		*Siphonoperla torrentium*	6	1							6	15	10	5	7	2+	
			Plecoptera (early instars)						12			17						
Zygoptera	Coenagrioniidae		*Coenagrion mercuriale*							4								
Hemiptera	Corixidae		*Sigara dorsalis*						1	10								
			Sigara venusta		2													
			Corixidae (nymphs)	16	334				13	40						20	22	14
	Micronectinae		*Micronecta poweri*			18												154
	Gerridae		*Gerris lacustris*							1								
	Vellidae		*Velia* (nymph)							1								
	Gyrinidae		*Orectochilus villosus*							1						1		
Coleoptera	Dytiscidae		*Agabus* (larvae)							3								
	Hydroporinae		*Hydroporus* sp.				2											
			Potamonectes depressus elegans	3	4	2			2		2							
			Potamonectes depressus depressus				6	1								4	1	1
			Potamonectes sp.			6	1				1							
			Hydroporinae (larvae)			1												

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.6. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Dan.

Date				25/04/96	22/05/96	25/06/96	25/07/96	27/08/96	24/09/96	24/09/96	25/10/96	27/01/97	14/03/97	14/03/97	14/03/97	18/04/97	08/05/97	17/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Plants (s)	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family	Subfamily	Species															
	Elmidae		*Limnius volckmari*	3				2	6			3	6	4	7	3	1	5
			Esolus parallelepipedus				13	3										
			Oulimnius tuberculatus		4	8	48	37	35	11		7	2	4	1	26	10	40
	Hydroptilidae		*Oxyethira* sp.		2								2	4				
			Hydroptila sp.	58	18		7	14	13	11		31	24	38	16	19	31	1
	Polycentropodidae		*Plectrocnemia conspersa*	3					7	3			2	2		2	3	2
			Plectrocnemia geniculata			1												
			Polycentropus flavomaculatus									9	2	2	8	1		1
			Polycentropus kingi			2		3	12	3			2					1
			Cyrnus trimaculatus						1							1		
	Psychomyiidae		*Tinodes maculicornis*						1									
			Tinodes waeneri			1												1
	Limnephilidae		*Limnephilus lunatus*	13	1													
			Limnephilidae (early Instars)									1						
			Anabolia nervosa															1
	Lepidostomatidae		*Lepidostoma hirtum*					6	15			11	7	8	9	2	3	
			Athripsodes cinereus									1	1		1		2	
			Mystacides azurea			29	1		42	1		24	26	8	20	5	19	6
			Mystacides longicornis	13	2													
			Mystacides (early instars)					24										
			Triaenodes bicolor							1								
	Sericostomatidae		*Sericostoma personatum*											1	1	2	1	1
Diptera	Tipulidae								1			2	3	2	1	2		
	Chironomidae		*Chaetocladius* sp.				6					-	-	-	-	-	-	-
			Corynoneura sp.				2	4		3		-	-	-	-	-	-	-
			Cricotopus/Orthocladius sp.		2		39	1		4		-	-	-	-	-	-	-
			Cryptochironomus sp.				1					-	-	-	-	-	-	-
			Microtendipes sp.			240						-	-	-	-	-	-	-
			Nanocladius sp.								1	-	-	-	-	-	-	-
			Parachironomus sp.				1					-	-	-	-	-	-	-
			Paratanytarsus sp.					3		1		-	-	-	-	-	-	-
			Paratendipes sp.						1			-	-	-	-	-	-	-
			Pentaneurini	2		16	1	1	1	3		-	-	-	-	-	-	-
			Psectrocladius sp.	3			22	1				-	-	-	-	-	-	-
			Stictochironomus sp.				4					-	-	-	-	-	-	-
			Tanytarsus sp.		32		20				1	-	-	-	-	-	-	-
			Chironomidae pupae	3	4		3		1			-	-	-	-	-	-	-
			Chironomidae Sum	8	38	256	99	10	3	11	2	8	1	8	2	2	2	5
	Ceratopogonidae																1	
	Empididae				1					1		1		2	1			
	Sciomyzidae								2									

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.7. Macroinvertebrate abundances (per sample) taken from the littoral region of Doolough.

Date			11/04/96	07/05/96	11/06/96	09/07/96	13/08/96	10/09/96	10/09/96	15/10/96	14/01/97	10/03/97	10/03/97	10/03/97	07/04/97	05/05/97	01/06/97
Habitat			Stones	Stone	Stone	Stone	Stone	Stone	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family Subfamily	Species															
Tricladida	Planariidae	*Polycelis nigra/tenuis*						7									
Gastropoda	Littoridininae	*Potamopyrgus jenkinsi*		1	2	3	3										
	Bithyniidae	*Bithynia tentaculata*						1									
	Lymnaeidae	*Lymnaea peregra*				5	3										3
		Lymnaea truncatula												1	2		
	Planorbidae	*Segmentina complanata*						1									
	Ancylidae	*Ancylus fluviatilis*									1						1
		Succinea putris						2									
Lamellibranchiata		*Pisidium* sp.				7	10										
Oligochaeta	Tubificidae	*Limnodrilus sp.*						1				-	-	-	-	-	-
		Peloscolex ferox			1		2					-	-	-	-	-	-
	Naididae	*Chaetogaster sp.*					1		1			-	-	-	-	-	-
		Nais communis	1									-	-	-	-	-	-
		Nais simplex							2			-	-	-	-	-	-
		Stylaria lacustris	28	176	31	5	14		43			-	-	-	-	-	-
	Enchytraeidae	Enchytraeidae spp.		16	2		3			6		-	-	-	-	-	-
	Lumbricidae	*Lumbriculus variegatus*	2	64	45		6					-	-	-	-	-	-
		Lumbricidae spp.	1	16								-	-	-	-	-	-
		immature Tubificidae with hair chaetae		16	5		2					-	-	-	-	-	-
		Oligochaeta Sum	32	288	84	5	28	1	46	6	59	2	9	10	27	1	35
Hydracarina		*Hydracarina* spp.		11		5	4		14		1				1		2
Amphipoda	Gammaridae	*Gammarus duebeni*	11	89	+	+	+	6	3		20			2	41	2	38
		Gammarus lacustris		32											31		
		Gammaridae (juveniles)	17		87	57	91					1					
Ephemeroptera	Beatidae	*Cloeon dipterum*					1										
		Cloeon simile		1		5			9		3						
	Caenidae	*Caenis horaria*		7													
		Caenis luctuosa	1	29	16	4		4			1				4		6
	Leptophlebiidae	*Leptophlebia marginata*									1						
		Leptophlebia vespertina	4	8								1	3				
Coleoptera	Gyrinidae	*Orectochilus villosus*							2								
	Haliplidae	*Haliplus fulvus*							1								
	Dytiscidae	Dytiscidae (larvae)															1
	Hydroporinae	*Potamonectes depressus elegans*	1														
	Elmidae	*Oulimnius tuberculatus*		13	3	2	23	5	3		6		1	1	1		
Trichoptera	Hydroptilidae	*Oxyethira* sp.											1				
		Hydroptila sp.							3								
	Polycentropodidae	*Plectrocnemia geniculata*					1										
	Leptoceridae	*Athripsodes cinereus*		1													
		Athripsodes (early instars)					1										

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.7. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Doolough.

Date				11/04/96	07/05/96	11/06/96	09/07/96	13/08/96	10/09/96	10/09/96	15/10/96	14/01/97	10/03/97	10/03/97	10/03/97	07/04/97	05/05/97	01/06/97
Habitat				Stones	Stone	Stone	Stone	Stone	Stone	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species															
Diptera	Chironomidae		*Corynoneura* sp.		4	1			-	4		-	-	-	-	-	-	
			Cricotopus/Orthocladius sp.	28	28	8		48	-	7		-	-	-	-	-	-	
			Endochironomus sp.		4	1		16	-	3		-	-	-	-	-	-	
			Glyptotendipes sp.			4			-			-	-	-	-	-	-	
			Microtendipes sp.			2			-			-	-	-	-	-	-	
			Pentaneurini			4	5	16	-	2		-	-	-	-	-	-	
			Polypedilum sp.					8	-			-	-	-	-	-	-	
			Potthastia gaedii	2			1		-	1		-	-	-	-	-	-	
			Psectrocladius sp.	2	24	1		8	-			-	-	-	-	-	-	
			Stempellinella sp.						-	1		-	-	-	-	-	-	
			Chironomidae pupae	4					-									
			Chironomidae Sum	35202	35252	35248	35261	35386	6	35336		46	24	15	14	63		12
	Ceratopogonidae												1					
	Tabanidae									1								

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.8. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Dromore.

Date				10/04/96	10/06/96	10/06/96	8/7/96	09/09/96	09/09/96	13/01/97	08/04/97	02/06/97
Habitat				Plants	Stones	Plants	Plants	Plants	Plants	Plants	Plants	Plants
Group	Family	Subfamily	Species									
Tricladida	Dugesiidae		*Dugesia lugubris*			1						
			Dugesia polychora							1		
	Planariidae		*Polycelis nigra/tenuis*	3	2	93	6	13		1	2	5
	Dendrocoelidae		*Dendrocoelum lacteum*				1					
Gastropoda	Neritidae		*Theodoxus fluviatilis*				3					
	Valvatidae		*Valvata cristata*			3						2
	Bithyniidae		*Bithynia tentaculata*			5	56		3			11
	Physidae		*Physa fontinalis*			1	2				1	14
	Lymnaeidae		*Lymnaea palustris*									1
			Lymnaea stagnalis									29
			Lymnaea peregra		6	56						
	Planorbidae		*Planorbis albus*			2						
			Planorbis carinatus						7			9
			Planorbis contortus			3	1	1	38			4
			Planorbis laevis						3			
			Planorbis leucostoma			1						
			Planorbis planorbis									12
	Ancylidae		*Acroloxus lacustris*			1						
Lamellibranchiata			*Pisidium* sp.				5					21
			Sphaerium sp.				30	15	4	1	16	2
			Pisidium/Sphaerium spp.			3						
Oligochaeta	Tubificidae		*Limnodrilus hoffmeisteri*				1			-	-	-
			Limnodrilus sp.				1	6	16	-	-	-
			Aulodrilus pluriseta			2	8			-	-	-
	Naididae		*Nais communis*			8				-	-	-
			Stylaria lacustris			20		6		-	-	-
	Lumbricidae		*Lumbriculus variegatus*						1	-	-	-
			immature Tubificidae with hair chaetae					1		-	-	-
			Oligochaeta Sum		2	30	10	13	17	5	31	70
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*				1		2		1	
			Helobdella stagnalis				7	1	6			
	Hirudidae		*Haemopis sanguisuga*					1				
	Erpobdellidae		*Dina lineata*						1			
			Trocheta byowskii					1				
Hydracarina			Hydracarina spp.				1	1				
Isopoda	Asellidae		*Asellus aquaticus*	29	18	64	1476	1	42	1	3	137
Amphipoda	Crangammaridae		*Crangonyx pseudogracilis*	6				1	1	5		6
	Gammaridae		*Gammarus duebeni*	3	2		+	1				
			Gammarus lacustris	16			+	5			1	2
			Gammaridae (juveniles)			1	92	1				
Ephemeroptera	Beatidae		*Cloeon dipterum*			1				1		2
	Caenidae		*Caenis luctuosa*				3				1	3
Zygoptera	Coenagrioniidae		*Coenagrion mercuriale*							2		1

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.8. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Dromore.

Date				10/04/96	10/06/96	10/06/96	8/7/96	09/09/96	09/09/96	13/01/97	08/04/97	02/06/97
Habitat				Plants	Stones	Plants	Plants	Plants	Plants	Plants	Plants	Plants
Group	Family	Subfamily	Species									
Zygoptera			*Enallagma cyathigerum*									1
	Coenagrioniidae		*Ischnura* sp.				1					
Anisoptera			Anisoptera (early instars)							1		
Hemiptera	Corixidae		*Callicorixa praeusta*			1						
			Sigara distincta			6						
			Sigara dorsalis			2						
			Sigara falleni			1						
			Cymatia bonsdorffi			3						
			Corixidae (nymphs)			8	2					3
	Notonectinae		*Notonecta* spp.			1						
	Gerridae		*Gerris* (nymph)									1
	Noteridae		*Noterus crassicornis*						1			
	Dytiscidae		*Agabus* (larvae)						1			2
	Hydroporinae		*Hygrotus quinquelineatus*			2						
			Hydroporus palustris								1	
			Hydroporus (larvae)									7
			Hydroporus sp.			2	1					
			Potamonectes depressus elegans			1					1	
			Potamonectes depressus depressus				16					
			Potamonectes sp.			16						
			Hydroporinae (larvae)			3						
	Hydraenidae		*Hydraena rufipes*							1		
Trichoptera	Polycentropodidae		*Polycentropus flavomaculatus*				1					
	Limnephilidae		*Limnephilus lunatus*	3			1				2	
			Limnephilus marmoratus							3		
			Limnephilidae (early Instars)			1				2		
	Goeridae		*Goera pilosa*					1				
			Athripsodes cinereus				22					
			Triaenodes bicolor							2		2
	Chaoboridae		*Chaoborus*								1	
	Chironomidae		*Cricotopus/Orthocladius* sp.	32	32	140				-	-	-
			Cryptochironomus sp.				1			-	-	-
			Endochironomus sp.	4			2	8	1	-	-	-
			Glyptotendipes sp.				26	1		-	-	-
			Microtendipes sp.		48	180	47			-	-	-
			Parachironomus sp.				2	2		-	-	-
			Pentaneurini				5	1	2	-	-	-
			Procladius sp.				2			-	-	-
			Psectrocladius sp.	12	24	40				-	-	-
			Stempellinella sp.						1	-	-	-
			Tanytarsus sp.						1	-	-	-
			Chironomidae Sum	48	104	360	85	12	5	5	6	9
	Ceratopogonidae				2					1		
	Empididae							1				
	Tabanidae											3
	Sciomyzidae							299				

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.9. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Easky.

Date Habitat Group	Family	Subfamily	Species	14/04/96 Stones	14/06/96 Stones	13/07/96 Stones	15/09/96 Stones	17/01/97 Stones	12/04/97 Stones	06/06/97 Stones
Tricladida	Planariidae		*Polycelis nigra/tenuis*						1	
Oligochaeta	Tubificidae		*Limnodrilus sp.*		9	2				
	Enchytraeidae		Enchytraeidae spp.	2	3	3				
	Lumbricidae		*Lumbriculus variegatus*		7	4				
			Stylodrilus heringianus	7						
			Lumbricidae spp.		2					
			immature Tubificidae with hair chaetae	12	7	2	2			
			Oligochaeta Sum	21	28	11	2	1	33	4
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*		1				1	
			Erpobdella octoculata/testacea		1					
Hydracarina						2			1	
Amphipoda	Gammaridae		*Gammarus duebeni*	22	+	+	4	3	13	10
			Gammarus lacustris	4						
			Gammaridae (juveniles)		77	78			19	
Plecoptera	Leuctridae		*Leuctra fusca*		3					
			Leuctra moselyi				3			
			Leuctra nigra				6			
	Capniidae		*Capnia atra*	5						
			Capnia bifrons					11		
	Chloroperlidae		*Siphonoperla torrentium*	26		1		1	11	1
Coleoptera	Elmidae		*Limnius volckmari*	32	19	9	2	2	14	
			Oulimnius tuberculatus			1			1	
Trichoptera	Hydroptilidae		*Hydroptila* sp.	3					4	
			Polycentropus flavomaculatus						2	
			Polycentropus kingi				1			
			Tinodes maculicornis	3						
			Tinodes waeneri			1				
	Limnephilidae		Limnephilidae (early Instars)	16						
	Lepidostomatidae		*Lepidostoma hirtum*		2	18			1	1
Diptera	Tipulidae		Tipulidae spp.			1				
			Corynoneura sp.				2			
			Cricotopus/Orthocladius sp.		3	1	1			
			Cryptochironomus sp.		3	1				
			Pentaneurini	1		1	1			
			Phaenopsectra sp.							
			Polypedilum sp.							
			Potthastia gaedii							
			Potthastis longimana sp.							
			Procladius sp.							
			Prodiamesa sp.							
			Psectrocladius sp.		7	1	6			
			Pseudochironomus sp.							
			Stempellinella sp.							
			Stictochironomus sp.				1			
			Synorthocladius sp.				1			
			Tanytarsus sp.			2				
			Zavreliella sp.							
			Chironomidae pupae							
			Chironomidae Sum	1	13	6	12		7	4
	Empididae						12			

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.10. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Egish.

Date				23/07/96	25/09/96	25/09/96	21/01/97	15/04/97	18/06/97
Habitat				Stones	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species						
Tricladida	Dugesiidae		*Dugesia lugubris*						5
			Dugesia polychora		6	42	78		
	Planariidae		*Planaria torva*						1
			Polycelis nigra/tenuis	83	16	99	114	12	12
	Dendrocoelidae		*Dendrocoelum lacteum*		35		30	2	
Gastropoda	Bithyniidae		*Bithynia tentaculata*	42	6	9		2	
	Lymnaeidae		*Lymnaea peregra*		4				4
	Planorbidae		*Planorbis albus*		17	39			12
			Planorbis carinatus	96	5	60			19
			Planorbis planorbis					6	
Lamellibranchiata			*Sphaerium* sp.	13	21	11	22	10	2
Oligochaeta	Tubificidae		*Limnodrilus sp.*		64	40	-	-	-
	Naididae		*Ophidonais serpentina*			8	-	-	-
			Dero digitata		24		-	-	-
	Lumbricidae		*Lumbriculus variegatus*			12	-	-	-
			immature Tubificidae with hair chaetae		32	8	-	-	-
			Oligochaeta Sum	550	120	68	1400	176	124
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*				2		
			Helobdella stagnalis	112	42	17	26	14	2
			Theromyzon tessulatum			1			1
	Hirudidae		*Haemopis sanguisuga*				2		
	Erpobdellidae		*Erpobdella testacea*		1	2			
			Dina lineata				2		
Hydracarina			*Hydracarina* spp.	6	2	28			4
Isopoda	Asellidae		*Asellus aquaticus*	266	350	441	144	146	84
	Gammaridae		*Gammarus lacustris*			1			
Ephemeroptera	Beatidae		*Cloeon dipterum*			1			
Zygoptera	Coenagrioniidae		*Coenagrion mercuriale*		7				
Hemiptera	Corixidae		*Arctocorisa germari*	3					
			Callicorixa praeusta	6			2		
			Callicorixa wollastoni	3					
			Corixa punctata	80	2	39			1
			Sigara dorsalis			2			
			Sigara concinna		2				7
			Corixidae (nymphs)	147	12	5			167
	Notonectinae		*Notonecta glauca*			5			
			Notonecta spp.			6			
Coleoptera	Gyrinidae		*Gyrinus natator*			1			
			Gyrinus (larvae)						1
	Haliplidae		*Haliplus confinus*					2	1
			Haliplus (larvae)	13					
	Noteridae		*Noterus clavicornis*					2	
	Dytiscidae		*Agabus* (larvae)			19	2		1
			Helophorus brevipalpis	6					
	Polycentropodidae		*Plectrocnemia conspersa*		1				
			Plectrocnemia geniculata			1			
			Tinodes waeneri			1			
			Limnephilus affins/incisus				41		
			Limnephilidae (early Instars)				16		
Diptera	Chironomidae		*Chironomus* sp.		4	1	-	-	-
			Cricotopus/Orthocladius sp.	130	12	59	-	-	-
			Dicrotendipes sp.		8		-	-	-
			Endochironomus sp.	10		2	-	-	-
			Glyptotendipes sp.		28	5	-	-	-
			Microtendipes sp.			3	-	-	-
			Parachironomus sp.	10			-	-	-
			Pentaneurini			1	-	-	-
			Psectrocladius sp.	10			-	-	-
			Chironomidae Sum	160	52	71	6	104	52
	Ceratopogonidae						2		

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.11. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Feeagh

Date			13/04/96	09/05/96	13/06/96	12/07/96	15/08/96	13/09/96	17/10/96	16/01/97	11/03/97	11/03/97	11/03/97	11/04/97	06/05/97	05/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family Subfamily	Species														
Tricladida	Planariidae	*Polycelis nigra/tenuis*	3					1								
Gastropoda	Littoridininae	*Potamopyrgus jenkinsi*	54	17	411	9	26			1				5	3	
	Lymnaeidae	*Lymnaea peregra*	10	1	9	23	34								1	4
	Ancylidae	*Ancylus fluviatilis*					2							1		
Lamellibranchiata		*Pisidium* sp.		1												
Oligochaeta	Tubificidae	*Limnodrilus sp.*	1		4					-	-	-	-	-	-	-
	Enchytraeidae	Enchytraeidae spp.				4	2			-	-	-	-	-	-	-
	Lumbricidae	*Lumbriculus variegatus*	4		6	3	2			-	-	-	-	-	-	-
		Lumbricidae spp.				1			1	-	-	-	-	-	-	-
		Oligochaeta Sum	5		10	8	4		1	18			2	7	19	9
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	3	1			1									
		Helobdella stagnalis													1	
	Erpobdellidae	*Dina lineata*										1				
Hydracarina		*Hydracarina* spp.	16	25			5	1				1		12		3
Isopoda	Asellidae	*Asellus meridianus*					1							1		
Amphipoda	Gammaridae	*Gammarus duebeni*	182	267	+	+	+	32	+	6	12	6	9	61	276	59
		Gammarus lacustris	371													
		Gammaridae (juveniles)			531	123	519		12				4	155	187	
Ephemeroptera	Beatidae	*Baetis rhodani*									1					
		Centroptilum luteolum		5												
	Heptageniidae	*Heptagenia sulphurea*	106	3	3		5	22		1		1	1	29	4	
	Ephemerellidae	*Ephemerella ignita*			14	1	17							1	15	31
	Caenidae	*Caenis luctuosa*	54		12			3			1			5	2	1
	Epehemeridae	*Ephemera danica*												1		
Plecoptera	Leuctridae	*Leuctra fusca*									1	1	1			1
	Perlodidae	*Diuro bicaudata*												1	1	1
		Isoperla grammatica					6									
	Chloroperlidae	*Siphonoperla torrentium*		1							7	3	2	3	14	
Hemiptera	Corixidae	Corixidae (nymphs)														1
	Micronectinae	*Micronecta poweri*														28
Coleoptera	Hydroporinae	*Coelambus nigrolineatus*												1		
		Potamonectes griseostriatus	10													
	Elmidae	*Elmis aenea*												2		
		Limnius volckmari	3				6	2				1		4	5	19
		Esolus parallelepipedus	96	9	2		15							11	1	
		Oulimnius tuberculatus			1		2	2				1		2	9	

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.11. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Feeagh.

Date				13/04/96	09/05/96	13/06/96	12/07/96	15/08/96	13/09/96	17/10/96	16/01/97	11/03/97	11/03/97	11/03/97	11/04/97	06/05/97	05/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species														
Trichoptera	Glossosomatidae		*Agapetus fuscipes*														
	Hydroptilidae		*Hydroptila* sp.	3					1								
	Psychomyiidae		*Psychomyia pusilla/Metalype fragilis*												1		
			Tinodes maculicornis		1												
			Tinodes unicolor												1		
			Tinodes waeneri			1		1									
	Lepidostomatidae		*Lepidostoma hirtum*			1										2	
	Leptoceridae		*Athripsodes albifrons*	6				3									
			Athripsodes cinereus												2	3	
			Athripsodes (early instars)			5								1			
			Mystacides azurea			2											
	Sericostomatidae		*Sericostoma personatum*	10		1											
	Chironomidae		*Brillia* sp.			3	1				-	-	-	-	-	-	-
			Cladotanytarsus sp.			1					-	-	-	-	-	-	-
			Corynoneura sp.	2					1		-	-	-	-	-	-	-
			Cricotopus/Orthocladius sp.	10		7	3				-	-	-	-	-	-	-
			Cryptochironomus sp.			5					-	-	-	-	-	-	-
			Endochironomus sp.			1					-	-	-	-	-	-	-
			Polypedilum sp.			24	1				-	-	-	-	-	-	-
			Potthastia gaedii	4		7			1		-	-	-	-	-	-	-
			Procladius sp.						1		-	-	-	-	-	-	-
			Synorthocladius sp.	14					4		-	-	-	-	-	-	-
			Chironomidae pupae	6							-	-	-	-	-	-	-
			Chironomidae Sum	35223	24	35287	35263	35296	35329		1		1		36	42	36
	Ceratopogonidae			29		1	1								1	1	

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.12. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Gara North.

Date				15/04/96	15/06/96	14/07/96	18/01/97	13/04/97	06/06/97
Habitat				Stones	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species						
Tricladida	Dugesiidae		*Dugesia polychora*				1		
Gastropoda	Neritidae		*Theodoxus fluviatilis*			5			
	Littoridininae		*Potamopyrgus jenkinsi*		53	44	1	9	
	Lymnaeidae		*Lymnaea peregra*				1		
	Ancylidae		*Ancylus fluviatilis*		1				
Lamellibranchiata			*Pisidium* sp.				3	14	1
			Sphaerium sp.		1		5		
			Pisidium/Sphaerium spp.		2				
Oligochaeta	Tubificidae		*Psammoryctides barbatus*		151		-	-	-
			Limnodrilus sp.		3	6	-	-	-
	Naididae		*Ophidonais serpentina*	16			-	-	-
			Nais simplex		1	1	-	-	-
			Stylaria lacustris			1	-	-	-
			Dero digitata		2		-	-	-
	Enchytraeidae		Enchytraeidae spp.	12	1		-	-	-
	Lumbricidae		*Lumbriculus variegatus*	4	3		-	-	-
			Stylodrilus heringianus		2		-	-	-
			Lumbricidae spp.	8			-	-	-
			immature Tubificidae with hair chaetae	16	8	1	-	-	-
			Oligochaeta Sum	88	171	9	50	40	16
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*			1			
			Helobdella stagnalis			1			
Amphipoda	Gammaridae		*Gammarus duebeni*	83	+	+	41	8	59
			Gammarus lacustris	153					
			Gammaridae (juveniles)		1027	83		35	3
Ephemeroptera	Beatidae		*Centroptilum luteolum*	8			10	4	11
	Ephemerellidae		*Ephemerella ignita*		17	11			
	Caenidae		*Caenis horaria*	2			2	15	2
			Caenis luctuosa	3	8	2	41	114	10
			Leptophlebia vespertina	1					
	Epehemeridae		*Ephemera danica*	6	2		3	3	1
Zygoptera	Coenagrioniidae		*Ischnura elegans*	2					
Hemiptera	Corixidae		*Sigara dorsalis*				1		
			Corixidae (nymphs)		1				
	Micronectinae		*Micronecta poweri*		2				3
Coleoptera	Gyrinidae		*Gyrinus* (larvae)	1					
	Haliplidae		*Haliplus ruficollis* grp.		1				
	Elmidae		*Oulimnius tuberculatus*	16	3	4	3	3	
	Helophorinae		*Helophorus* sp.		1				
Trichoptera	Hydroptilidae		*Hydroptila* sp.					1	
	Polycentropodidae		*Polycentropus flavomaculatus*			1			
			Polycentropus flavomaculatus/kingi		3				
	Psychomyiidae		*Tinodes waeneri*		3	8		9	
	Limnephilidae		*Limnephilus affins/incisus*				2		
			Limnephilus lunatus	1			1		
			Limnephilus vittatus				1	1	
			Anabolia nervosa			1			
	Leptoceridae		*Athripsodes cinereus*		1				1
Diptera	Tipulidae		Tipulidae spp.	1				1	
	Psychodidae		Psychodidae spp.	1					
	Chironomidae		*Cladotanytarsus* sp.			4	-	-	-
			Cricotopus/Orthocladius sp.	56	9	4	-	-	-
			Epoicocladius sp.	8			-	-	-
			Glyptotendipes sp.			1	-	-	-
			Microtendipes sp.			13	-	-	-
			Paracladopelma sp.		10		-	-	-
			Paratanytarsus sp.	16			-	-	-
			Pentaneurini		1	27	-	-	-
			Polypedilum sp.		2	1	-	-	-
			Potthastia gaedii			1	-	-	-
			Psectrocladius sp.	16			-	-	-
			Stictochironomus sp.			1	-	-	-
			Synorthocladius sp.		4		-	-	-
			Tanytarsus sp.	8	8	11	-	-	-
			Chironomidae pupae			1			
			Chironomidae Sum	139	34	64	3	95	9
	Ceratopogonidae				2	1	1	3	
	Empididae						3		
	Dolichopodidae			1					

NOTE: '+' indicates presence of the taxa. -' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.13. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Gara South.

Date Habitat Group	Family	Subfamily	Species	13/07/96 Stone	15/09/96 Plants	17/01/97 Stone	12/04/97 Stone	06/06/97 Stone
Tricladida	Dugesiidae		*Dugesia lugubris*	1			1	1
	Dendrocoelidae		*Dendrocoelum lacteum*					1
	Littoridininae		*Potamopyrgus jenkinsi*	1				
	Bithyniidae		*Bithynia tentaculata*	5	2			
	Lymnaeidae		*Lymnaea palustris*		1			
			Lymnaea peregra	1				
	Planorbidae		*Planorbis laevis*				2	
Lamellibranchiata			*Pisidium* sp.	13	29		52	9
			Sphaerium sp.		1	1	2	
Oligochaeta	Tubificidae		*Limnodrilus sp.*		2	-	-	-
	Naididae		*Stylaria lacustris*	8	7	-	-	-
			Oligochaeta Sum	8	11	13	165	53
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*	1			2	
			Helobdella stagnalis	3				
	Erpobdellidae		*Erpobdella testacea*		1		2	
Isopoda	Asellidae		*Asellus aquaticus*	110	31	11	55	152
Amphipoda	Gammaridae		*Gammarus duebeni*	+	9	42	16	7
			Gammaridae (juveniles)	23			14	
Ephemeroptera	Beatidae		*Centroptilum luteolum*	5			2	
			Cloeon simile	3	2			
	Caenidae		*Caenis horaria*		1	1	1	2
			Caenis luctuosa	8	13	6	99	22
	Leptophlebiidae		*Leptophlebia marginata*				1	
			Leptophlebia vespertina				6	
	Epehemeridae		*Ephemera danica*	1		1	18	
Hemiptera	Corixidae		*Callicorixa praeusta*				4	
			Sigara distincta				1	
			Sigara dorsalis				3	
			Sigara falleni				2	
			Corixidae (nymphs)	5	3			
	Micronectinae		*Micronecta poweri*					8
Coleoptera	Haliplidae		*Haliplus confinus*				1	
	Elmidae		*Oulimnius tuberculatus*	3	3	1	8	2
Trichoptera	Hydroptilidae		*Hydroptila* sp.		1			
			Agraylea multipunctata		1			
	Polycentropodidae		*Polycentropus flavomaculatus*	2			4	
			Polycentropus kingi	1				
			Cyrnus flavidus		8		2	
			Cyrnus trimaculatus				1	
	Psychomyiidae		*Metalype fragilis*		1			
			Tinodes waeneri	11			22	1
	Phryganeidae		*Agrypnia pagetana*				1	
	Limnephilidae		*Limnephilus vittatus*			1		
			Limnephilidae (early Instars)			1	1	
	Leptoceridae		*Athripsodes aterrimus*		1			
			Athripsodes cinereus					1
	Chironomidae		*Corynoneura* sp.		1	-	-	-
			Cryptochironomus sp.		2	-	-	-
			Microtendipes sp.	4	4	-	-	-
			Pentaneurini	2	1	-	-	-
			Procladius sp.	1		-	-	-
			Psectrocladius sp.	15	7	-	-	-
			Pseudochironomus sp.		3	-	-	-
			Tanytarsus sp.		2	-	-	-
			Chironomidae Sum	22	21	1	40	1

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.14. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Gowna.

Date Habitat Group	Family Subfamily	Species	15/04/96 Stones	09/05/96 Stones	15/06/96 Stone	14/7/96 Stone	15/08/96 Stone	15/09/96 Stones	15/09/96 Plants	17/10/09 Stone	12/03/97 Stone	12/03/97 Stone	12/03/97 Stone	13/04/97 Stone	07/05/97 Stone	07/06/97 Stone
Tricladida	Dugesiidae	*Dugesia lugubris*						1								
	Planariidae	*Planaria torva*				2										
Gastropoda	Valvatidae	*Valvata cristata*							3							
	Littoridininae	*Potamopyrgus jenkinsi*	3		213	119	40	20	42	61						19
	Lymnaeidae	*Lymnaea stagnalis*				22										
		Lymnaea peregra			1	4	1			1						1
		Lymnaea truncatula							2							
	Planorbidae	*Planorbis laevis*													1	
Lamellibranchiata		*Pisidium* sp.				1										
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri*			2						-	-	-	-	-	-
		Limnodrilus sp.	1		3		1	2		1	-	-	-	-	-	-
	Naididae	*Ophidonais serpentina*			26			1			-	-	-	-	-	-
		Nais elinguis		37				1			-	-	-	-	-	-
		Nais simplex		11			1	1		1	-	-	-	-	-	-
		Stylaria lacustris		6	9		2	14		2	-	-	-	-	-	-
	Enchytraeidae				5		5			5	-	-	-	-	-	-
	Lumbricidae	*Lumbriculus variegatus*	2		4	1			1		-	-	-	-	-	-
		immature Tubificidae with hair chaetae			4						-	-	-	-	-	-
		Oligochaeta Sum	10	65	53	1			1	9	2	6	1	6	14	67
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*												1		
Hydracarina																1
Isopoda	Asellidae	*Asellus aquaticus*			8	10	3	131	21					1	1	1
Amphipoda	Gammaridae	*Gammarus duebeni*	61	292	+	+	+	1	157	+	47	25	46	809	41	56
		Gammarus lacustris	214													
		Gammaridae (juveniles)			494	1136	281			36				401	298	
Ephemeroptera	Beatidae	*Centroptilum luteolum*	3	1										2		
	Caenidae	*Caenis horaria*	3	32				4						19	5	3
		Caenis luctuosa	3	5	30	3		6		1					25	50
Zygoptera	Coenagrioniidae	*Ischnura elegans*						1								
Hemiptera	Corixidae	*Arctocorisa germari*					1									
		Callicorixa praeusta					2					1				
		Sigara falleni				1	2									
		Corixidae (nymphs)			5	15	3									1
Coleoptera	Hydroporinae	*Hygrotus quinquelineatus*							1							
	Elmidae	*Limnius volckmari*													1	
		Oulimnius tuberculatus			1			1								

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.14. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Gowna.

Date				15/04/96	09/05/96	15/06/96	14/7/96	15/08/96	15/09/96	15/09/96	17/10/09	12/03/97	12/03/97	12/03/97	13/04/97	07/05/97	07/06/97
Habitat				Stones	Stones	Stone	Stone	Stone	Stones	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species														
Trichoptera	Polycentropodidae		*Cyrnus trimaculatus*			1											
	Psychomyiidae		*Tinodes waeneri*													2	2
	Limnephilidae		*Limnephilus marmoratus*														1
	Leptoceridae		*Athripsodes cinereus*			3											
Diptera	Chironomidae		*Cladotanytarsus* sp.		16	32	1					-	-	-	-	-	-
			Cricotopus/Orthocladius sp.	8	120		2		12	2		-	-	-	-	-	-
			Endochironomus sp.				12	5	6			-	-	-	-	-	-
			Glyptotendipes sp.	3	8	128			2	10	3	-	-	-	-	-	-
			Microtendipes sp.			288	2		4		80	-	-	-	-	-	-
			Polypedilum sp.		8							-	-	-	-	-	-
			Stictochironomus sp.			32						-	-	-	-	-	-
			Synorthocladius sp.	1					6	2		-	-	-	-	-	-
			Tanytarsus sp.	1		96			6			-	-	-	-	-	-
			Chironomidae pupae	1			4		2	1							
			Chironomidae Sum	61	74	576	21	5		16	83	1	6		23	61	97
	Ceratopogonidae			3							2				2	7	3
	Empididae												1				
	Ephydridae														1		

Appendix 1.15. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Graney.

Date				09/04/96	09/06/96	09/06/96	07/07/96	08/09/96	08/09/96	12/01/97	06/04/97	31/05/97
Habitat				Stones	Stones	Stones	Stones	Stones	Plants	Stones	Stones	Stones
Group	Family	Subfamily	Species									
Tricladida	Dugesiidae		*Dugesia lugubris*				1					
			Dugesia polychora					5		2		
	Planariidae		*Polycelis nigra/tenuis*							1	1	
	Dendrocoelidae		*Dendrocoelum lacteum*				1	3		1		3
Gastropoda	Littoridininae		*Potamopyrgus jenkinsi*	3	1	48	12	2	6			1
	Lymnaeidae		*Lymnaea peregra*	1	11	44	15				1	2
	Planorbidae		*Planorbis albus*								1	
			Planorbis carinatus		1				1			
	Ancylidae		*Ancylus fluviatilis*							4	1	1
			Acroloxus lacustris		3			1	1	1		
Lamellibranchiata			*Pisidium* sp.		3	13	1	3	8	11		3
			Sphaerium sp.	2							10	
Oligochaeta	Tubificidae		*Limnodrilus sp.*					7		-	-	-
	Naididae		*Ophidonais serpentina*					1		-	-	-
			Nais simplex		4					-	-	-
			Stylaria lacustris		172	124	11	10	1	-	-	-
	Lumbricidae		*Lumbriculus variegatus*			8		8	1	-	-	-
			Oligochaeta Sum	3	278	169	11	36	2	68	89	43
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*				1					
			Helobdella stagnalis							5	2	2
			Hemiclepsis marginata	1								
Hydracarina					2	1		1			3	
Isopoda	Asellidae		*Asellus aquaticus*	2	25	10	13	50	29	108	7	33
Amphipoda	Gammaridae		*Gammarus duebeni*			1						
			Gammaridae (juveniles)				1					
Ephemeroptera	Beatidae		*Centroptilum luteolum*	26	12	11	13	7		111	92	9
	Heptageniidae		*Heptagenia fuscogrisea*							3	1	
			Heptagenia sulphurea	1								
	Caenidae		*Caenis horaria*								1	
			Caenis luctuosa	45	22	50	5	20	2	614	97	24
			Caenis rivulorum								3	
Hemiptera	Corixidae		*Sigara distincta*							1		
			Sigara falleni		2	1			1			
			Sigara spp.		2							
			Corixidae (nymphs)		19	1				20	90	1
	Micronectinae		*Micronecta poweri*		6	57	2					27
	Aphelocheirinae		*Aphelocheirus aestivalis*								1	
	Gerridae		*Gerris (nymph)*						1			

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.15 (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Graney.

Date				09/04/96	09/06/96	09/06/96	07/07/96	08/09/96	08/09/96	12/01/97	06/04/97	31/05/97
Habitat				Stones	Stones	Stones	Stones	Stones	Plants	Stones	Stones	Stones
Group	Family	Subfamily	Species									
Coleoptera	Gyrinidae		*Orectochilus villosus*							1		1
			Gyrinus aeratus			12				3		
			Gyrinus spp.	1								
	Haliplidae		*Haliplus confinus*	1	1							
			Haliplus (larvae)		1			1				
	Hydroporinae		*Potamonectes depressus elegans*							1	1	
	Elmidae		*Elmis aenea*					3	1			
			Oulimnius tuberculatus	20	3	3	2	62	7	64	2	
Trichoptera	Hydroptilidae		*Agraylea multipunctata*		7	1						
	Polycentropodidae		*Plectrocnemia conspersa*							9	1	
			Polycentropus flavomaculatus									2
			Polycentropus kingi			1		1		2		
			Cyrnus flavidus								1	
			Cyrnus trimaculatus			1				1		5
	Psychomyiidae		*Lype reducta*		2							
			Tinodes waeneri	1			1		3	15	1	
	Ecnomidae		*Ecnomus tenellus*			1				1		1
	Limnephilidae		Limnephilidae (early Instars)							2		
	Goeridae		*Goera pilosa*					1		1		
	Leptoceridae		*Athripsodes cinereus*			3						
			Triaenodes bicolor								1	
			Leptoceridae (early instars)					1				
Diptera	Tipulidae						7					
	Chaoboridae		Chaoborus					1	2			
	Chironomidae		*Corynoneura* sp.						1	-	-	-
			Cricotopus/Orthocladius sp.		8	6	3			-	-	-
			Micropsectra sp.			1				-	-	-
			Pentaneurini			2				-	-	-
			Psectrocladius sp.		28	19				-	-	-
			Synorthocladius sp.					1		-	-	-
			Tanytarsus sp.			4				-	-	-
			Chironomidae pupae		8	3						
			Chironomidae Sum	3	64	34	3	1	1	1	25	31
	Ceratopogonidae				1				4	2		

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.16. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Inchiquin.

Date			10/04/96	10/06/96	10/07/96	13/08/96	11/09/96	11/09/96	14/01/97	09/03/97	09/03/97	09/03/97	09/04/97	04/05/97	01/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Plants	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family Subfamily	Species													
Tricladida	Dugesiidae	*Dugesia lugubris*			2										1
		Dugesia polychora	8				1							1	
	Planariidae	*Planaria torva*				1									1
		Polycelis nigra/tenuis	442	45	5		3	1	7	4	3	4		15	2
	Dendrocoelidae	*Dendrocoelum lacteum*		5	1										
Gastropoda	Neritidae	*Theodoxus fluviatilis*	11		1		8		3				2		2
	Viviparidae	*Viviparus fasciatus*	2										8		
	Valvatidae	*Valvata cristata*			1		2	1							
		Valvata macrostoma					1		1					1	
	Littoridininae	*Potamopyrgus jenkinsi*								1	4	6	6	13	
	Bithyniidae	*Bithynia tentaculata*	2	18	22	1	4				1			13	
		Bithynia leachi									1	1			
	Physidae	*Physa fontinalis*		1	6			2							
	Lymnaeidae	*Lymnaea palustris*		1											
		Lymnaea peregra		21	2	1	3	3					1		
		Lymnaea truncatula		2											
	Planorbidae	*Planorbis albus*											2		1
		Planorbis contortus		1											
		Planorbis laevis		2					1						
Lamellibranchiata		*Pisidium* sp.	5	53	6		13							14	
		Sphaerium sp.	2		20	12	4	1	12		3	5	11		5
Oligochaeta	Tubificidae	*Limnodrilus* sp.		8	4	2	12	4	-	-	-	-	-	-	-
		Aulodrilus pluriseta			1				-	-	-	-	-	-	-
	Naididae	*Stylaria lacustris*		24	63	29	4	23	-	-	-	-	-	-	-
	Lumbricidae	*Lumbriculus variegatus*		64	1				-	-	-	-	-	-	-
		Stylodrilus heringianus					1		-	-	-	-	-	-	-
		immature Tubificidae with hair chaetae		8	3	1	3		-	-	-	-	-	-	-
		Oligochaeta Sum	32	146	72	32	24	34	91	8	10	10	41	74	55
Hirudinea	Glossiphoniidae	*Glossiphonia heteroclita*				1									
		Helobdella stagnalis	5	6	3	1	1	1							
	Erpobdellidae	*Erpobdella testacea*													2
		Erpobdella octoculata					3	1							
		Dina lineata							4				1		
Hydracarina				6	2	1		4	6						12
Isopoda	Asellidae	*Asellus aquaticus*	608	78	94	11	23	27	254	4	6	7	69	30	60
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	22					2	7				15		
	Gammaridae	*Gammarus duebeni*	2	117			40	3	16	1	3	1	18	1	232
		Gammarus lacustris	8			+							42		
		Gammaridae (juveniles)			3	9				28	23	10			

NOTE: '+' indicates presence of the taxa. -' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.16. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Inchiquin.

Date Habitat Class/Order	Family Subfamily	Species	10/04/96 Stones	10/06/96 Stones	10/07/96 Stones	13/08/96 Stones	11/09/96 Stones	11/09/96 Plants	14/01/97 Stones	09/03/97 Stones	09/03/97 Stones	09/03/97 Stones	09/04/97 Stones	04/05/97 Stones	01/06/97 Stones
	Beatidae	*Baetis rhodani*							2						
		Baetis muticus											1		
		Centroptilum luteolum			1			3							
		Cloeon dipterum									1				
		Cloeon simile				2		2			1				
	Ephemerellidae	*Ephemerella ignita*				9									6
	Caenidae	*Caenis horaria*				1							4		2
		Caenis luctuosa	93	45			253	408	592		1	1	72	1	26
		Leptophlebia vespertina	2												
	Epehemeridae	*Ephemera danica*	2												
Plecoptera	Leuctridae	*Leuctra nigra*								1					
Hemiptera	Corixidae	*Callicorixa praeusta*	5	1	4										
		Sigara dorsalis						2							
		Sigara fallenoidea									1				
		Corixidae (nymphs)		3	22										
	Notonectinae	*Notonecta glauca*									1				
		Notonecta spp.			1										
Coleoptera	Gyrinidae	*Orectochilus villosus*					3	2	15				20		
		Gyrinus spp.	3												
		Haliplus confinus													5
		Haliplus flavicollis	2	1											
		Haliplus (larvae)					6		1	1	1		4		
	Hydroporinae	*Hyphydrus ovatus*							1						
		Potamonectes depressus elegans							1						2
		Hydroporinae (larvae)			5										
	Elmidae	*Elmis aenea*						1	2						
		Oulimnius tuberculatus	13	1		5	23	11	5	3	1	1	2		3
	Hydrophilidae	*Hydrophilus* sp.			1										
	Helophorinae	*Helophorus arvernicus*		1											
	Hydrophilinae	*Laccobius biguttatus*			1										
Trichoptera	Glossosomatidae	*Agapetus fuscipes*							1						
	Hydroptilidae	*Hydroptila* sp.					7	29	5		1			1	
	Polycentropodidae	*Plectrocnemia conspersa*							20	1					
		Plectrocnemia (early instars)						8							
		Polycentropus flavomaculatus				16	35		13						5
		Polycentropus kingi						5					2		
		Holocentropus dubius						2							
	Psychomyiidae	*Tinodes waeneri*	77				3						4		
	Limnephilidae	*Limnephilus lunatus*			1										
		Limnephilus marmoratus											1		
		Limnephilidae (early Instars)									1	1			
		Halesus radiatus	5				1								
	Lepidostomatidae	*Lepidostoma hirtum*							11				3	1	3

Appendix 1.16. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Inchiquin.

Date				10/04/96	10/06/96	10/07/96	13/08/96	11/09/96	11/09/96	14/01/97	09/03/97	09/03/97	09/03/97	09/04/97	04/05/97	01/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Plants	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family	Subfamily	Species													
	Leptoceridae		*Athripsodes aterrimus*													2
			Athripsodes bilineatus			1										
			Athripsodes cinereus	2	8									2	1	3
			Athripsodes (early instars)							1						
			Mystacides azurea								1					
	Sericostomatidae		*Sericostoma personatum*	5						1				2		
Diptera	Tipulidae						1			1	1			1		
	Psychodidae													2		
	Chaoboridae		*Chaoborus*	2	9					-	-	-	-	-	-	-
	Chironomidae		*Cladotanytarsus* sp.		8	2		8		-	-	-	-	-	-	-
			Corynoneura sp.						1	-	-	-	-	-	-	-
			Cricotopus/Orthocladius sp.		24	9	8		3	-	-	-	-	-	-	-
			Microtendipes sp.		4	3	8	48	3	-	-	-	-	-	-	-
			Parachironomus sp.				1			-	-	-	-	-	-	-
			Pentaneurini		4	1	2			-	-	-	-	-	-	-
			Polypedilum sp.		8	1				-	-	-	-	-	-	-
			Potthastis longimana sp.		4					-	-	-	-	-	-	-
			Procladius sp.				2	1		-	-	-	-	-	-	-
			Psectrocladius sp.		24	3				-	-	-	-	-	-	-
			Synorthocladius sp.						1	-	-	-	-	-	-	-
			Tanytarsus sp.					3	6	-	-	-	-	-	-	-
			Chironomidae pupae				1		1							
			Chironomidae Sum	5	73	19	22	82	13	283	2			47	4	43
	Ceratopogonidae				6			2	1	5		2		4	5	3
	Empididae													1		
	Tabanidae												1			
	Ephydridae									1						

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.17. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Lene.

Date		24/04/96	27/06/96	24/07/96	28/08/96	26/09/96	24/10/96	22/01/97	13/03/97	16/04/97	15/05/97	19/06/97
Sample Substrate		Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Species											
Tricladida	*Planaria torva*		1									
	Polycelis nigra/tenuis					1		3	3		3	2
	Dugesia lugubris			1						1	3	1
Gastropoda	*Theodoxus fluviatilis*					1						
	Potamopyrgus jenkinsi		1			3	1			1	4	7
	Lymnaea palustris										2	
	Lymnaea truncatula									1		
	Lymnaea stagnalis								1			
	Physa fontinalis			1								
	Planorbis albus					1						
	Planorbis carinatus					1						
	Planorbis contortus								2	1		
	Planorbis laevis			3								
	Ancylus fluviatilis							1				
	Succinea ?(oblonga)											
Bivalvia	*Pisidium* sp.		4		2	61	34	2		11	4	7
	Sphaerium sp.							3			8	4
Oligochaeta	*Aulodrilus pluriseta*			3		-		-	-	-	-	-
	Enchytraeidae		1			-		-	-	-	-	-
	Limnodrilus sp.		1	35	1	-	8	-	-	-	-	-
	Lumbricidae		2			-		-	-	-	-	-
	Lumbriculus variegatus		7	6	1	-		-	-	-	-	-
	Peloscolex ferox					-		-	-	-	-	-
	Stylaria lacustris			4		-		-	-	-	-	-
	Uncinais uncinata			7		-		-	-	-	-	-
	Immature Tubificidae		2	80	7	-	1	-	-	-	-	-
	Olighochaeta SUM		13	135	9		9	284	16	25	39	55
Hirudina	*Glossiphonia complanata*				1						2	
	Helobdella stagnalis			1		3	1	2			1	3
	Erpobdella octoculata/testacea			1								
Hydracarina				1				1				2
Ostracoda								1				
Isopoda	*Asellus aquaticus*			102	2			3		1	1	1
Amphipoda	*Gammarus duebeni*	371	+		+	321	+	27	56	75	49	368
	Gammarus lacustris		+	+					92			
	Gammaridae (juveniles)		546	33	270		25	25		195	14	182

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.17. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Lene.

Date		24/04/96	27/06/96	24/07/96	28/08/96	26/09/96	24/10/96	22/01/97	13/03/97	16/04/97	15/05/97	19/06/97
Sample Substrate		Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Species											
Ephemeroptera	*Centroptilum luteolum*			9								
	Heptagenia sulphurea						4					
	Caenis luctuosa		14	2		4	10	260	1	2		6
	Caenis horaria											
Plecoptera	*Capnia bifrons*								1			
Zygoptera	*Coenagrion mercuriale*										1	
	Enallagma cyathigerum		1									
Hemiptera	*Orectochilus villosus*			2								
	Sigara dorsalis							1				
	Corixidae (nymphs)			1						37	4	
	Micronecta poweri		3									
Coleoptera	*Orectochilus villosus*											
	Oulimnius tuberculatus	3	2			3	1	7	1	8		4
Megaloptera	*Sialis lutaria*											
Trichoptera	*Lepidostoma hirtum*						2	4				
	Sericostoma personatum				2		1				5	3
	Athripsodes aterrimus			2								3
	Athripsodes cinereus		4								1	1
	Oecetis furva			1								
	Psychomyia pusilla/Metalype fragilis						1					
	Metalype fragilis						1					
	Agrypnia obsoleta							1				
	Cyrnus flavidus							1				
Diptera	Tipulidae							2	1			
	Ceratopogonidae		4					2		2	5	8

Appendix 1.17. (Continued). Macroinvertebrate species abundances (per sample) taken from the littoral region of Lough Lene.

Date Sample Substrate Group	Species	24/04/96 Stones	27/06/96 Stones	24/07/96 Stones	28/08/96 Stones	26/09/96 Stones	24/10/96 Stones	22/01/97 Stones	13/03/97 Stones	16/04/97 Stones	15/05/97 Stones	19/06/97 Stones
Chironomidae	*Cladotanytarsus* sp.		2	8		-		-	-	-	-	-
	Cricotopus/Orthocladius sp.	1				-	2	-	-	-	-	-
	Cryptochironomus sp.			1		-		-	-	-	-	-
	Endochironomus sp.				1	-		-	-	-	-	-
	Glyptotendipes sp.					-		-	-	-	-	-
	Microtendipes sp.			9		-		-	-	-	-	-
	Pentaneurini			1		-		-	-	-	-	-
	Polypedilum sp.		2			-		-	-	-	-	-
	Potthastia gaedii				3	-		-	-	-	-	-
	Procladius sp.					-		-	-	-	-	-
	Psectrocladius sp.					-	1	-	-	-	-	-
	Tanytarsus sp.			2		-		-	-	-	-	-
	Chironomidae pupae		1			-	1	-	-	-	-	-
	Chironomidae SUM	3	5	21	4	1	4	50	6	3	15	4
	Ephydridae								1			
	Dolichopodidae								1			
	Stratiomyidae							1		2		

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.18. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Lettercraffroe.

Date Habitat Group	Family	Subfamily	Species	12/04/96 Stones	12/06/96 Stone	11/07/96 Stone	12/09/96 Stone	15/01/97 Stone	10/04/97 Stone	04/06/97 Stone
Tricladida	Planariidae		*Polycelis nigra/tenuis*					6	2	
	Dendrocoelidae		*Dendrocoelum lacteum*					1		
Lamellibranchiata			*Pisidium* sp.	3	1		7	9		
			Sphaerium sp.					5	2	
Oligochaeta	Tubificidae		*Limnodrilus* sp.	20	17	4		-	-	-
			Peloscolex ferox			2		-	-	-
	Naididae		*Stylaria lacustris*		60	30		-	-	-
			Dero digitata		3			-	-	-
	Lumbricidae		*Lumbriculus variegatus*	40	75	49	4	-	-	-
			Lumbricidae spp.		1			-	-	-
			immature Tubificidae with hair chaetae	28	27	4	6	-	-	-
			Oligochaeta Sum	420	183	89	14	178	104	254
Hirudinea	Glossiphoniidae		*Helobdella stagnalis*				2	5	2	3
	Erpobdellidae		*Erpobdella octoculata/testacea*			1				
			Dina lineata					1		
Hydracarina							5			3
Isopoda	Asellidae		*Asellus aquaticus*							1
			Asellus meridianus					10	1	
Ephemeroptera	Caenidae		*Caenis luctuosa*	3			3	3		
			Leptophlebia vespertina	384	8			22	27	1
Plecoptera	Leuctridae		*Leuctra nigra*	3						
Hemiptera	Corixidae		*Callicorixa praeusta*		3	1				
			Sigara fallenoidea	3						
			Sigara falleni		1	1				
			Sigara scotti		4	4			4	2
			Corixidae (nymphs)			231				2
Coleoptera	Gyrinidae		*Gyrinus* spp.			3				
			Gyrinus (larvae)							1
	Dytiscidae		*Agabus* (larvae)					1		
	Hydroporinae		*Stictotarsus duodecimpustulatus*			3				
			Hydroporus nigrita	3						
			Potamonectes depressus elegans							1
	Elmidae		*Oulimnius tuberculatus*				1			
Trichoptera	Polycentropodidae		*Plectrocnemia conspersa*					1		
			Polycentropus flavomaculatus			4				
			Polycentropus kingi	16	4	2				
			Cyrnus trimaculatus		1					
	Psychomyiidae		*Tinodes waeneri*			1		4	3	1
	Limnephilidae		*Limnephilus lunatus*	16				16	1	
			Limnephilidae (early Instars)					2		
			Halesus digitatus/ radiatus					4		
	Leptoceridae		*Triaenodes bicolor*				1			
Diptera	Chironomidae		*Corynoneura* sp.	32				-	-	-
			Cricotopus/Orthocladius sp.	8	12	5		-	-	-
			Heterotrissocladius sp.	8				-	-	-
			Microtendipes sp.			1	2	-	-	-
			Pentaneurini	16	24	1	4	-	-	-
			Polypedilum sp.				2	-	-	-
			Potthastis longimana sp.				1	-	-	-
			Psectrocladius sp.		8	7		-	-	-
			Pseudochironomus sp.				1	-	-	-
			Stictochironomus sp.				3	-	-	-
			Tanytarsus sp.	24			1	-	-	-
			Chironomidae pupae			1		-	-	-
			Chironomidae Sum	256	44	15	14	106	30	26

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.19. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Lickeen

Date		11/04/96	07/05/96	11/06/96	09/07/96	13/08/96	10/09/96	15/10/96	14/01/97	10/03/97	07/04/97	05/05/97	01/06/97
Sample Substrate		Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Species												
Tricladida	*Planaria torva*											1	5
	Polycelis nigra/tenuis											1	1
	Dugesia lugubris										1	2	
	Dugesia polychora						3						
Gastropoda	*Potamopyrgus jenkinsi*							1					
	Lymnaea peregra				1							12	1
Oligochaeta	*Enchytraeidae*	1	1				1		-	-	-	-	-
	Limnodrilus sp.			2		5	2		-	-	-	-	-
	Lumbricidae							3	-	-	-	-	-
	Lumbriculus variegatus			26		9	14	1	-	-	-	-	-
	Nais variabilis		1						-	-	-	-	-
	Peloscolex ferox		8			4	3		-	-	-	-	-
	Stylaria lacustris		2		8				-	-	-	-	-
	Stylodrilus heringianus	7							-	-	-	-	-
	Immature Tubificidae	1	2	11					-	-	-	-	-
	Oligochaeta SUM	9	14	39	8	18	20	4					
Hirudina	*Erpobdella testacea*												1
Hydracarina			10		3						1		
Isopoda	*Asellus aquaticus*	3		1	10	7	12	29			19	6	79
	Asellus meridianus				+						2		
Amphipoda	*Crangonyx pseudogracilis*										3		
	Gammarus duebeni	24	326	+		+	79		34	12	25	24	206
	Gammarus lacustris	24	992	+							42		
	Gammaridae (juveniles)			112	61	70		1		16		28	
Ephemeroptera	*Cloeon simile*				6								
	Heptagenia sulphurea		3										
	Caenis luctuosa	3	10		2		13				4		1
Hemiptera	*Sigara fallenoidea*		13										
	Sigara falleni				3								
	Corixidae (nymphs)				83		1						
Coleoptera	*Gyrinus* (larvae)						1						
	Potamonectes depressus elegans										1		
	Potamonectes depressus depressus				1								
	Potamonectes sp.			1									
	Oulimnius tuberculatus		61	1			4				1		3
Trichoptera	*Lepidostoma hirtum*		32										
	Halesus radiatus												
	Limnephilus lunatus									4	1		
	Limnephilus nigriceps												
	Limnephilidae (early Instars)												
	Orectochilus villosus		22		1								3
	Tinodes waeneri												1
	Polycentropus kingi				5								

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.19. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Lickeen

Date / Sample Substrate / Group		Species	11/04/96 Stones	07/05/96 Stones	11/06/96 Stones	09/07/96 Stones	13/08/96 Stones	10/09/96 Stones	15/10/96 Stones	14/01/97 Stones	10/03/97 Stones	07/04/97 Stones	05/05/97 Stones	01/06/97 Stones
Diptera	Tipuliudae								1					
Chironomidae		*Cricotopus/Orthocladius* sp.	12	2		6				-	-	-	-	-
		Cryptochironomus sp.		1	1					-	-	-	-	-
		Glyptotendipes sp.						10		-	-	-	-	-
	Pentaneurini									-	-	-	-	-
		Stempellinella sp.						1		-	-	-	-	-
		Synorthocladius sp.		7				5		-	-	-	-	-
	Chironomidae SUM		12	10	1	6		16	2		27			

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.20. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Maumwee.

Date Habitat Group	Family	Subfamily	Species	12/04/96 Stones	12/06/96 Stone	11/07/96 Stone	12/09/96 Stone	12/09/96 Plant	15/01/97 Stone	10/04/97 Stone	04/06/97 Stone	18/09/97 Stone
Tricladida	Dendrocoelidae		*Dendrocoelum lacteum*								2	
Lamellibranchiata			*Sphaerium* sp.						1			
Oligochaeta	Tubificidae		*Peloscolex ferox*	1			1		-	-	-	1
	Naididae		*Nais elinguis*						-	-	-	
			Stylaria lacustris				3		-	-	-	
	Enchytraeidae						1		-	-	-	
	Lumbricidae		*Lumbriculus variegatus*	2	5		6		-	-	-	1
			Oligochaeta Sum	16	5		15		29	1	25	2
Hirudinea	Glossiphoniidae		*Helobdella stagnalis*	6	1							
Hydracarina				3								
Amphipoda	Crangammaridae		*Crangonyx pseudogracilis*	10	9		13	15	21	9	14	
Ephemeroptera	Caenidae		*Caenis luctuosa*	26	8		17		90	9	16	
	Leptophlebiidae		*Leptophlebia vespertina*	26					6	1		
Plecoptera	Leuctridae		*Leuctra hippopus*			2						
			Leuctra nigra								5	
	Chloroperlidae		*Siphonoperla torrentium*						1			
Hemiptera	Corixidae		Corixidae (nymphs)			1						
Coleoptera	Hydraenidae		*Limnebius truncatellus*						1			
Trichoptera	Hydroptilidae		*Oxyethira* sp.					1				
	Polycentropodidae		*Plectrocnemia geniculata*	3								
			Polycentropus flavomaculatus								3	
			Polycentropus kingi									
			Cyrnus flavidus									1
	Psychomyiidae		*Tinodes waeneri*		3							
	Limnephilidae		Limnephilidae (early Instars)					1				
	Lepidostomatidae		*Lepidostoma hirtum*		1				2		3	
	Leptoceridae		*Ceraclea fulva*								3	
			Mystacides azurea	10			1		3	1		
			Oecetis furva								1	
			Oecetis ochracea	6								
			Leptoceridae (early instars)					4				
	Sericostomatidae		*Sericostoma personatum*						1		2	
Diptera	Chironomidae		*Chironomus* sp.				1		-	-	-	
			Cladotanytarsus sp.	1					-	-	-	
			Corynoneura sp.					2	-	-	-	
			Cricotopus/Orthocladius sp.	1					-	-	-	
			Cryptochironomus sp.				1		-	-	-	
			Demicryptochironomus sp.		1				-	-	-	
			Dicrotendipes sp.						-	-	-	1
			Endochironomus sp.						-	-	-	2
			Lauterborniella sp.			1			-	-	-	
			Macropelopia sp.		4				-	-	-	
			Parametriocnemus sp.		1				-	-	-	
			Pentaneurini	1	5		2	1	-	-	-	
			Polypedilum sp.					2	-	-	-	
			Procladius sp.	2					-	-	-	
			Psectrocladius sp.		1	1	1	2	-	-	-	1
			Stempellinella sp.	4					-	-	-	
			Tanytarsus sp.				1		-	-	-	1
			Chironomidae pupae		1			1				
			Chironomidae Sum	26	13	2	8	9	49	63	38	5
	Ceratopogonidae		Ceratopogonidae spp.		1		1				1	
	Empididae										1	
	Tabanidae								14			

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.21. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Moher.

Date				13/04/96	08/05/96	13/06/96	13/06/96	12/07/96	14/08/96	13/09/96	13/09/96	16/10/96	16/10/96	16/01/97	11/03/97	11/03/97	11/03/97	11/04/97	06/05/97	05/06/97
Habitat				Stones	Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily	Species																	
Tricladida	Planariidae		*Polycelis nigra/tenuis*							2										
Gastropoda	Littoridininae		*Potamopyrgus jenkinsi*	176	16	1		11	2	4	31	6	3	144		3		49	47	60
	Lymnaeidae		*Lymnaea palustris*				1													
			Lymnaea stagnalis								1									
			Lymnaea peregra				1	1	1											1
	Planorbidae		*Planorbis laevis*								1									
Lamellibranchiata			*Pisidium* sp.		1		13	2	1	4	17				9	5	6	2	7	1
			Sphaerium sp.											6						4
Oligochaeta	Tubificidae		*Limnodrilus* sp.				3		3	9		2		-	-	-	-	-	-	-
			Peloscolex ferox				1				1			-	-	-	-	-	-	-
			Aulodrilus pluriseta	1	1	1		1		6		1		-	-	-	-	-	-	-
	Naididae		*Nais communis*	2	5	1								-	-	-	-	-	-	-
			Nais simplex			1								-	-	-	-	-	-	-
			Nais variabilis											-	-	-	-	-	-	-
			Stylaria lacustris	13	50	15		1				1		-	-	-	-	-	-	-
	Enchytraeidae					3	38						4	-	-	-	-	-	-	-
	Lumbricidae		*Lumbriculus variegatus*	2	1	11		8	7	10	8	35	15	-	-	-	-	-	-	-
			Stylodrilus heringianus				101							-	-	-	-	-	-	-
			Lumbricidae spp.			2						2	1	-	-	-	-	-	-	-
			immature Tubificidae with hair chaetae			1	21			9	2	27	4	-	-	-	-	-	-	-
			Oligochaeta Sum	83	58	35	164	10	10	57	16	68	24	87	12	27	18	54	5	60
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*							1										
			Helobdella stagnalis						15	1				2			1			2
			Theromyzon tessulatum							1	1									
			Boreobdella verrucata					1												
Hydracarina																		1	2	
Isopoda	Asellidae		*Asellus aquaticus*							1										
			Asellus meridianus						1	1	3			11		3		1		6
Amphipoda	Crangammaridae		*Crangonyx pseudogracilis*			1	10	13	4	30		4	1							
	Gammaridae		*Gammarus duebeni*		3					3	7			3	1		2	9	5	25
			Gammarus lacustris	3										6				9		
			Gammaridae (juveniles)						2			1					1			
Ephemeroptera	Siphlonuridae		*Siphlonurus alternatus*				5													
	Beatidae		*Centroptilum luteolum*	6	2			5	11	1	7		1	101	2		2	46	8	6
			Cloeon simile		1						6	1		24				5	2	
	Caenidae		*Caenis horaria*							5	2		1	32		1	3	12	3	
			Caenis luctuosa	6				1		17	14	2	19	225	16	13	39	68	10	19
	Leptophlebiidae		*Leptophlebia marginata*	42										1					3	
			Leptophlebia vespertina	3	10		6								11	14	9	10	1	7
Anisoptera			Anisoptera (early instars)																1	
Hemiptera	Corixidae		*Sigara distincta*	16			3			1								4	1	
			Sigara dorsalis								1									
			Sigara fallenoidea								1			1						
			Sigara falleni			2			4				1							
			Sigara fossarum				2							1						

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.21. (Continued). Macroinvertebrate abundances taken from the littoral region of Lough Moher

Date			13/04/96	08/05/96	13/06/96	13/06/96	12/07/96	14/08/96	13/09/96	13/09/96	16/10/96	16/10/96	16/01/97	11/03/97	11/03/97	11/03/97	11/04/97	06/05/97	05/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family Subfamily	Species																	
Hemiptera	Corixidae	*Sigara* spp.		1															
		Cymatia bonsdorffi				3			1									2	
		Corixidae (nymphs)					12	17	2										
	Notonectinae	*Notonecta* spp.					2												
		Notonceta (nymphs)																4	
Coleoptera	Haliplidae	*Haliplus confinus*								1			1	1			2	3	
		Haliplus lineatocollis														1			
		Haliplus ruficollis grp.			1	2	1												
		Haliplus (larvae)							3	1				1	2				
	Dytiscidae	*Agabus* (larvae)		1									1						
	Hydroporinae	*Hygrotus quinquelineatus*								1									
		Hygrotus inaequalis																1	
		Hydroporus palustris															1		
		Hydroporus (larvae)															1		
		Hydroporus sp.						1											
		Suphrodytes dorsalis	83																
		Potamonectes depressus depressus						1											
		Potamonectes sp.					1												
	Elmidae	*Oulimnius tuberculatus*																	1
	Helophorinae	*Helophorus nigritta*											1						
		Helophorus sp.				1													
	Hydraenidae	*Limnebius truncatellus*				1													
Megaloptera	Sialidae	*Sialis lutaria*					1	3	1	1							3		
Trichoptera	Polycentropodidae	*Polycentropus flavomaculatus*							1										
	Phryganeidae	*Phryganea* (early instar)					1												
		Limnephilus affins/incisus											1						
		Limnephilus flavicornis											3						
		Limnephilus lunatus															1		
		Limnephilidae (early Instars)										2	1	1	1	1			
	Lepidostomatidae	*Lepidostoma hirtum*															1	1	
		Mystacides azurea																	2
		Triaenodes bicolor							4									2	
	Sericostomatidae	*Sericostoma personatum*												1					
	Beraeidae	*Beraea pullata*						1											

Appendix 1.21. (Continued). Macroinvertebrate abundances taken from the littoral region of Lough Moher

Date			13/04/96	08/05/96	13/06/96	13/06/96	12/07/96	14/08/96	13/09/96	13/09/96	16/10/96	16/10/96	16/01/97	11/03/97	11/03/97	11/03/97	11/04/97	06/05/97	05/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Stones	Stones	Plants	Stone	Plants	Stone	Stone	Stone	Stone	Stone	Stone	Stone
Group	Family	Subfamily Species																	
Diptera	Tipulidae				3	1													
	Chironomidae	*Cladotanytarsus* sp.					1						-	-	-	-	-	-	-
		Corynoneura sp.	4							1		2	-	-	-	-	-	-	-
		Cricotopus/Orthocladius sp.	4		9		1						-	-	-	-	-	-	-
		Cryptochironomus sp.								2			-	-	-	-	-	-	-
		Demicryptochironomus sp.					1	2					-	-	-	-	-	-	-
		Endochironomus sp.						10					-	-	-	-	-	-	-
		Macropelopia sp.					16						-	-	-	-	-	-	-
		Microtendipes sp.						3	1	6		1	-	-	-	-	-	-	-
		Pentaneurini	2	1	1		6					1	-	-	-	-	-	-	-
		Phaenopsectra sp.							1				-	-	-	-	-	-	-
		Procladius sp.	1		1			5	1				-	-	-	-	-	-	-
		Psectrocladius sp.	2	1	33							1	-	-	-	-	-	-	-
		Stictochironomus sp.						1					-	-	-	-	-	-	-
		Synorthocladius sp.											-	-	-	-	-	-	-
		Chironomidae pupae	2		2														
		Chironomidae Sum	48	3	46		25	21	3	12		5		5	21	9	23	15	12
	Ceratopogonidae														2	2	1	6	6
	Tabanidae								1										1
	Ephydridae																	1	

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.22. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Muckno.

Date Sample Substrate Group	Species	23/04/96 Stones	26/06/96 Stones	23/07/96 Stones	25/09/96 Stones	21/01/97 Stones	15/04/97 Stones	18/06/97 Stones
Tricladida	*Planaria torva*		1					
	Polycelis nigra/tenuis	5	6	8	18		2	4
	Dugesia polychora				5	2		
Gastropoda	*Valvata cristata*		1		1			
	Potamopyrgus jenkinsi		1					1
	Lymnaea peregra			1				4
	Lymnaea truncatula							
	Physa fontinalis							
	Planorbis albus							
	Planorbis carinatus			2				
	Planorbis planorbis		1		+			
	Valvata piscinalis			4				
	Ancylus fluviatilis			1				
Nematoda			4					
Oligochaeta	Enchytraeidae	8	6			-	-	-
	Limnodrilus sp.				8	-	-	-
	Lumbriculus variegatus		56	5	56	-	-	-
	Nais simplex			1		-	-	-
	Peloscolex ferox		1		8	-	-	-
	Stylaria lacustris	1	3	191	40	-	-	-
	Immature Tubificidae				16	-	-	-
	Oligocaheta SUM	9	66	197	128	24	68	114
Hirudina	*Haemopis sanguisuga*					1		
Hydracarina							3	3
Ostracoda							1	
Isopoda	*Asellus aquaticus*		92	136	29	6	1	14
Amphipoda	*Gammarus lacustris*	1					2	5
Ephemeroptera	*Centroptilum luteolum*				2	3	4	
	Ephemera danica				1			
	Caenis luctuosa				11	3	1	4
	Caenis horaria		1		1	1	3	1
Hemiptera	*Callicorixa praeusta*						5	
	Sigara distincta						7	4
	Sigara falleni	2		6			2	
	Corixidae (nymphs)			57	4			73
Coleoptera	*Haliplus* (larvae)	2			1			
	Orectochilus villosus				1			
	Stictotarsus duodecimpustulatus			1	1			
	Hygrotus inaequalis			1				
Megaloptera	*Sialis lutaria*	1						
Trichoptera	*Mystacides azurea*						1	
	Tinodes waeneri				1			
	Ecnomus tenellus				1			1
Diptera	Psychodidae					1		
	Ceratopogonidae					1	1	
Chironomidae	*Cladotanytarsus* sp.		8			-	-	-
	Corynoneura sp.				3	-	-	-
	Cricotopus/Orthocladius sp.		56	27	43	-	-	-
	Endochironomus sp.			6	41	-	-	-
	Glyptotendipes sp.			1	10	-	-	-
	Parachironomus sp.			4	1	-	-	-
	Paratanytarsus sp.				5	-	-	-
	Polypedilum sp.		40	5		-	-	-
	Procladius sp.			1		-	-	-
	Psectrocladius sp.		16	1	1	-	-	-
	Stictochironomus sp.			3		-	-	-
	Synorthocladius sp.				8	-	-	-
	Tanytarsus sp.		8	2		-	-	-
	Chironomidae pupae	1		6	4			
	Chironomidae SUM	1	128	56	116	4	63	95

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.23. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Mullagh.

Date				23/04/96	26/06/96	24/07/96	26/09/96	26/09/96	26/10/96	22/01/97	15/04/97	18/06/97
Habitat				Stones	Stones	Plants (s)	Plants (s)	Plants (s)	Stones	Stones	Stones	Stones
Group	Family	Subfamily	Species									
Tricladida	Dugesiidae		*Dugesia lugubris*						1			
			Dugesia polychora				9					
	Planariidae		*Planaria torva*		1	1					4	
			Polycelis nigra/tenuis	51		1	53	67		14	20	
Gastropoda	Valvatidae		*Valvata macrostoma*							1		
	Physidae		*Physa fontinalis*	10	6	1	1					
	Lymnaeidae		*Lymnaea palustris*				1					
			Lymnaea peregra			1						
	Planorbidae		*Planorbis albus*						5			
			Planorbis carinatus						1			
Lamellibranchiata			*Pisidium* sp.	3						2		
			Sphaerium sp.									1
Oligochaeta	Tubificidae		*Limnodrilus hoffmeisteri*			1			-	-	-	-
			Limnodrilus sp.			51	19		-	-	-	-
	Naididae		*Stylaria lacustris*			6		5	-	-	-	-
	Lumbricidae		*Lumbriculus variegatus*			1			-	-	-	-
			immature Tubificidae with hair chaetae			72	9		-	-	-	-
			Oligochaeta Sum	90		131	35	5		206	83	1952
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*			9						2
			Helobdella stagnalis		1	1	3			18	2	6
			Batracobdella paludosa				1			1		
			Hemiclepsis marginata							1		
	Hirudidae		*Haemopis sanguisuga*	3								
	Erpobdellidae		*Erpobdella testacea*				2			2		
			Erpobdella octoculata								6	
			Erpobdella octoculata/testacea		5	1			2			
			Trocheta byowskii					1				
Hydracarina			*Hydracarina spp.*		1							
Isopoda	Asellidae		*Asellus aquaticus*	317	1185	781	657	129	182	69	232	54
			Asellus meridianus								10	
Amphipoda	Gammaridae		*Gammarus duebeni*	3								
			Gammarus lacustris	86	+	+	109	84		30	104	2
			Gammaridae (juveniles)	240	40	70			2		40	
Ephemeroptera	Beatidae		*Cloeon dipterum*							1		
Hemiptera	Corixidae		*Arctocorisa germari*							2		
			Callicorixa praeusta	3	3					1		
			Sigara distincta							1		
			Sigara dorsalis								2	
			Sigara fallenoidea					1		1		
			Cymatia bonsdorffi							1		
			Corixidae (nymphs)		133	3		1	1			2
	Notonectinae		*Notonecta glauca*					6		1		
			Notonecta spp.		3							

NOTE: '+' indicates presence of the taxa. -' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.23. (Continued). Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Mullagh.

Date Habitat Group	Family Subfamily	Species	23/04/96 Stones	26/06/96 Stones	24/07/96 Plants (s)	26/09/96 Plants (s)	26/09/96 Plants (s)	26/10/96 Stones	22/01/97 Stones	15/04/97 Stones	18/06/97 Stones
Coleoptera	Gyrinidae	*Orectochilus villosus*				1					
		Gyrinus aeratus			1				2		
		Gyrinus spp.		5							
		Gyrinus (larvae)									3
	Hydroporinae	*Hyphydrus ovatus*	6		1		1				3
		Hyphydrus sp.			2						
		Potamonectes depressus elegans									1
		Potamonectes assimilis				1					
		Hydroporinae (larvae)		5							
	Helophorinae	*Helophorus granularis*									1
	Hydraenidae	*Hydraena rufipes*					1				
Trichoptera	Hydroptilidae	*Agraylea multipunctata*		2							
	Polycentropodidae	*Plectrocnemia conspersa*				1					
		Polycentropus kingi				1					
		Holocentropus picicornis							1	8	
		Cyrnus flavidus		1		5	1		2	4	
	Psychomyiidae	*Tinodes waeneri*			3	5			7	4	
	Phryganeidae	*Phryganea bipunctata*			3						
	Limnephilidae	*Limnephilus flavicornis*								10	
		Limnephilus marmoratus							2		
		Limnephilus vittatus		1							
		Limnephilidae (early Instars)							7		
	Leptoceridae	*Athripsodes aterrimus*								2	
Diptera	Chaoboridae	Chaoborus	3								
	Chironomidae	*Cricotopus/Orthocladius* sp.	1		4		5	-	-	-	-
		Dicrotendipes sp.			1			-	-	-	-
		Endochironomus sp.	2			2	7	-	-	-	-
		Glyptotendipes sp.	2		5	18	3	-	-	-	-
		Microtendipes sp.				2		-	-	-	-
		Stictochironomus sp.	1					-	-	-	-
		Chironomidae pupae	1								
		Chironomidae Sum	22		10	28	15		12	56	60
	Ephydridae								16		

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.24. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Oughter.

Date Habitat Group	 Family	 Subfamily	 Species	15/04/96 Stones	15/06/96 Stones	14/07/96 Stones	15/09/96 Stones	15/09/96 Plant	18/01/97 Stones	13/04/97 Stones	07/06/97 Stones
Tricladida	Planariidae		*Polycelis nigra/tenuis*		3						
Gastropoda		Littoridininae	*Potamopyrgus jenkinsi*	3	2	185	1	5	1		5
	Bithyniidae		*Bithynia tentaculata*					1			
	Physidae		*Physa fontinalis*					1			
			Lymnaea peregra		1	1					
			Lymnaea truncatula	3							
Lamellibranchiata			*Pisidium* sp.			3					
Oligochaeta	Tubificidae		*Limnodrilus* sp.	8	8		10		-	-	-
			Ophidonais serpentina	3		16	3	2	-	-	-
			Nais simplex				1		-	-	-
			Stylaria lacustris	3	48	3	30	1	-	-	-
	Enchytraeidae			7	4		1		-	-	-
	Lumbricidae		*Lumbriculus variegatus*	1	14			2	-	-	-
			immature Tubificidae with hair chaetae		7				-	-	-
			Oligochaeta Sum	74	81	19	54	8	66	85	6
Hirudinea	Glossiphoniidae		*Glossiphonia complanata*			4					
			Helobdella stagnalis			19		5		1	
			Theromyzon tessulatum					3			
			Hemiclepsis marginata			1					
	Erpobdellidae		*Erpobdella octoculata/testacea*		1						
Hydracarina						3				3	
Isopoda	Asellidae		*Asellus aquaticus*	237	786	76	30	248	7		33
Amphipoda	Gammaridae		*Gammarus duebeni*	96	+	+	2	164	9	10	
			Gammarus lacustris	1014							23
			Gammaridae (juveniles)		924	2			63	24	182
Ephemeroptera	Beatidae		*Centroptilum luteolum*	6							
	Caenidae		*Caenis horaria*		4					3	
			Caenis luctuosa	3	4	9	8	45	1	24	2
Hemiptera	Corixidae		*Callicorixa praeusta*	3		1					
			Sigara fallenoidea	0				1			
			Corixidae (nymphs)			41	1	1			1
Coleoptera	Gyrinidae		*Gyrinus* spp.			1					
		Hydroporinae	*Stictotarsus duodecimpustulatus*				1	3			
			Hydroporinae (larvae)			1					
Trichoptera	Polycentropodidae		*Polycentropus kingi*			1					
	Phryganeidae		Phryganea (early instar)							1	
	Limnephilidae		*Glyphotaelius pellucidus*					1			
	Leptoceridae		*Mystacides azurea*			5	2	1			
			Triaenodes bicolor				1				
	Sericostomatidae		*Sericostoma personatum*								1

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample.

Appendix 1.24. (Continued). Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Oughter.

Date				15/04/96	15/06/96	14/07/96	15/09/96	15/09/96	18/01/97	13/04/97	07/06/97
Habitat				Stones	Stones	Stones	Stones	Plant	Stones	Stones	Stones
Group	Family	Subfamily	Species								
Diptera	Chironomidae		*Chironomus* sp.		1	19	10		-	-	-
			Cladotanytarsus sp.			44			-	-	-
			Cricotopus/Orthocladius sp.	22	10	6	18		-	-	-
			Cryptochironomus sp.			2			-	-	-
			Endochironomus sp.			2	19	8	-	-	-
			Glyptotendipes sp.		2	173	14	64	-	-	-
			Microtendipes sp.		47	10	4		-	-	-
			Parachironomus sp.			2			-	-	-
			Polypedilum sp.		10	9	27		-	-	-
			Synorthocladius sp.		5			8	-	-	-
			Tanytarsus sp.		12	39	3	8	-	-	-
			Chironomidae pupae		1	9	1				
			Chironomidae Sum	70	88	315	101	105	3	13	29
	Ceratopogonidae									2	9

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.25. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Owel.

Date		24/04/96	27/06/96	24/07/96	28/08/96	26/09/96	24/10/96	22/01/97	13/03/97	16/04/97	15/05/97	19/06/97
Sample Substrate		Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Species											
Tricladida	*Polycelis nigra/tenuis*			2		2		3		2	4	
(Flatworms)	*Dugesia lugubris*						1			1		
	Dugesia polychora					5						
	Dendrocoelum lacteum					1	1					
	Bdellocephala punctata							1				
Gastropoda	*Theodoxus fluviatilis*				9		1	1				
(Snails)	*Viviparus viviparus*										1	
	Potamopyrgus jenkinsi										1	
	Bithynia tentaculata		1									
	Lymnaea peregra											13
	Physa fontinalis			1								
	Planorbis albus				+							
	Planorbis carinatus		10	31		1	1	2		9	1	85
	Planorbis planorbis			1								
	Planorbis laevis									1		
Bivalvia	*Pisidium* sp.				3		1			26	17	5
(Muscles)	*Sphaerium* sp.				4	3	4	19			6	
Oligochaeta	*Limnodrilus* sp.	-	-	-	-		-	-	-	-	-	-
(Segmented worms)	*Lumbriculus variegatus*	-	-	-	-	24	-	-	-	-	-	-
	Stylaria lacustris	-	-	-	-	48	-	-	-	-	-	-
	Immature Tubificidae	-	-	-	-	32	-	-	-	-	-	-
	Oligochaetae SUM	16	11	14	24	104	65	95	189	64	49	55
Hirudina	*Glossiphonia complanata*				1			3		1		
(Leeches)	*Helobdella stagnalis*				1	3	1	1			1	
	Haemopis sanguisuga	3									1	
	Erpobdella octoculata/testacea			3			2					
Hydracharina (Mites)				10		15		2		5	3	2
Isopoda	*Asellus aquaticus*		56	204	54	136	78	90		19	57	20
Amphipoda	*Gammarus duebeni*	128	+	+	+	2	+		7		1	25
(Shrimps)	*Gammarus lacustris*								4	1		
	Gammaridae (juveniles)		75	89	4		4					
Ephemeroptera	*Centroptilum luteolum*			2		1						
(Mayflies)	*Heptagenia sulphurea*						4	1				
	Caenis luctuosa	6	39	6		25	10	98	1	53	83	7
	Ephemerella ignita		14	4								11
Hemiptera (Bugs)	Corixidae (nymphs)			2	1							
Coleoptera	*Orectochilus villosus*					1						
(Beetles)	*Haliplus* (larvae)	10										
	Oulimnius tuberculatus	10	23	9	10	20	3	70		5	3	1

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.25. (Continued). Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Owel.

Date		24/04/96	27/06/96	24/07/96	28/08/96	26/09/96	24/10/96	22/01/97	13/03/97	16/04/97	15/05/97	19/06/97
Sample Substrate		Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Species											
Trichoptera	*Limnephilus lunatus*		3									1
(Caddisflies)	*Limnephilus vittatus*		3							3		1
	Limnephilidae (early Instars)							56				
	Potamophylax latipennis							5		1		
	Anabolia nervosa	10						67	3	2	3	
	Sericostoma personatum				1		3					
	Athripsodes aterrimus		3	5	1							2
	Athripsodes (early instars)					8						
	Leptoceridae (early instars)							1				
	Tinodes waeneri			4								
	Lype phaeopa							1				
	Metalype fragilis		2									
	Plectrocnemia conspersa							9				
	Polycentropus flavomaculatus										1	
Diptera	Tipulidae	6							1			
(True flies)	Ceratopogonidae		1			1		3		1	3	6
Chironomidae	*Chironomus* sp.	-	-	-	-	45	-	-	-	-	-	-
	Endochironomus sp.	-	-	-	-	11	-	-	-	-	-	-
	Microtendipes sp.	-	-	-	-	1	-	-	-	-	-	-
	Synorthocladius sp.	-	-	-	-	3	-	-	-	-	-	-
	Chironomidae SUM		23	20	5	61	14	96	13	5	16	6
	Ephydridae							7		1		
	Stratiomyidae								1		1	

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.26. Macroinvertebrate abundances (per sample) taken from the littoral region of Poullaphuca Reservoir.

Date			25/04/96	25/06/96	25/07/96	24/09/96	27/01/97	18/04/97	17/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family Subfamily	Species							
Tricladida	Littoridininae	*Potamopyrgus jenkinsi*				10			
	Ancylidae	*Acroloxus lacustris*				2			
Oligochaeta	Naididae	*Stylaria lacustris*			10	1	-	-	-
	Enchytraeidae			1	1	7	-	-	-
	Lumbricidae	*Lumbriculus variegatus*		4	8		-	-	-
		Stylodrilus heringianus				11	-	-	-
		Oligochaeta Sum		5	19	23	14	30	7
Hydracarina				39	7			2	
Isopoda	Asellidae	*Asellus aquaticus*					1		
Amphipoda	Gammaridae	*Gammarus duebeni*			+	6			
		Gammarus lacustris						1	
		Gammaridae (juveniles)		1	4				
Ephemeroptera	Beatidae	*Centroptilum luteolum*			1				
	Caenidae	*Caenis horaria*	3	3				1	
		Caenis luctuosa		1		211	16		
	Epehemeridae	*Ephemera danica*		1		2			
Hemiptera	Corixidae	*Sigara falleni*					1		
		Corixidae (nymphs)	282					55	
	Micronectinae	*Micronecta poweri*		154					5
Coleoptera	Hydroporinae	*Coelambus impressopunctatus*	13						
		Coelambus nigrolineatus						1	
		Oreodytes septentrionalis		3					
		Hydroporinae (larvae)		6					
	Elmidae	*Oulimnius tuberculatus*					1		
Trichoptera	Hydroptilidae	*Oxyethira* sp.			1				
	Polycentropodidae	*Cyrnus trimaculatus*				1			
	Leptoceridae	*Mystacides longicornis*				1			
Diptera	Chironomidae	*Cladotanytarsus* sp.			17		-	-	-
		Cricotopus/Orthocladius sp.		2			-	-	-
		Endochironomus sp.		1	22		-	-	-
		Potthastia gaedii		2	7		-	-	-
		Procladius sp.			1		-	-	-
		Stictochironomus sp.		2		1	-	-	-
		Tanytarsus sp.		13			-	-	-
		Chironomidae pupae		7	3				
		Chironomidae Sum		27	50	1	3	20	
	Ceratopogonidae	Ceratopogonidae spp.						1	

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.27. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Ramor.

Date			23/04/96	26/06/96	28/08/96	25/09/96	25/09/96	24/10/96	24/10/96	21/01/97	12/03/97	12/03/97	12/03/97	15/04/97	15/05/97	18/06/97
Habitat			Stone	Stone	Stone	Plant	Plant	Stone	Plant	Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family Subfamily	Species														
Group	Dugesiidae	*Dugesia lugubris*			1										3	
		Dugesia polychora					5			1				3		
	Planariidae	*Planaria torva*			1											
		Polycelis nigra/tenuis					210			6	2			2	1	
	Dendrocoelidae	*Dendrocoelum lacteum*		6			3			1						
Gastropoda	Valvatidae	*Valvata macrostoma*						1								
		Valvata piscinalis		4												
	Littoridininae	*Potamopyrgus jenkinsi*		14	1	1					1			1		
	Bithyniidae	*Bithynia tentaculata*						1								
	Physidae	*Physa fontinalis*					2									
		Lymnaea peregra		4		1	1	3	3				4			
	Planorbidae	*Planorbis albus*												1		
		Planorbis carinatus					1						1			
		Planorbis laevis		1												
		Acroloxus lacustris					1									
Lamellibranchiata		*Pisidium* sp.		2						4				2	3	
		Sphaerium sp.				1	3				11	1	14			
Oligochaeta	Tubificidae	*Limnodrilus* sp.		7	170	3	8	8	-	-	-	-	-	-	-	-
	Naididae	*Nais communis*		11	1				-	-	-	-	-	-	-	-
		Nais simplex		4	2				-	-	-	-	-	-	-	-
		Stylaria lacustris		30	13	42	14	3	-	-	-	-	-	-	-	-
	Enchytraeidae	Enchytraeidae spp.		6		4	4	2	-	-	-	-	-	-	-	-
	Lumbricidae	*Lumbriculus variegatus*		28	25	2	2		-	-	-	-	-	-	-	-
		Lumbricidae spp.	5					1	-	-	-	-	-	-	-	-
		immature Tubificidae with hair chaetae		2					-	-	-	-	-	-	-	-
		Oligochaeta Sum	7	88	211	57	35	13	14	89		13	19	19	60	11
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*		3										1		
		Boreobdella verrucata									1					
	Erpobdellidae	*Erpobdella testacea*				1				5				1		
		Erpobdella octoculata/testacea		2	3											
		Dina lineata											1			
Hydracarina				1												
Isopoda	Asellidae	*Asellus aquaticus*		518	108	25	143	25	9	563	26	13	23	63	9	16
Amphipoda	Gammaridae	*Gammarus duebeni*									8	4	16			
		Gammarus lacustris	2			1	5			11	20	4	17			
		Gammarus pulex		+	+				+						9	
		Gammaridae (juveniles)		88	16			3	6		5	3	6	4		
Ephemeroptera	Beatidae	*Centroptilum luteolum*			1	1				2				2		
	Caenidae	*Caenis luctuosa*		70		2	1			53	1		2	8	18	2
	Leptophlebiidae	*Leptophlebia marginata*												1		
		Leptophlebia vespertina											1			
Hemiptera	Corixidae	*Arctocorisa germari*						3		1						

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.27. (Continued). Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Ramor.

Date Habitat Group	Family Subfamily	Species	23/04/96 Stone	26/06/96 Stone	28/08/96 Stone	25/09/96 Plant	25/09/96 Plant	24/10/96 Stone	24/10/96 Plant	21/01/97 Stones	12/03/97 Stones	12/03/97 Stones	12/03/97 Stones	15/04/97 Stones	15/05/97 Stones	18/06/97 Stones
Hemiptera	Corixidae	*Callicorixa praeusta*	1	1												
		Sigara distincta							2							
		Sigara fallenoidea								1						
		Sigara falleni		3	1			1	5					2		
		Corixidae (nymphs)		44	2	117	5			4	3	8		39	887	1
	Micronectinae	*Micronecta poweri*		1025												
	Notonectinae	Notonceta (nymphs)														1
Coleoptera	Hydroporinae	*Potamonectes depressus elegans*	1													
		Potamonectes depressus depressus		1												
	Elmidae	*Limnius volckmari*												1		
		Oulimnius tuberculatus		2		3	1			4			1			
Trichoptera	Hydroptilidae	*Hydroptila* sp.												1		
	Polycentropodidae	*Plectrocnemia conspersa*				1										
		Polycentropus flavomaculatus		1						3				2		5
		Polycentropus kingi				2										
	Psychomyiidae	*Tinodes waeneri*		24	2	37	2			73				36	11	9
	Limnephilidae	*Limnephilus affins/incisus*											1			
		Limnephilus lunatus		1												
		Limnephilus vittatus								6	1					
		Limnephilidae (early Instars)									1		1			
		Anabolia nervosa											1			
	Leptoceridae	*Athripsodes cinereus*					6								1	
Diptera	Tipulidae	Tipulidae spp.	4					4	1	7		2	1			
	Chironomidae	*Chironomus* sp.				4				-	-	-	-	-	-	-
		Cladotanytarsus sp.		33		12	2			-	-	-	-	-	-	-
		Cricotopus/Orthocladius sp.	1	62	103	8	6		1	-	-	-	-	-	-	-
		Cryptochironomus sp.		1						-	-	-	-	-	-	-
		Cyphomella sp.			2					-	-	-	-	-	-	-
		Endochironomus sp.		75		8		1	3	-	-	-	-	-	-	-
		Eukiefferiella sp.	1							-	-	-	-	-	-	-
		Glyptotendipes sp.		104		12	14			-	-	-	-	-	-	-
		Microtendipes sp.		100		12				-	-	-	-	-	-	-
		Parachironomus sp.		11	1					-	-	-	-	-	-	-
		Paratanytarsus sp.		2						-	-	-	-	-	-	-
		Pentaneurini		1		8			1	-	-	-	-	-	-	-
		Potthastia gaedii			2			1		-	-	-	-	-	-	-
		Psectrocladius sp.		1						-	-	-	-	-	-	-
		Synorthocladius sp.			11		2			-	-	-	-	-	-	-
		Zavreliella sp.			1					-	-	-	-	-	-	-
		Chironomidae pupae		68	1					-	-	-	-	-	-	-
		Chironomidae Sum	2	458	121	58	24	2	5	29	19	6	17	79	70	44
	Ceratopogonidae			2		3		1		8				1	2	
	Anthomyidae														4	

NOTE: '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.28. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Rea.

Date Habitat Group	 Family	 Subfamil Species	09/04/96 Stones	9/6/96 Stones	07/07/96 Stones	08/09/96 Stones	08/09/96 Plants	12/01/97 Plants	06/04/97 Stones	31/05/97 Stones
Tricladida	Dugesiidae	*Dugesia lugubris*		1				7	29	2
		Dugesia polychora				4	2			
	Planariidae	*Planaria torva*						6		
		Polycelis nigra/tenuis	3	1				38	64	23
	Dendrocoelidae	*Dendrocoelum lacteum*		1				5	3	
Gastropoda	Neritidae	*Theodoxus fluviatilis*			2					1
	Viviparidae	*Viviparus fasciatus*							1	
	Bithyniidae	*Bithynia tentaculata*			3	1				1
	Lymnaeidae	*Lymnaea palustris*								
		Lymnaea stagnalis								
		Lymnaea peregra			9					1
	Planorbidae	*Planorbis contortus*		1			1			
		Planorbis planorbis					3			
Lamellibranchiata		*Pisidium* sp.		1						
		Sphaerium sp.			1				1	
Oligochaeta	Tubificidae	*Psammoryctides barbatus*		4	12			-	-	-
		Limnodrilus hoffmeisteri		2				-	-	-
		Limnodrilus sp.		324		5	2	-	-	-
		Peloscolex ferox				1		-	-	-
		Aulodrilus pluriseta		3				-	-	-
	Naididae	*Nais simplex*		1				-	-	-
	Enchytraeidae						2	-	-	-
	Lumbricidae	*Lumbriculus variegatus*		2			1	-	-	-
		immature Tubificidae with hair chaetae		9		1	3	-	-	-
		Oligochaeta Sum	10	345	12	8	10	86	64	50
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*			2		2			
		Helobdella stagnalis		7	1	1	1		2	
	Piscicolidae	*Pisciola geometra*							1	
	Erpobdellidae	*Erpobdella testacea*					3			2
		Erpobdella octoculata/testacea		3	5					
		Dina lineata							1	
Hydracarina					6	1		4	3	
Isopoda	Asellidae	*Asellus aquaticus*		6	38	14	1	66	74	158
		Asellus meridianus			35					
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*						17	10	12
	Gammaridae	*Gammarus duebeni*		+	+	1	3			2
		Gammarus lacustris	139					1		
		Gammaridae (juveniles)		20	8					
Ephemeroptera	Beatidae	*Cloeon dipterum*							1	
		Cloeon simile					1			
	Heptageniidae	*Heptagenia sulphurea*			1			1		
	Caenidae	*Caenis horaria*			7				4	2
		Caenis luctuosa	6	35	12		3	17	5	7
Zygoptera	Coenagrioniidae	*Coenagrion mercuriale*						3		
		Coenagrion lunulatum							1	
Hemiptera	Corixidae	*Sigara dorsalis*							1	1
		Sigara spp.					1			
		Cymatia bonsdorffi							1	
		Corixidae (nymphs)				3	3			1
	Gyrinidae	*Orectochilus villosus*							1	
Coleoptera	Haliplidae	*Haliplus confinus*			2					
		Haliplus (larvae)							3	2
	Dytiscidae	*Graptodytes pictus*								2
	Elmidae	*Elmis aenea*							2	2
		Limnius volckmari							1	
		Esolus parallelepipedus			1			1	10	12
		Oulimnius tuberculatus		1	1	1	5	53	10	12
		Hydraena ?(nigrata)						2		
Trichoptera	Polycentropodidae	*Plectrocnemia conspersa*							1	
		Polycentropus kingi		2			1			
	Psychomyiidae	*Tinodes unicolor*							2	
		Tinodes waeneri		7	4			2	15	22
	Limnephilidae	*Limnephilus vittatus*				4				
		Limnephilidae (early Instars)						1		
	Leptoceridae	*Athripsodes cinereus*		4	1					1
		Mystacides longicornis		2						
	Sericostomatidae	*Sericostoma personatum*				1		1	1	
Diptera	Chironomidae	*Cladotanytarsus* sp.		36				-	-	-
		Corynoneura sp.				1		-	-	-
		Cricotopus/Orthocladius sp.	1	3	2			-	-	-
		Dicrotendipes sp.			1			-	-	-
		Glyptotendipes sp.			1			-	-	-
		Microtendipes sp.		7				-	-	-
		Paratendipes sp.		45	1			-	-	-
		Pentaneurini		1	2			-	-	-
		Polypedilum sp.		8				-	-	-
		Procladius sp.				1		-	-	-
		Psectrocladius sp.			2	1		-	-	-
		Synorthocladius sp.	1				1	-	-	-
		Tanytarsus sp.		6				-	-	-
		Chironomidae pupae	1	1						
		Chironomidae Sum	10	107	9	3	1	6	5	7
	Stratiomyidae							1	2	

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 1.29. Macroinvertebrate abundances (per sample) taken from the littoral region of Lough Talt.

Date			14/04/96	14/06/96	13/07/96	14/09/96	17/01/97	12/04/97	06/06/97
Habitat			Stones	Stones	Stones	Stones	Stones	Stones	Stones
Group	Family Subfamily	Species							
Gastropoda	Littoridininae	*Potamopyrgus jenkinsi*	3	17	36	3	3		1
Oligochaeta	Tubificidae	*Limnodrilus* sp.		4					
	Enchytraeidae	Enchytraeidae spp.		4					
	Lumbricidae	*Lumbriculus variegatus*	1	21	6				
		immature Tubificidae with hair chaetae	3	7					
		Oligochaeta Sum	16	36	6		3	9	35
Hydracarina					1				
Amphipoda	Gammaridae	*Gammarus duebeni*	3	+	+	3		7	47
		Gammarus lacustris	6		+				
		Gammarus pulex							14
		Gammaridae (juveniles)		77	57			10	
Ephemeroptera	Beatidae	*Centroptilum luteolum*	6						
	Heptageniidae	*Heptagenia lateralis*					3	4	
		Heptagenia sulphurea				4		1	
	Caenidae	*Caenis horaria*							1
		Caenis luctuosa						2	2
	Epehemeridae	*Ephemera danica*	3					1	1
Plecoptera	Leuctridae	*Leuctra nigra*							1
		Capnia bifrons						1	
	Chloroperlidae	*Siphonoperla torrentium*						1	
Hemiptera	Corixidae	Corixidae (nymphs)	288		1			4	
	Micronectinae	*Micronecta poweri*			9				22
Coleoptera	Haliplidae	*Haliplus* (larvae)							1
Trichoptera	Hydroptilidae	*Oxyethira* sp.	3					3	
		Hydroptila sp.					2		
		Agraylea multipunctata							8
	Polycentropodidae	*Polycentropus flavomaculatus*					1	1	
	Psychomyiidae	*Tinodes waeneri*						1	3
	Leptoceridae	*Athripsodes cinereus*							2
	Chironomidae	*Cricotopus/Orthocladius* sp.	10	3	27	-	-	-	-
		Endochironomus sp.	1			-	-	-	-
		Microtendipes sp.		2		-	-	-	-
		Pentaneurini		1	1	-	-	-	-
		Polypedilum sp.			1	-	-	-	-
		Psectrocladius sp.			2	-	-	-	-
		Stictochironomus sp.		10		-	-	-	-
		Synorthocladius sp.	1			-	-	-	-
		Tanytarsus sp.		5	5	-	-	-	-
		Chironomidae pupae			3				
		Chironomidae Sum	42	21	39	4	3	25	32
	Ceratopogonidae								1

NOTE: '+' indicates presence of the taxa. '-' indicates that taxonomic resolution was not taken so far for the indicated sample

Appendix 2.1. Macroinvertebrate abundances of triplicate samples from the littoral region of Lough Inchiquin over sample times of 5, 10, 15, 30 and 60 seconds.

Date sampled			03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97
Sample time (Seconds)			5	5	5	10	10	10	15	15	15	30	30	30	60	60	60
Group	Family	Species															
Tricladida	Planariidae	*Planaria torva*						1				3					
		Polycelis spp.	30	19	33	50	75	51	62	96	81	36	97	89	86	41	91
	Dugesiidae	*Dugesia lugubris*	7	1	4	5	7	5	12	7	7	9	7	2	7	11	13
		Dugesia polychora							2		1						
	Dendrocoelidae	*Dendrocoelum lacteum*	2	3	1	5	5	8		8	9	4	3	7	6	11	9
Archeogastropoda	Neritidae	*Theodoxus fluviatilis*	2				5		4	4	3		2	4	7	14	18
		Viviparus viviparus		5		3	2	3	7	1	8	8	31	20	9	7	15
		Potamopyrus jenkinsi				2											
		Lymnaea peregra					1		2					1	1		
		Physa heterostropha											1	1			
	Planorbidae	*Planorbus albus*												1			
		Planorbis contortus		1										1			
		Planorbis laevis				2	1	1	2		1		4	5	10	2	2
		Segmentian nitida											1				
Lamellibranchiata		*Pisidium* sp.		1		3	2		10	17	8	15	24	18	24	5	14
		Sphaerium sp.	1	8	1		3	1		4	8	2	5	10	3		4
Oligochaeta			207	76	129	161	353	373	423	785	318	660	615	890	560	395	540
		Glossiphonia complanata		1	1		1										3
		Helobdella stagnalis	3	1	2	14	6	5	11	12	1	6				7	5
		Theromyzon tessulatum												1			
Gnathobdellae	Hirudinidae	*Haemopis sanguisuga*							2								
Pharyngobdellae	Erpobdellidae	*Erpobdella octoculata*				1	3	1	1	4	1	7	1	1	1	2	6
Hydracharina				1	3	5	8	5	3	4	2	3		9	11		4
Isopoda	Asellidae	*Asellus aquaticus*	195	289	208	320	383	581	1040	735	735	530	920	1325	1660	1420	1135
Amphipoda	Gammaridae	*Crangonyx pseudogracilis*	3	1	13	18	15	28	28	21	24	17	39	32	59	41	30
		Gammarus duebeni									3		1			3	2
Ephemeroptera	Caenidae	*Caenis luctuosa*	9	1	8	12	16	17	8	11	9	10	34	34	36	30	26
		Caenis horaria					5	3		1			5	1	4	3	2
	Ephemerellidae	*Ephemerella ignita*										1					
		Coenagrion mercuriale					1		1				1			1	
		Enallagma cyathigerum											1				
Hemiptera	Corixidae	Corixidae (nymphs)			2								1				
	Vellidae	*Velia* (nymph)											1				
Coleoptera	Haliplidae	*Haliplus confinus*			1	1	1				1		7	2	3	3	8
		Haliplus (larvae)				2	1	1		1	1			1	3		
		Potamonectes depressus elegans	1	1			3	10	2	4	1		5	4	7	4	7
		Potamonectes (larvae)													1		
	Hydrobidae	*Laccobius biguttatus*												1	1		
		Oulimnius tuberculatus (adults)	2	1	3	10	7	9	16	6	7	3	16	21	19	10	17
		Oulimnius tuberculatus (larvae)	6	3	1	7	1	16	10	4	11	5	11	14	11	26	11

Appendix 2.1. (Continued). Macroinvertebrate abundances of triplicate samples from the littoral region of Lough Inchiquin over sample times of 5, 10, 15, 30 and 60 seconds.

Date sampled			03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97
Sample time (Seconds)			5	5	5	10	10	10	15	15	15	30	30	30	60	60	60
Group	Family	Species															
Trichoptera	Hydroptilidae	*Hydroptila*														1	
		Agraylea multipunctata					1										
	Lepidostomatidae	*Lepidostoma hirtum*														1	
	Sericostomatidae	*Sericostoma personatum*		1						1				1			3
		Athripsodes cinereus	1			1	1		2	1	2		2		2		5
		Athripsodes aterrimus											1		1		2
		Mystacides longicornis						1						1	1		1
		Tinodes waeneri	10	25	16	64	15	44	97	66	89	105	182	139	80	195	207
		Holocentropus picicornis															1
Diptera	Ceratopogonidae	*Forcipomyia*	3		1	6	2	6	4	3	3	1	1	3	5	20	2
	Chironomidae		20	17	14	36	18	17	22	20	11	10	9	6	24	40	37

Appendix 2.2. Macroinvertebrate abundances of triplicate samples from the littoral region of Lough Inchiquin over sample times of 12 seconds and areas of 0.25, 0.5, 1.0 and 2.0 by 0.25 m.

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97
Area (meters)			0.25	0.25	0.25	0.5	0.5	0.5	1	1	1	2	2	2	4	4	4
Group	Family	Species															
Tricladida	Planariidae	*Planaria torva*															
		Polycelis spp.	53	63	34		91	1	27	115	66	263	80	200	65	146	76
	Dugesiidae	*Dugesia lugubris*	7	12	11		17		12	7	6	19	14	8	2	14	5
	Dendrocoelidae	*Dendrocoelum lacteum*	3		4				5	8	4	18	10	6	2	15	3
Archeogastropoda	Neritidae	*Theodoxus fluviatilis*				2	7	7	12	27	18	18	36		31	25	7
		Valvata macrostoma		1		7	2		2	2	2	4	6	37	5	5	6
		Valvata cristata														1	
		Viviparus viviparus/ Valvata fasciatus	5	3	3	19	22	32	12	33	14	40	12	60	22	17	21
		Potamopyrus jenkinsi															
		Lymnaea peregra	1											1		3	
		Physa fontinalis				1				3							
	Planorbidae	*Planorbus albus*															
		Planorbis contortus		1		1					2			1	2	1	
		Planorbis laevis				1											
		Segmentian nitida	1														
		Segmentian complanata								1							
Lamellibranchiata		*Pisidium* spp.	10	8	5	17	11	4	9	15	8	19	2	92	7	13	62
		Sphaerium spp.	2	1	1	1	7	3	7	12	2	7	2	17	5	6	8
Oligochaeta			235	213	131	63	525	57	515	660	530	560	765	285	520	197	390
Hirudinea	Glossipohnodae	*Glossiphonia complanata*			1			1		1		1		2	1		2
		Helobdella stagnalis	5	1	1	4	1	4	3	2	3	4	5	2	14	5	8
		Theromyzon tessulatum												16			
Gnathobdellae	Hirudidae	*Haemopis sanguisuga*															
Pharyngobdellae	Erpobdellidae	*Erpobdella octoculata*	3	2	1	4	5		3	2		6	5	3	8	5	2
	Piscicolidae	*Piscicola geometra*													1		
Hydracharina			5	9	4	8	5		8	7	4	8	5	13	8	9	14
Isopoda	Asellidae	*Asellus aquaticus*	285	259	328	545	885	735	1085	1520	1085	1560	1130	2070	1320	1180	1840
Amphipoda	Gammaridae	*Crangonyx pseudogracilis*	11	16	9	4	32	29	59	49	31	80	50	41	33	34	23
		Gammarus duebeni		2	2				3			1	2		2	3	
	Caenidae	*Caenis luctuosa*	1	6	4	3	6	7	17	21	4	7	22	16	55	16	8
		Caenis horaria	1						1	4	1	1	2	3	6	3	
	Baetidae	*Centroptilum luteolum*								1							
	Ephemerellidae	*Ephemerella ignita*										1	1	1			
Zygoptera	Coenagrionidae	*Coenagrion mercuriale*															
		Enallagma cyathigerum															
		Ischnura elegans			1					1		1					
Hemiptera	Corixidae	*Calicorixia praeusta*		1							2	1					
		Corixidae (nymphs)		1	5		5		2		2			1	1	1	1
	Vellidae	*Velia* (nymph)	1														

Appendix 2.2. (Continued). Macroinvertebrate abundances of triplicate samples from the littoral region of Lough Inchiquin over sample times of 12 seconds and areas of 0.25, 0.5, 1.0 and 2.0 by 0.25 m.

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97	03/06/97
Area (meters)			0.25	0.25	0.25	0.5	0.5	0.5	1	1	1	2	2	2	4	4	4
Group	Family	Species															
Coleoptera	Haliplidae	*Haliplus confinus*	1				4	3	1	2	1	2	2	3	13	1	
		Haliplus (larvae)			1	3		1	1	1	1	1	2	1	2		2
	Hydroporinae	*Potamonectes depressus elegans*			1		2	4	4	2	1	1	1		12	2	1
		Potamonectes (larvae)															
	Hydrobidae	*Laccobius biguttatus*	1				3		2	3	5			1	2	4	
		Laccobius (larvae)						1	1								
	Elminthidae	*Oulimnius tuberculatus*	15	11	13	25	28	38	24	41	36	34	46	84	59	90	64
	Gyrinidae	*Orectochilus* (larvae)														1	
Trichoptera	Hydroptilidae	*Hydroptila* sp.				1	1	1									
		Agraylea multipunctata														2	1
	Lepidostomatidae	*Lepidostoma hirtum*							1								
	Sericostomatidae	*Sericostoma personatum*					1			1	1						1
		Athripsodes cinereus	1	1		1				1	1		4	1	6	2	1
		Athripsodes aterrimus							2	1		1	1	3	3		1
		Mystacides longicornis		1		1	4	5	5	4	6	2	6	7	8		2
		Triaenodes bicolor														1	
	Limnephilidae	*Limnephilus stigma*													1		
		Tinodes waeneri	54	58	61	101	17	57	67	81	9	90	49	128	73	60	113
		Polycentropus fluvomaticulatus			1			1									
		Holocentropus picicornis															
Lepidoptera		*Paraponyx stratiotata*									1	1	22				1
Diptera	Ceratopogonidae		4	2	3	24	14	22	7	8	10	5		11	51	37	21
	Chironomidae		29	26	15	33	35	55	45	46	22	48	72	69	96	54	45
	Pericoma (larvae)									1							

Appendix 3. Descriptions of visually discrete meso-habitats sampled in Lough Inchiquin in September 1997.

Code	Abbreviation	Habitat description
A	Stone & Fontinalis	Pebbles 30%, cobbles 20%, sand 50% & Fontinalis (mid-density).
B	Sand & CPOM	Sand & coarse particulate organic matter, sheltered.
C	Boulders & stone	Boulders 20%, cobbles 40%, pebbles 40% & mares tails (Hippuris vulgaris) (sparse).
D	Sand & Littorella	Sand 60% cobbles 5% & pebbles 15% & Littorella uniflora, (mid-density) sheltered by Phragmites.
E	Stone & Littorella.	Cobble 40%, pebbles 20% & Littorella uniflora (mid-density), + other submerged macrophytes (sparse).
F	*Cladophora & pebbles*	*Cladophora covering pebbles.*
G	*Cladophora & marl*	*Cladophora covering marl & sand.*
H	*Phragmites & sand*	Base of Phragmites (sparse), algae (sparse) & sand 80%.
I	*Lemna & grass spp.*	*Lemna trisulca (mid-density) & grass spp. (dense).*
J	Cobbles & boulders	Cobbles 60%, boulders 20%, schist 20%, Fontinalis antipyretica & Potamogeton spp. (sparse).
K	Dense filamentous macrophytes	Filamentous macrophytes, (dense) Zannichellia palustris and Fontinalis antipyretica covering pebble & marl.
L	Dense non-filamentous macrophytes	Non-filamentous vegetation (dense), Hippuris vulgaris, Marsupella emarginata & (?) Stragnalisor platycarpa
M	Cobbles & pebbles	Cobbles 60%, pebbles 30% & marl 10%
N	Sand & Isoetes	Sand 80% & calcium carbonate covering Isoetes lacustris
O	Sand & marl	Sand 80%, marl, coarse particulate organic matter, Fontinalis antipyretica & Elodea canadensis (sparse)

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			A	A	A	A	A	B	B	B	B	B
Replicate			1	2	3	4	5	1	2	3	4	5
Group	Family	Species										
Tricladida	Dugesiidae	*Dugesia polychora*										4
	Planariidae	*Polycelis nigra/tenuis*	33	148	92	72	120	20	36	32	68	100
	Dendrocoelidae	*Dendrocoelum lacteum*				2	1				1	1
Gastropoda	Neritidae	*Theodoxus fluviatilis*	35		36	8	20					
	Viviparidae	*Viviparus fasciatus*	47									
	Valvatidae	*Valvata cristata*										
		Valvata macrostoma	9	4		8	8					
		Valvata contortus										
		Valvata piscinalis										
	Littoridininae	*Potamopyrgus jenkinsi*	1									
	Bithyniidae	*Bithynia tentaculata*		20	48	12	20					4
		Bithynia leachi										
	Physidae	*Physa fontinalis*	30	20	20	12	8	1	1			
	Lymnaeidae	*Lymnaea peregra*	2	12	2	4	2					
		Lymnaea stagnalis										
	Planorbidae	*Planorbis planorbis*										
		Planorbis albus	10	4	4		16	4				
		Planorbis contortus	2	4								
		Planorbis crista				8	8					
		Planorbis vortex	1									1
		Planorbis carinatus										
		Segmentina complanata										
	Succineidae	*Succinea ?(palustris)*						1				
Lamellibranchiata		*Pisidium* spp.	11			16	4				1	8
		Sphaerium spp.	15	36	36	12	20		1			
	Acroloxidae	*Acroloxus lacustris*										
Oligochaeta Sum			14	28	24	76	28	60	76	88	144	172
Hirudinea	Piscicolidae	*Piscicola geometra*	2	4								
	Glossiphoniidae	*Theromyzon tessulatum*		24								
		Glossiphonia heteroclita										
		Glossiphonia complanata	3								2	4
		Helobdella stagnalis	3			8						
		Boreobdella verrucata										
	Erpobdellidae	*Erpobdella octoculata*	7		4	1	4	4			4	4
Arachnidae								4		1		3
Hydracarina			5	12					4			
Isopoda	Asellidae	*Asellus aquaticus*	260	668	456	224	196	312	192	88	280	448

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			A	A	A	A	A	B	B	B	B	B
Replicate			1	2	3	4	5	1	2	3	4	5
Group	Family	Species										
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	7	52	28	16	28	4	12		16	8
	Gammaridae	*Gammarus duebeni*	14	24		12	2					
Ephemeroptera	Beatidae	*Baetis rhodani*										
		Baetis muticus		1								
		Centroptilum luteolum										
		Cloeon dipterum										
		Cloeon simile										
		Baetidae (early instars)										
	Heptageniidae	*Heptagenia sulphurea*										
	Caenidae	*Caenis horaria*										
		Caenis luctuosa	4		4	4	4		8			8
	Epehemeridae	*Ephemera danica*										
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*										
		Ischnura elegans										
		Zygoptera (early instars)										
Megaloptera	Sialidae	*Sialis lutaria*					4		1	4		
Neuroptera	Sisyridae	*Sisyra fuscata*										
Hemiptera	Corixidae	*Arctocorisa germari*										
		Callicorixa praeusta										1
		Corixa panzeri										
		Hesperocorixa linnaei										
		Sigara distincta										
		Sigara dorsalis										
		Sigara falleni										
		Corixidae (nymphs)										
	Cymatiinae	*Cymatia bonsdorffi*										
	Notonectinae	*Notonecta glauca*										
Coleoptera	Gyrinidae	*Orectochilus villosus*										
		Gyrinus larvae	1									
	Chrysomelidae	*Macroplea appendiculata*										
		Macroplea (larvae)										
	Haliplidae	*Haliplus confinus*										
		Haliplus flavicollis										
		Haliplus (larvae)	2	8						1		4
	Noteridae	*Noterus clavicornis* (larger sp.)										
	Dytiscidae	*Agabus* (larvae)										

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			A	A	A	A	A	B	B	B	B	B
Replicate			1	2	3	4	5	1	2	3	4	5
Group	Family	Species										
	Hydroporinae	*Stictotarsus duidecimpustulatus*										
		Hygrotus quinquelineatus										
		Hygrotus ?(inaequalis)										
		Potamonectes depressus elegans										
	Elmidae	*Elmis aenea*	6				4					
		Oulimnius tuberculatus	33	88	16	44	12		4	8	8	12
	Hydrophilidae	*Hydrophilus* spp.										
		Helophorus dubius										
	Hydrophilinae	*Laccobius biguttatus*										
		Laccobius (larvae)										
	Hydraenidae	*Hydraena ?(gracilis)*										
Trichoptera	Glossosomatidae	*Agapetus fuscipes*	4		12	4						
	Hydroptilidae	Hydroptilidae instars II - IV										
		Agraylea multipunctata	4	16	4		8					
		Hydroptila spp.	13	4		12	4					
	Phryganeidae	*Phryganea bipunctata*	1									
	Polycentropodidae	*Neureclipsis bimaculata*	25	12	36	4						
		Plectrocnemia conspersa	119	196	116	132	124					
		Polycentropus flavomaculatus	220	184	180	96	108					
		Holocentropus dubius	136	156	196	40	112	4				4
		Holocentropus picicornis										
	Psychomyiidae	*Tinodes waeneri*						4				
	Hydropsychidae	*Hydropsyche pellucidula*	1	4								
	Limnephilidae	*Limnephilus flavicornis*						1	4		1	8
		Limnephilus marmoratus										
		Limnephilidae (early Instars)										
	Lepidostomatidae	*Lepidostoma hirtum*	2	24	4	12	4					
	Leptoceridae	*Athripsodes aterrimus*	12	56	32	24	16	1			8	4
		Athripsodes cinereus	22	20	16	32	4	4				
		Ceraclea nigronervosa										
		Mystacides longicornis	1	8	4	4						
		Triaenodes bicolor				4						
	Sericostomatidae	*Sericostoma personatum*									1	1
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*	1				4					
Diptera	Tipulidae							1				
	Chironomidae		320	256	420	176	296	40	16	16	84	40
	Ceratopogonidae		1						4			
	Tabanidae											
	Simuliidae		1									

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			C	C	C	C	C	D	D	D	D	D	E	E	E	E	E
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Tricladida	Dugesiidae	*Dugesia polychora*					4						8	4	20	28	4
	Planariidae	*Polycelis nigra/tenuis*	48	20	40	108	48	36	8	60	20	32	108	96	52	152	72
	Dendrocoelidae	*Dendrocoelum lacteum*	8	4	4	8		4		4	1		4	4	4	12	4
Gastropoda	Neritidae	*Theodoxus fluviatilis*	1	4	4		28	8			4	12			1		
	Viviparidae	*Viviparus fasciatus*								4		8			1	4	1
	Valvatidae	*Valvata cristata*															
		Valvata macrostoma	4	4		1	1	4	16	1	4						
		Valvata contortus															
		Valvata piscinalis															
	Littoridininae	*Potamopyrgus jenkinsi*															
	Bithyniidae	*Bithynia tentaculata*	28	20	104	16	24	20	16	20	36	52	20	4	12	52	1
		Bithynia leachi															
	Physidae	*Physa fontinalis*	8	1	12	8	1	16	9	2		4		1	4	4	4
	Lymnaeidae	*Lymnaea peregra*						4	2				1				
		Lymnaea stagnalis															
	Planorbidae	*Planorbis planorbis*															
		Planorbis albus								1						4	
		Planorbis contortus					1	2	1	8		4					
		Planorbis crista															
		Planorbis vortex															
		Planorbis carinatus															
		Segmentina complanata															
	Succineidae	*Succinea ?(palustris)*															
Lamellibranchiata		*Pisidium* spp.	1	8	36	12	4	12	16	60	32	80	12		8		4
		Sphaerium spp.			4				12	4							
	Acroloxidae	*Acroloxus lacustris*															
Oligochaeta Sum			260	156	336	188	180	80	96	112	160	96	276	220	172	128	204
Hirudinea	Piscicolidae	*Piscicola geometra*															
	Glossiphoniidae	*Theromyzon tessulatum*															
		Glossiphonia heteroclita															
		Glossiphonia complanata			2	1		1		1		2					1
		Helobdella stagnalis	5	4	1	1	4		8	8	1	4	1				
		Boreobdella verrucata															
	Erpobdellidae	*Erpobdella octoculata*	4		1	2	1	12		4	1	3	8		1		
Arachnidae									4								
Hydracarina					4			4			4		1	4	4	4	4
Isopoda	Asellidae	*Asellus aquaticus*	812	628	740	732	708	904	528	940	636	908	584	424	484	692	432

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			C	C	C	C	C	D	D	D	D	D	E	E	E	E	E
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	8	4	4	8	20	12	24	4	24	36	24	20	24	44	8
	Gammaridae	*Gammarus duebeni*													3		
Ephemeroptera	Beatidae	*Baetis rhodani*															
		Baetis muticus															
		Centroptilum luteolum															
		Cloeon dipterum															
		Cloeon simile															
		Baetidae (early instars)															
	Heptageniidae	*Heptagenia sulphurea*															
	Caenidae	*Caenis horaria*															
		Caenis luctuosa	16		24			40	20	48	28	40	52	32	36	44	12
	Epehemeridae	*Ephemera danica*															
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*								1	1						
		Ischnura elegans															
		Zygoptera (early instars)								4							
Megaloptera	Sialidae	*Sialis lutaria*															
Neuroptera	Sisyridae	*Sisyra fuscata*			1												
Hemiptera	Corixidae	*Arctocorisa germari*															
		Callicorixa praeusta		1						1			1		1	3	4
		Corixa panzeri															
		Hesperocorixa linnaei															
		Sigara distincta							1	4				4			4
		Sigara dorsalis	8					4		4	1		4	12	1	4	20
		Sigara falleni						1									
		Corixidae (nymphs)					4						1	4		4	
	Cymatiinae	*Cymatia bonsdorffi*												8			
	Notonectinae	*Notonecta glauca*															
Coleoptera	Gyrinidae	*Orectochilus villosus*															
		Gyrinus larvae															
	Chrysomelidae	*Macroplea appendiculata*															
		Macroplea (larvae)															
	Haliplidae	*Haliplus confinus*	4	2	12	12	2	8		1		1	2	8	7	4	4
		Haliplus flavicollis															
		Haliplus (larvae)		1		2	4		8	4	1	4	4		12	8	2
	Noteridae	*Noterus clavicornis* (larger sp.)															
	Dytiscidae	*Agabus* (larvae)									1						
	Hydroporinae	*Stictotarsus duidecimpustulatus*															

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			C	C	C	C	C	D	D	D	D	D	E	E	E	E	E
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
		Hygrotus quinquelineatus													1		
		Hygrotus ?(inaequalis)															
		Potamonectes depressus elegans		1	2			1	4	4			1	4	2	4	1
	Elmidae	*Elmis aenea*									4						
		Oulimnius tuberculatus	56	24	16	68	28	48	12	16	32	24	12	16	32	36	24
	Hydrophilidae	*Hydrophilus* spp.		1													
		Helophorus dubius				4											
	Hydrophilinae	*Laccobius biguttatus*															
		Laccobius (larvae)															
	Hydraenidae	*Hydraena ?(gracilis)*															
Trichoptera	Glossosomatidae	*Agapetus fuscipes*															
	Hydroptilidae	*Hydroptilidae* instars II - IV															
		Agraylea multipunctata					1										
		Hydroptila spp.	4		16	16	8					8	4	1			
	Phryganeidae	*Phryganea bipunctata*															
	Polycentropodidae	*Neureclipsis bimaculata*															
		Plectrocnemia conspersa			8												
		Polycentropus flavomaculatus		4	8	4		4		4							
		Holocentropus dubius	8	8													
		Holocentropus picicornis															
	Psychomyiidae	*Tinodes waeneri*	96	44	28	36	28	48	44	48	32	44	32	40	20	44	20
	Hydropsychidae	*Hydropsyche pellucidula*															
	Limnephilidae	*Limnephilus flavicornis*							1								
		Limnephilus marmoratus															
		Limnephilidae (early Instars)															
	Lepidostomatidae	*Lepidostoma hirtum*															
	Leptoceridae	*Athripsodes aterrimus*	4		4	2			4			12					
		Athripsodes cinereus									4						
		Ceraclea nigronervosa															
		Mystacides longicornis	1		4		8						2		4	12	8
		Triaenodes bicolor															
	Sericostomatidae	*Sericostoma personatum*	1	8	12	2	5	8	20	16	2	40	4	3	4	8	4
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*				1				1							
Diptera	Tipulidae					8											
	Chironomidae		76	88	80	68	32	92	72	140	44	128	24	24	76	32	28
	Ceratopogonidae									4		12		4		4	4
	Tabanidae																
	Simuliidae																

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			F	F	F	F	F	G	G	G	G	G	H	H	H	H	H
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Tricladida	Dugesiidae	*Dugesia polychora*			4			4	16	16	4		4	4	8		8
	Planariidae	*Polycelis nigra/tenuis*	32	64	72	80	44	384	248	68	52	68	160	208	196	124	180
	Dendrocoelidae	*Dendrocoelum lacteum*	4	8	4	4							4			4	4
Gastropoda	Neritidae	*Theodoxus fluviatilis*															
	Viviparidae	*Viviparus fasciatus*			8			8	4	1	4	4	4	1	2	1	1
	Valvatidae	*Valvata cristata*												8			
		Valvata macrostoma	60	60	184	48	180	1492	172	628	880	1200	96	224	104	168	132
		Valvata contortus								8							
		Valvata piscinalis															
	Littoridininae	*Potamopyrgus jenkinsi*															
	Bithyniidae	*Bithynia tentaculata*	12	8	48	20	16	140	12	36	40	80		1	16	12	8
		Bithynia leachi															
	Physidae	*Physa fontinalis*	4						8	1					4		8
	Lymnaeidae	*Lymnaea peregra*	1		3		1		4						4		
		Lymnaea stagnalis															
	Planorbidae	*Planorbis planorbis*															
		Planorbis albus	4		8	4		12	8	4	4	4		1		4	8
		Planorbis contortus	4		4		1	4	4	4	28	24			4	8	
		Planorbis crista						32			4	8					
		Planorbis vortex							8				20	4	4	40	8
		Planorbis carinatus															
		Segmentina complanata			8	4	4			4	4			8	44	52	32
	Succineidae	*Succinea ?(palustris)*															
Lamellibranchiata		*Pisidium* spp.	24	12	32	4	12	364	180	228	208	108	28	4	32	56	20
		Sphaerium spp.			4			16	4	12	24	4		4			
	Acroloxidae	*Acroloxus lacustris*													1	12	4
Oligochaeta Sum			384	296	452	264	456	740	244	600	388	204	76	220	440	188	312
Hirudinea	Piscicolidae	*Piscicola geometra*															
	Glossiphoniidae	*Theromyzon tessulatum*	4	4				12	4	4		4	1	4			
		Glossiphonia heteroclita															
		Glossiphonia complanata			8		4	1	1						4		
		Helobdella stagnalis	24	16	40	12	8	68	60	48	16	48	4	16	4	8	24
		Boreobdella verrucata															
	Erpobdellidae	*Erpobdella octoculata*	12	4	3	8	12	24	4	12	4	4	4	4	20	2	12
Arachnidae							1						1			8	8
Hydracarina									4								
Isopoda	Asellidae	*Asellus aquaticus*	732	720	988	464	908	1944	2480	1660	2144	1696	596	892	1372	1736	1812

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			F	F	F	F	F	G	G	G	G	G	H	H	H	H	H
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	36	48	108	36	24	44	128	24	124	24	56	28	44	92	52
	Gammaridae	*Gammarus duebeni*													1	8	16
Ephemeroptera	Beatidae	*Baetis rhodani*															
		Baetis muticus															
		Centroptilum luteolum															
		Cloeon dipterum															
		Cloeon simile															
		Baetidae (early instars)				4			4							4	
	Heptageniidae	*Heptagenia sulphurea*															
	Caenidae	*Caenis horaria*															
		Caenis luctuosa	8	24	8	12		8	8	20	32	4	20	12	8	32	
	Epehemeridae	*Ephemera danica*															
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*															
		Ischnura elegans												4			
		Zygoptera (early instars)															
Megaloptera	Sialidae	*Sialis lutaria*									4						
Neuroptera	Sisyridae	*Sisyra fuscata*															
Hemiptera	Corixidae	*Arctocorisa germari*															
		Callicorixa praeusta							1	1	2		24	20			4
		Corixa panzeri									8				3	1	2
		Hesperocorixa linnaei															
		Sigara distincta	4		1		1				1						
		Sigara dorsalis	4	4					8	4	4		4	1	4		
		Sigara falleni															
		Corixidae (nymphs)	8	4	4	2	2	1	16	4	8		2	4	12		4
	Cymatiinae	*Cymatia bonsdorffi*							8	1	2		24	2	4	1	8
	Notonectinae	*Notonecta glauca*															
Coleoptera	Gyrinidae	*Orectochilus villosus*															
		Gyrinus larvae															
	Chrysomelidae	*Macroplea appendiculata*															
		Macroplea (larvae)															
	Haliplidae	*Haliplus confinus*				1	1		4	4					4		1
		Haliplus flavicollis															
		Haliplus (larvae)	4	24	8	12	16	24			20	16		4	12	12	4
	Noteridae	*Noterus clavicornis* (larger sp.)															
	Dytiscidae	*Agabus* (larvae)											2	8	1		
	Hydroporinae	*Stictotarsus duidecimpustulatus*															

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			F	F	F	F	F	G	G	G	G	G	H	H	H	H	H
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
		Hygrotus quinquelineatus															
		Hygrotus ?(inaequalis)															
		Potamonectes depressus elegans			4												
	Elmidae	*Elmis aenea*															
		Oulimnius tuberculatus	4	20		4											
	Hydrophilidae	*Hydrophilus* spp.															
		Helophorus dubius															
	Hydrophilinae	*Laccobius biguttatus*															
		Laccobius (larvae)															
	Hydraenidae	*Hydraena ?(gracilis)*															
Trichoptera	Glossosomatidae	*Agapetus fuscipes*															
	Hydroptilidae	Hydroptilidae instars II - IV	12	36	20		28										
		Agraylea multipunctata	12	20	12	16	24		1		4	4			4		
		Hydroptila spp.	8		4	20	4							4		4	
	Phryganeidae	*Phryganea bipunctata*															
	Polycentropodidae	*Neureclipsis bimaculata*															
		Plectrocnemia conspersa							8								
		Polycentropus flavomaculatus															
		Holocentropus dubius							4				32	12			
		Holocentropus picicornis													12	24	12
	Psychomyiidae	*Tinodes waeneri*		4													
	Hydropsychidae	*Hydropsyche pellucidula*															
	Limnephilidae	*Limnephilus flavicornis*															
		Limnephilus marmoratus															
		Limnephilidae (early Instars)															
	Lepidostomatidae	*Lepidostoma hirtum*															
	Leptoceridae	*Athripsodes aterrimus*	4	4	4			4	4		4	4		8	4	12	20
		Athripsodes cinereus				4		4	8		12						
		Ceraclea nigronervosa															
		Mystacides longicornis	32	60	52	24	4	12	84	12	16	4	20	8			8
		Triaenodes bicolor							4				8	12	20	12	1
	Sericostomatidae	*Sericostoma personatum*			1		4		4								
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*															
Diptera	Tipulidae							4			1		8				
	Chironomidae		64	68	28	28	44	12	132	24	28	4	36	12	32	28	84
	Ceratopogonidae		24	76		16	36				1						
	Tabanidae												4				
	Simuliidae																

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			I	I	I	I	I	J	J	J	J	J	K	K	K	K	K
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Tricladida	Dugesiidae	*Dugesia polychora*	24	4	20	24		8	8	8	4	12	16		12	12	4
	Planariidae	*Polycelis nigra/tenuis*	204	80	140	84	40	40	184	68	96	96	132	76	92	104	36
	Dendrocoelidae	*Dendrocoelum lacteum*			4			4	8	12	12	12	8	4		12	32
Gastropoda	Neritidae	*Theodoxus fluviatilis*						4	32	8	12	68	4				
	Viviparidae	*Viviparus fasciatus*	2		1			4				1	8	4	4	8	
	Valvatidae	*Valvata cristata*															
		Valvata macrostoma	316	72	92	8	8	12	24	24	8	24	108	144	236	96	164
		Valvata contortus															
		Valvata piscinalis															
	Littoridininae	*Potamopyrgus jenkinsi*															
	Bithyniidae	*Bithynia tentaculata*	20				1		20	24	8	8	96	16	28	40	44
		Bithynia leachi						8									
	Physidae	*Physa fontinalis*						8	16	4		1	20	16	256	92	28
	Lymnaeidae	*Lymnaea peregra*	1	1	4					4			8	12	20	8	12
		Lymnaea stagnalis		12													
	Planorbidae	*Planorbis planorbis*															
		Planorbis albus	8	8	12		4	8	4	4		8	4	16	40	32	28
		Planorbis contortus		4	12		4		1	1	4		12	12	84	36	28
		Planorbis crista	12	4	4							4					
		Planorbis vortex	1	8	8	4	4										
		Planorbis carinatus															
		Segmentina complanata	36		8		4		4	4	4	4					
	Succineidae	*Succinea ?(palustris)*															
Lamellibranchiata		*Pisidium* spp.	132	12	8		4	44	36	4	16	12	24	12	56	40	12
		Sphaerium spp.		8					4			8		8		4	4
	Acroloxidae	*Acroloxus lacustris*															
Oligochaeta Sum			68	36	56	4		184	136	116	176	232	112	80	60	124	180
Hirudinea	Piscicolidae	*Piscicola geometra*										4	1				8
	Glossiphoniidae	*Theromyzon tessulatum*	4	1	1	2							1	8			8
		Glossiphonia heteroclita			4	4											
		Glossiphonia complanata							8				8				
		Helobdella stagnalis	8	12	8		8	12		4	20	12	16	12	24	16	16
		Boreobdella verrucata													8	4	8
	Erpobdellidae	*Erpobdella octoculata*	2	2	4		1	24	16	1	4	4	4	8	4	12	4
Arachnidae				4													
Hydracarina								4							4		4
Isopoda	Asellidae	*Asellus aquaticus*	460	252	352	116	104	512	620	348	532	620	600	668	1340	2148	1060

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			I	I	I	I	I	J	J	J	J	J	K	K	K	K	K
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	180	104	20	56	172	12	28	24	8	12	24	20	8	60	36
	Gammaridae	*Gammarus duebeni*						4	4				2	4			
Ephemeroptera	Beatidae	*Baetis rhodani*															
		Baetis muticus															
		Centroptilum luteolum															
		Cloeon dipterum				4											4
		Cloeon simile	1														
		Baetidae (early instars)															
	Heptageniidae	*Heptagenia sulphurea*															
	Caenidae	*Caenis horaria*		4	4		4										
		Caenis luctuosa	16	4	20	20	4	24	28	24	32	20		4			4
	Epehemeridae	*Ephemera danica*															
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*															
		Ischnura elegans													8		
		Zygoptera (early instars)															
Megaloptera	Sialidae	*Sialis lutaria*															
Neuroptera	Sisyridae	*Sisyra fuscata*															
Hemiptera	Corixidae	*Arctocorisa germari*											4	8	16	36	4
		Callicorixa praeusta	120	84	24	56	100			8	1	2		8	20	20	4
		Corixa panzeri	4	1		2	4										
		Hesperocorixa linnaei	4		1												
		Sigara distincta		4					1								
		Sigara dorsalis	4	4									3	8	12	12	4
		Sigara falleni															
		Corixidae (nymphs)	20	4	4	3	4							8			
	Cymatiinae	*Cymatia bonsdorffi*	8	20	20	28	8						1	40	8	28	4
	Notonectinae	*Notonecta glauca*	1														
Coleoptera	Gyrinidae	*Orectochilus villosus*								4							
		Gyrinus larvae															
	Chrysomelidae	*Macroplea appendiculata*											1				4
		Macroplea (larvae)											4	8	8	16	
	Haliplidae	*Haliplus confinus*						2	5	4	1	1		24		20	
		Haliplus flavicollis													1		
		Haliplus (larvae)	8		8			8	20	8	4	12		4		8	8
	Noteridae	*Noterus clavicornis* (larger sp.)				4											
	Dytiscidae	*Agabus* (larvae)	3	4	1	8	1										
	Hydroporinae	*Stictotarsus duidecimpustulatus*															

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			I	I	I	I	I	J	J	J	J	J	K	K	K	K	K
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
		Hygrotus quinquelineatus					1										
		Hygrotus ?(inaequalis)			1												
		Potamonectes depressus elegans							1								
	Elmidae	*Elmis aenea*															
		Oulimnius tuberculatus						12	24	32	40	36	4			4	
	Hydrophilidae	*Hydrophilus sp.*															
		Helophorus dubius															
	Hydrophilinae	*Laccobius biguttatus*	1														
		Laccobius (larvae)				4											
	Hydraenidae	*Hydraena ?(gracilis)*															
Trichoptera	Glossosomatidae	*Agapetus fuscipes*															
	Hydroptilidae	Hydroptilidae instars II - IV															
		Agraylea multipunctata															
		Hydroptila spp.						24	16	12	8	20			4		4
	Phryganeidae	*Phryganea bipunctata*															
	Polycentropodidae	*Neureclipsis bimaculata*															
		Plectrocnemia conspersa						1	8	4	1						
		Polycentropus flavomaculatus						8									
		Holocentropus dubius															
		Holocentropus picicornis		4				4									
	Psychomyiidae	*Tinodes waeneri*						16	8	20	12	12	1				
	Hydropsychidae	*Hydropsyche pellucidula*															
	Limnephilidae	*Limnephilus flavicornis*															
		Limnephilus marmoratus											4			4	
		Limnephilidae (early Instars)															
	Lepidostomatidae	*Lepidostoma hirtum*						4									
	Leptoceridae	*Athripsodes aterrimus*			4					8	4	1	4		4		
		Athripsodes cinereus						4									
		Ceraclea nigronervosa							1								
		Mystacides longicornis	8	4	4		4	20	24	40	24	12	4	20	52	32	28
		Triaenodes bicolor	20	8		8	8						4				
	Sericostomatidae	*Sericostoma personatum*										4			4		
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*															
Diptera	Tipulidae																
	Chironomidae		20	8	12	8	12	92	92	20	72	84	44	24	4	12	12
	Ceratopogonidae		8					4									
	Tabanidae																
	Simuliidae																

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			L	L	L	L	L	M	M	M	M	M	N	N	N	N	N
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Tricladida	Dugesiidae	*Dugesia polychora*		4		4				8	4	4	12	4	8		
	Planariidae	*Polycelis nigra/tenuis*	120	144	44	160	340	40	48	60	8	24	88	28	64	64	68
	Dendrocoelidae	*Dendrocoelum lacteum*			1			4	4	16	8	8	4		1	4	4
Gastropoda	Neritidae	*Theodoxus fluviatilis*							8	12							
	Viviparidae	*Viviparus fasciatus*								2		4	4		4		1
	Valvatidae	*Valvata cristata*															
		Valvata macrostoma	172	140	52	204	344			4			36	36	24	60	28
		Valvata contortus															
		Valvata piscinalis	4			1											
	Littoridininae	*Potamopyrgus jenkinsi*				4	12							2	4		
	Bithyniidae	*Bithynia tentaculata*			1	8		68	48	44	44	84	1		8	12	
		Bithynia leachi															
	Physidae	*Physa fontinalis*	128	88	60	76	176	4		4		1	4	4	4	12	
	Lymnaeidae	*Lymnaea peregra*	4			1	8					1					
		Lymnaea stagnalis		4				2					2	1			
	Planorbidae	*Planorbis planorbis*					4										
		Planorbis albus	20	16	12	16	28					1	4	4	4	4	
		Planorbis contortus	36		8	8	4					1	4			8	4
		Planorbis crista	20	12	8	4	4										4
		Planorbis vortex											40	4	36	32	24
		Planorbis carinatus													1	1	
		Segmentina complanata														4	
	Succineidae	*Succinea ?(palustris)*															
Lamellibranchiata		*Pisidium* spp.						4	4	4	8	36		20		4	4
		Sphaerium spp.								4	4	1		4			
	Acroloxidae	*Acroloxus lacustris*	4	8													
Oligochaeta Sum			268	120	152	312	176	64	56	80	100	156	958	52	380	208	748
Hirudinea	Piscicolidae	*Piscicola geometra*															
	Glossiphoniidae	*Theromyzon tessulatum*	4	1				4				4			4		
		Glossiphonia heteroclita															
		Glossiphonia complanata		1		4	4				1	4	8		8	4	8
		Helobdella stagnalis	36	8	8	4	28		4		8		4	8	20	4	8
		Boreobdella verrucata	4														
	Erpobdellidae	*Erpobdella octoculata*			2		8		8	4	12	8	1				
Arachnidae								4					1	4	4	4	1
Hydracarina			16	12	16	36	56	4	4			4					
Isopoda	Asellidae	*Asellus aquaticus*	636	560	600	508	716	120	212	276	192	224	584	536	896	676	372

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			L	L	L	L	L	M	M	M	M	M	N	N	N	N	N
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*	36	40	48	48	72	8	8	24	4	12	56		84	68	48
	Gammaridae	*Gammarus duebeni*				1								4		4	
Ephemeroptera	Beatidae	*Baetis rhodani*	4		8	8	12										
		Baetis muticus															
		Centroptilum luteolum					8								4		
		Cloeon dipterum		8											4		
		Cloeon simile															
		Baetidae (early instars)															
	Heptageniidae	*Heptagenia sulphurea*					4										
	Caenidae	*Caenis horaria*														4	
		Caenis luctuosa			4			12		4	4	4	8	8	16		8
	Epehemeridae	*Ephemera danica*							2	4	4	8					
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*															
		Ischnura elegans															
		Zygoptera (early instars)															
Megaloptera	Sialidae	*Sialis lutaria*															
Neuroptera	Sisyridae	*Sisyra fuscata*						4			4	4					
Hemiptera	Corixidae	*Arctocorisa germari*															
		Callicorixa praeusta	4	16	12	12							16	3		4	12
		Corixa panzeri		4	4	2	4							4	24	1	12
		Hesperocorixa linnaei															
		Sigara distincta															
		Sigara dorsalis	24	20	28	12	12						1		4		
		Sigara falleni															
		Corixidae (nymphs)		4									4		12	4	
	Cymatiinae	*Cymatia bonsdorffi*											1		1	12	
	Notonectinae	*Notonecta glauca*															
Coleoptera	Gyrinidae	*Orectochilus villosus*															
		Gyrinus larvae															
	Chrysomelidae	*Macroplea appendiculata*															
		Macroplea (larvae)													1		
	Haliplidae	*Haliplus confinus*													1	4	
		Haliplus flavicollis															
		Haliplus (larvae)	12	8	4	1	16		8	4	1	4	36	16	36		4
	Noteridae	*Noterus clavicornis* (larger sp.)															
	Dytiscidae	*Agabus* (larvae)	4	1		4	4						4		4		
	Hydroporinae	*Stictotarsus duidecimpustulatus*										1					

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			L	L	L	L	L	M	M	M	M	M	N	N	N	N	N
Replicate			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Group	Family	Species															
		Hygrotus quinquelineatus															
		Hygrotus ?(inaequalis)															
		Potamonectes depressus elegans															
	Elmidae	*Elmis aenea*	8	4		4											
		Oulimnius tuberculatus						8	16	16	8	16	8		16	12	
	Hydrophilidae	*Hydrophilus* spp.															
		Helophorus dubius															
	Hydrophilinae	*Laccobius biguttatus*															
		Laccobius (larvae)															
	Hydraenidae	*Hydraena ?(gracilis)*									4						
Trichoptera	Glossosomatidae	*Agapetus fuscipes*															
	Hydroptilidae	Hydroptilidae instars II - IV															
		Agraylea multipunctata											4	4	8		4
		Hydroptila sp.															
	Phryganeidae	*Phryganea bipunctata*															
	Polycentropodidae	*Neureclipsis bimaculata*															
		Plectrocnemia conspersa						4	4	8	16	16					
		Polycentropus flavomaculatus			4			28	4	16	12	24					
		Holocentropus dubius															
		Holocentropus picicornis															
	Psychomyiidae	*Tinodes waeneri*						76	64	24	72	68	4	4			4
	Hydropsychidae	*Hydropsyche pellucidula*															
	Limnephilidae	*Limnephilus flavicornis*															
		Limnephilus marmoratus	4				4	4	4								
		Limnephilidae (early Instars)									4	8					
	Lepidostomatidae	*Lepidostoma hirtum*		12	8	8	4	4			4						
	Leptoceridae	*Athripsodes aterrimus*	4			12				4	4			4	4		4
		Athripsodes cinereus															
		Ceraclea nigronervosa															
		Mystacides longicornis	20	24	12	12	56			4				8			
		Triaenodes bicolor											4				4
	Sericostomatidae	*Sericostoma personatum*	4	4											4		
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*															
Diptera	Tipulidae																
	Chironomidae		140	48	156	160	224	272	408	140	356	436	104	24	68	40	112
	Ceratopogonidae														8	4	
	Tabanidae																
	Simuliidae																

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			O	O	O	O	O
Replicate			1	2	3	4	5
Group	Family	Species					
Tricladida	Dugesiidae	*Dugesia polychora*					
	Planariidae	*Polycelis nigra/tenuis*	20		8		16
	Dendrocoelidae	*Dendrocoelum lacteum*					
Gastropoda	Neritidae	*Theodoxus fluviatilis*					
	Viviparidae	*Viviparus fasciatus*	8	8	8	4	2
	Valvatidae	*Valvata cristata*					
		Valvata macrostoma	8	12	1		
		Valvata contortus					
		Valvata piscinalis					
	Littoridininae	*Potamopyrgus jenkinsi*	20	136	96	64	8
	Bithyniidae	*Bithynia tentaculata*		40		8	
		Bithynia leachi					
	Physidae	*Physa fontinalis*			8		
	Lymnaeidae	*Lymnaea peregra*				4	1
		Lymnaea stagnalis					
	Planorbidae	*Planorbis planorbis*					
		Planorbis albus					
		Planorbis contortus		4			
		Planorbis crista					
		Planorbis vortex			1		
		Planorbis carinatus					
		Segmentina complanata					
	Succineidae	*Succinea ?(palustris)*					
Lamellibranchiata		*Pisidium* spp.	20	44	8	40	12
		Sphaerium spp.	8		4		16
	Acroloxidae	*Acroloxus lacustris*					
Oligochaeta Sum			80	65	212	112	88
Hirudinea	Piscicolidae	*Piscicola geometra*	1				
	Glossiphoniidae	*Theromyzon tessulatum*					
		Glossiphonia heteroclita					
		Glossiphonia complanata					
		Helobdella stagnalis	1				
		Boreobdella verrucata					
	Erpobdellidae	*Erpobdella octoculata*	3		8	4	16
Arachnidae							
Hydracarina							
Isopoda	Asellidae	*Asellus aquaticus*	48	16	144	32	356

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			O	O	O	O	O
Replicate			1	2	3	4	5
Group	Family	Species					
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*					16
	Gammaridae	*Gammarus duebeni*	1	4		4	1
Ephemeroptera	Beatidae	*Baetis rhodani*					
		Baetis muticus					
		Centroptilum luteolum					
		Cloeon dipterum					
		Cloeon simile					
		Baetidae (early instars)					
	Heptageniidae	*Heptagenia sulphurea*					
	Caenidae	*Caenis horaria*					
		Caenis luctuosa					
	Epehemeridae	*Ephemera danica*			1	4	
Zygoptera	Coenagrionidae	*Enallagma cyathigerum*					
		Ischnura elegans					
		Zygoptera (early instars)					
Megaloptera	Sialidae	*Sialis lutaria*					1
Neuroptera	Sisyridae	*Sisyra fuscata*					
Hemiptera	Corixidae	*Arctocorisa germari*					
		Callicorixa praeusta				4	
		Corixa panzeri					
		Hesperocorixa linnaei					
		Sigara distincta					
		Sigara dorsalis					
		Sigara falleni					
		Corixidae (nymphs)					
	Cymatiinae	*Cymatia bonsdorffi*					
	Notonectinae	*Notonecta glauca*					
Coleoptera	Gyrinidae	*Orectochilus villosus*					
		Gyrinus larvae					
	Chrysomelidae	*Macroplea appendiculata*					
		Macroplea (larvae)					
	Haliplidae	*Haliplus confinus*					
		Haliplus flavicollis					
		Haliplus (larvae)			1	4	8
	Noteridae	*Noterus clavicornis* (larger sp.)					
	Dytiscidae	*Agabus* (larvae)					
	Hydroporinae	*Stictotarsus duidecimpustulatus*					

Appendix 3. (Continued). Macroinvertebrate abundances (per sample) for taken from fifteen meso-habitats around the littoral region of Lough Inchiquin. (Habitat descriptions are given on page 251).

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			30/09/98	30/09/98	30/09/98	30/09/98	30/09/98
Meso-habitat			O	O	O	O	O
Replicate			1	2	3	4	5
Group	Family	Species					
		Hygrotus quinquelineatus					
		Hygrotus ?(inaequalis)					
		Potamonectes depressus elegans					
	Elmidae	*Elmis aenea*					
		Oulimnius tuberculatus			8		12
	Hydrophilidae	*Hydrophilus* spp.					
		Helophorus dubius					
	Hydrophilinae	*Laccobius biguttatus*					
		Laccobius (larvae)					
	Hydraenidae	*Hydraena ?(gracilis)*					
Trichoptera	Glossosomatidae	*Agapetus fuscipes*					
	Hydroptilidae	Hydroptilidae instars II - IV					
		Agraylea multipunctata					
		Hydroptila spp.					
	Phryganeidae	*Phryganea bipunctata*					
	Polycentropodidae	*Neureclipsis bimaculata*					
		Plectrocnemia conspersa					
		Polycentropus flavomaculatus					
		Holocentropus dubius					
		Holocentropus picicornis					
	Psychomyiidae	*Tinodes waeneri*					
	Hydropsychidae	*Hydropsyche pellucidula*					
	Limnephilidae	*Limnephilus flavicornis*					
		Limnephilus marmoratus					4
		Limnephilidae (early Instars)					
	Lepidostomatidae	*Lepidostoma hirtum*					
	Leptoceridae	*Athripsodes aterrimus*					
		Athripsodes cinereus					
		Ceraclea nigronervosa					
		Mystacides longicornis					
		Triaenodes bicolor					4
	Sericostomatidae	*Sericostoma personatum*	4	1	8	8	4
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*					
Diptera	Tipulidae						
	Chironomidae		32	80	24	64	68
	Ceratopogonidae						
	Tabanidae						
	Simuliidae						

Appendix 4. Macroinvertebrate abundances for twenty replicate samples taken from a marl and coarse particulate organic matter meso-habitat in the littoral region of Lough Inchiquin

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97
Replicate			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group	Family	Species																				
Tricladida	Dugesiidae	*Dugesia polychora*																			4	
	Planariidae	*Polycelis nigra/tenuis*	8	1	8	4	1	32		4	4	8	12	4	4		16	12		8	8	12
	Dendrocoelidae	*Dendrocoelum lacteum*																1				
Gastropoda	Valvatidae	*Valvata macrostoma*	4	2		4															4	
	Bithyniidae	*Bithynia tentaculata*		12	8	8		4		4	1			12	3	4	1		4	4	4	1
	Planorbidae	*Planorbis crista*	94																			
		Planorbis vortex	1																			
Lamellibranchiata		*Pisidium* spp.	116	96	24	144	20	20	56	36	136	32	64	228	28	16	44	16	36	64	88	152
		Sphaerium spp.		1							1											
Oligochaeta			152	584	552	596	164	248	304	132	188	128	420	288	468	324	308	256	304	408	396	564
Hirudinea	Glossiphoniidae	*Theromyzon tessulatum*									1											
		Glossiphonia complanata		1		4				1			1									
		Helobdella stagnalis	8	8		8	2	8	4	4		2	4	2	4	4	2	4	1		4	16
	Erpobdellidae	*Erpobdella octoculata*		5	1	6	2	3	4	2	4	1		4			2	4	2	1		1
Hydracarina							4	4						4						4		
Isopoda	Asellidae	*Asellus aquaticus*	324	92	16	56	28	124	44	56	136	52	40	88	52	80	24	76	44	88	92	72
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*								4	4			4						4		
	Gammaridae	*Gammarus lacustris*		4	32	12	8	4	8	4	4	8	8	16	8	8	1	4	4	8	4	8
Ephemeroptera	Caenidae	*Caenis luctuosa*	324	116	168	172	204	176	152	192	296	92	184	288	280	300	188	284	196	196	100	212
Anisoptera	Corduliidae	*Sympeterum danae*								4												
Coleoptera	Haliplidae	*Haliplus confinus*		4																		
		Haliplus (larvae)	4							4	4											
	Elmidae	*Oulimnius tuberculatus*													4							
	Psychomyiidae	*Tinodes waeneri*											4				2					8
	Limnephilidae	*Limnephilus marmoratus*			4			1													1	
	Leptoceridae	*Athripsodes cinereus*	32	16	4	12	16	20	8	1	4		4	12	16	12	24	8		8	4	24
	Sericostomatidae	*Sericostoma personatum*	1	2			1	1												1		
Diptera	Chironomidae		108	36	28	120	68	116	40	32	192	36	88	112	64	152	48	116	120	96	40	152
	Ceratopogonidae		8		4	8		4	4				2		4	4		4	4	4	8	4
	Tabanidae		4				1															

Appendix 4. (Continued). Macroinvertebrate abundances for twenty replicate samples taken from a cobble and pebble meso-habitat in the littoral region of Lough Inchiquin

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97	09/04/97
Replicate			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group	Family	Species																				
Tricladida	Dugesiidae	*Dugesia polychora*					4									4	4		12	8		4
	Planariidae	*Polycelis nigra/tenuis*	44	56	116	60	108	68	44	52	44	28	116	64	72	24	100	116	84	76	100	28
	Dendrocoelidae	*Dendrocoelum lacteum*			1	4	4			4	4	1		4			4					
Gastropoda	Neritidae	*Theodoxus fluviatilis*	4		4	4	8	8	8	12	12	1	4	3	8	12	12		4	8	4	1
	Valvatidae	*Valvata piscinalis*				4																
	Bithyniidae	*Bithynia tentaculata*	4	1	8	8	8	1							36	4	4		1		4	1
	Physidae	*Physa fontinalis*						2									1				4	
	Lymnaeidae	*Lymnaea peregra*								1			1	2			1				4	
	Planorbidae	*Planorbis albus*											1									
		Planorbis contortus																				1
	Succineidae	*Succinea ?(palustris)*														4						
Lamellibranchiata		*Pisidium* spp.		1							8		2	4	4	4					8	
		Sphaerium spp.						1	1	4	1									1	1	
Oligochaeta			84	152	104	244	352	148	112	288	228	276	252	156	124	56	208	252	104	120	104	140
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*															4			4		
		Helobdella stagnalis		4	8							4			8		4				1	8
	Erpobdellidae	*Erpobdella octoculata*		4	4	4				4					4		1					4
Hydracarina								4			4					4				4		
Isopoda	Asellidae	*Asellus aquaticus*	116	136	268	176	200	160	100	272	140	44	240	124	164	96	172	52	172	124	128	160
Amphipoda	Crangammaridae	*Crangonyx pseudogracilis*		1	8		8	8	8			4		12	8	4			4	8	8	
	Gammaridae	*Gammarus duebeni*									1	1	1						2	4		
Ephemeroptera	Beatidae	*Cloeon dipterum*																	4			
	Caenidae	*Caenis luctuosa*	28	32	260	332	308	16	8	32	20	212	84	80	164	12	84	124	44	16	132	96
	Epehemeridae	*Ephemera danica*			2	4	8	1			2	1	4		8		1		4		1	
Hemiptera	Corixidae	*Sigara distincta*		1								2									1	
		Sigara dorsalis					1															
Coleoptera	Gyrinidae	*Orectochilus villosus*		4	4																	
	Hydroporinae	*Hyphydrus ovatus*																			1	
	Elmidae	*Elmis aenea*											4									
		Oulimnius tuberculatus	8	12	40	12	4	24	16	20	8	8	28	12	4	8	12	8	32	8	16	4
	Hydrophilinae	*Laccobius biguttatus*	1																			
Trichoptera	Hydroptilidae	*Agraylea multipunctata*										1										
	Polycentropodidae	*Plectrocnemia conspersa*		1								4			4						4	
		Polycentropus flavomaculatus													8		4				8	1
	Psychomyiidae	*Tinodes waeneri*	4	36	4	12	28		4		8	40	16	44	8	4		84			24	
	Limnephilidae	*Halesus radiatus*			4						1	1							1			
	Leptoceridae	*Mystacides azurea*										1						4				
	Sericostomatidae	*Sericostoma personatum*	3		4	12	4	2		8	3	2	3	4	8	4	8	4	2	4	3	4
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*	1	4				1			1									1		
Diptera	Chironomidae			48	28	44	108	4	4			52	20	8	28		16	44	4		28	20
	Ceratopogonidae				4								4		4			4				

Appendix 4. (Continued). Macroinvertebrate abundances for twenty replicate samples taken from a *Phragmites* meso-habitat in the littoral region of Lough Inchiquin

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97	17/09/97
Replicate			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group	Family	Species																				
Tricladida	Dugesiidae	*Dugesia polychlora*			4	1				2		1	3					3			1	
	Planariidae	*Polycelis nigra/tenuis*	29	15	10	15	33	17	24	23	21	4	6	8	2	7	15	34	1	1	1	
	Dendrocoelidae	*Dendrocoelum lacteum*		3		1	2	2	2													
Gastropoda	Neritidae	*Theodoxus fluviatilis*															2					
	Valvatidae	*Valvata macrostoma*					1						1	1	1	5		1			4	4
	Viviparidae	*Viviparus fasciatus*	14	6	6	3	14	8	4	8	11	13	3	11	4	6	7	4			4	
	Physidae	*Physa fontinalis*					2		1			2	1	1	4			2				
	Lymnaeidae	*Lymnaea stagnalis*				1	3									1						
		Lymnaea peregra								2		1	2	1			2					
	Planorbidae	*Planorbus albus*														2					1	
		Planorbis contortus				2			1		1											
		Planorbis vortex	1		2	10	10	6	9		2			1				1				
	Acroloxidae	*Acroloxus lacustris*							2													
		Succinea ?(palustris)															3	5		1		
Oligochaeta		*Oligochaeta*					1	1					1				1				2	5
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*													1		1					
		Helobdella stagnalis				2	4	2	5		1			2	1							
		Theromyzon tessulatum		2	2	3				1	1			1				2				
	Erpobdellidae	*Erpobdella octoculata*					6		1			1	1									
Arachnidae			2	4	5		3	1	5	5	3	3	1			2	4	3				
Hydracarina										1			1									
Isopoda	Asellidae	*Asellus aquaticus*	52	27	24	61	48	24	46	56	49	58	27	90	57	25	36	17	14	21	44	28
Amphipoda	Gammaridae	*Crangonyx pseudogracilis*	1	3	1		3	1		1	1	4			1		2					
Ephemeroptera	Caenidae	*Caenis luctuosa*							1													
	Beatidae	*Centroptilum luteolum*															2					
Zygoptera		*Ischnura elegans*					1			2				1				2				
Hemiptera		*Calicorixia praeusta*									1											
		Sigara dorsalis										2										
		Corixidae (nymphs)		4			2	1		1	1	1	1		1							
	Cymatiinae	*Cymatia bonsdorffi*				6	6	1	2					1								
	Gerridae	*Gerris (odontogaster)?*	2		1	1																
		Gerridae (nymph)						1				1										
Coleoptera	Gyrinidae	*Gyrinus marinus*	1		1				1													
	Halipidae	*Haliplus confinus*	4			1	9		3	7	2	1	1	4	1	3		2				
		Haliplus (larvae)	1	1																		
	Noteridae	*Noterus crassicornis* (the smaller sp.)	2		1				1	1												
	Hydroporinae	*Potamonectes depressus elegans*												1								
	Elmidae	*Oulimnius tuberculatus*	1																			
	Hydrophilidae	*Hydrobius fuscipes*							2													
	Helophorinae	*Helophorus (dorsalis/ brevipalpis)?*	1			1																
	Hydrophilinae	*Laccobius biguttatus*	6	2	8	5	5	2	10	2		4			1	6	1	8				
		Laccobius (larvae)										1					1					
	Hydraenidae	*Hydraena palustris*							1		1											
Trichoptera	Hydroptilidae	*Agraylea multipunctata*									1											
		Mystacides (early instar)							1						1			2				
Lepidoptera	Pyraustidae	*Paraponyx stratiotata*																				1
Diptera	Chaoborus											2	2	1								
	Chironomidae		6	1		3	3		4	6		8		5	2	8	1	7		6	3	2
	Tipulidae			1	1	2		2										1				
	Pericoma (larvae)									1												

Appendix 4. (Continued). Macroinvertebrate abundances for twenty replicate samples taken from a *Scirpus lacustris* meso-habitat in the littoral region of Lough Inchiquin

Lake			Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin	Inchiquin
Date sampled			17/09/97	18/09/97	19/09/97	20/09/97	21/09/97	22/09/97	23/09/97	24/09/97	25/09/97	26/09/97	27/09/97	28/09/97	29/09/97	30/09/97	01/10/97	02/10/97	03/10/97	04/10/97	05/10/97	06/10/97
Replicate			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group	Family	Species																				
Tricladida	Dugesiidae	Dugesia polychlora		1			1	1				1	1	1	2		2	4	1		1	1
		Polycelis nigra/tenuis	1	1		3	10	4	4	3	13	8	6	4	5	8	3	9	6		6	4
	Dendrocoelidae	Dendrocoelum lacteum															1					1
Gastropoda	Valvatidae	Valvata macrostoma			1		3	4	4	5	10	3						1	4		1	
	Viviparidae	Viviparus fasciatus	1	3	4	19	7	32	38	4	11	5	3			2	1	3	4	12	2	8
	Physidae	Physa fontinalis													1						1	
	Lymnaeidae	Lymnaea stagnalis												1								
		Lymnaea peregra														2		1	1			
	Planorbidae	Planorbus albus																	1		1	1
Lamellibranchiata		Pisidium			2																	
	Acroloxidae	Acroloxus lacustris				1	1	7	11	1	3	4	8	1		3						
Oligochaeta		Oligochaeta		27	76	31	95	47	36	83	57	160	179	34	29	61	232	136	129	24	4	8
Hirudinea	Glossiphoniidae	Glossiphonia complanata											2									
		Helobdella stagnalis							3	1			2				2	1	1			
		Theromyzon tessulatum							2	2			1						2			1
	Erpobdellidae	Erpobdella octoculata							1									1				1
Arachnidae		Arachnidae									1			1								1
Hydracarina		Hydracarina		2			1			3	4	3		1	2	5	2	1	3	8	4	
Isopoda	Asellidae	Asellus aquaticus	11	14	10	18	34	11	5	7	7	3	11	4	1		4	8	18	21	23	18
Amphipoda	Gammaridae	Crangonyx pseudogracilis			1									1								
Ephemeroptera	Caenidae	Caenis luctuosa		1	1								1				1	1				
		Caenis horaria					1		1													
	Baetidae	Baetidae (early instars)								1												
		Centroptilum luteolum															1					
Zygoptera	Coenagrionidae	Ischnura elegans		1	2	1												1				
Hemiptera	Corixidae	Corixidae (nymphs)																				1
Coleoptera	Gyrinidae	Gyrinus (larvae)																				1
	Halipidae	Haliplus confinus				1			1	1		1		1	1				1			
	Elmidae	Oulimnius tuberculatus						1														
	Hydrophilinae	Laccobius biguttatus			1												1					1
		Laccobius (larvae)										2										
Trichoptera	Hydroptilidae	Agraylea multipunctata														1		1				
Diptera	Ceratopogonidae	Forcipomyia											1		1			1				
	Chaoborus															8						
	Chironomidae		1	1	8	1	9	4	3	7	7	5	5	8	1	9	6	10	3	2	8	3