Comparison of water quality using aquatic macrophytes, in three rivers in Northern Ireland.

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COMPARISON OF WATER QUALITY USING AQUATIC MACROPHYTES, IN THREE RIVERS IN NORTHERN IRELAND

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Research Project Report
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SUMMARY

The use of macrophytes (ie. aquatic plants visible to the naked eye) as indicators of levels of organic pollution in three major rivers in Northern Ireland (namely the Rivers Lagan, Ballinderry and Kilbroney) was conducted during the summer of 1992. Established methods of biological water quality assessment have normally centred on the use of macroinvertebrates as indicator species. The aim of this project was to assess whether macro-phytes could be used to monitor river quality in a similar manner to macroinvertebrates or be used to augment any current river monitoring programme.

Field data was collected using HMSO (1987) standard methodology of river survey work. A biological index (the plant score) was used to interpret the macrophyte data. In addition macroinvertebrates were sampled for comparison with both macrophyte and available water chemistry data.

By using the MIS and plant score values, similar macrophyte communities were grouped together. By using ecological data from Haslam (1978, 1982), an assessment of the trophic status of sections of river could be made.

This split the River Lagan up into three sections, an upper *Ranunculus penicillatus* - *Fontinalis antipyretica* zone, indicating meso-oligotrophic conditions, a middle zone dominated by *Elodea canadensis*, *Potamogeton natans* and *Sparganium emersum*, indicating semi-eutrophic conditions, and a lower impoverished macrophyte species zone dominated by *Cladophora* algae, *Nuphur lutea* and *P. pectinatus* suggesting eutrophic conditions, brought about by nutrient enrichment from domestic and industrial discharges, and diffuse agricultural sources. This would make the lower reaches a "sensitive area", according to the EC Urban Waste Water Directive.

Macrophyte communities found on the Ballinderry River, suggest meso-oligotrophic conditions in the upper and middle reaches of the river. Downstream sites indicate semi-eutrophic conditions. The macrophyte species found at the sample sites along the short course of Kilbroney River, would suggest oligotrophic conditions.

It is concluded that macrophytes respond to temporal and spatial changes in river water quality in a sensitive and clearly defined manner. They may therefore be used to monitor river quality in a similar manner to the systems using macroinvertebrates employed at present by river biologists. Moreover, macrophytes were shown to respond to different factors than macroinvertebrates (enabling the detection of problems which might otherwise be missed).

They are less sensitive than macroinvertebrates to short-term fluctuations in water quality, thereby providing a more integrated picture for river classification purposes. It is proposed that surveys of river macrophytes could play a significant role in future biological monitoring programmes.

INTRODUCTION

Water quality conditions in river systems may be quantitatively determined by measuring certain chemical parameters. The results from these analyses may be used to calculate the trophic status of rivers at selected sites at the time of sampling (Manga et al 1993). These results however, provide no information on the status of the river prior to sampling.

Biological communities, on the other hand, provide a more refined system by which long-term changes in water quality conditions in a river may be gauged (Extence et al 1987). This is because the responses of these aquatic communities integrate all the habitat factors which operate on organisms and not just those commonly measured in the field or laboratory. For this reason, biotic communities are seen as a valuable tool for water quality monitoring (Extence & Ferguson 1989).

The biological component most frequently used for quality assessment is the macroinvertebrate community. This reflects the extensive literature (Hynes 1960, 1970, Hellawell 1978,1986) which deals with the ecological and trophic tolerances of many macroinvertebrate species. The biological responses of macroinvertebrates to levels of pollution are generally predictable. This predictability in community change allows biologists to detect and accurately pin-point sources of pollution within a river system, without involving time-consuming laboratory practices (Lucey 1987, 1991). In many instances the patterns of community change may also serve to roughly quantify the levels of pollution. The nature and quantity of the pollution discharged into a river determines the degree of community change (Balloch et al 1976, Hellawell 1986).

In organically polluted rivers, there is a tendency for the total biomass of macroinvertebrates to increase accompanied by a decrease in species diversity (Whitehurst & Lindsey 1990). Certain species which are pollution tolerant (eg chironomid larvae and tubificid worms) will do well in such circumstances. Further downstream from the pollution source, filter and deposit feeders will increase whilst more sensitive species such as mayflies (Ephemeroptera), stoneflies (Plecoptera) and some caddis flies (Trichoptera) are reduced. The presence or absence of certain "indicator" species which are sensitive to even low levels of pollution, can provide a means of assessing pollution. These detectable changes in biotic communities, reflects the degree of perturbation in ecological conditions caused by a discharge (Mason 1991).

A number of biotic indices have been developed by biologists, to assess water quality (reviewed in Metcalfe 1989). These biotic indices take account of the sensitivity or tolerance of individual species or groups to pollution and assigns them a value, the sum of which gives an index of pollution for a site.

The Biological Monitoring Working Party Group (BMWP) biotic scoring system (Table 1) has been widely used for over a decade by the National Rivers Authority (and its predecessors) in England and Wales, River Purification Boards in Scotland and, in Northern Ireland, by the Environment Service of the Department of Environment (NI), where river quality monitoring for the whole province and river investigation work, such as fish kills and pollution incidents is contracted out to freshwater biologists from the Industrial Science Centre (ISC) of the Department of Economic Development.

The BMWP score is designed to give a broad indication of the biological condition of rivers throughout the UK (Extence et al 1987). Identification of the macroinvertebrate taxa is to family level. Each family is given a score between 1 and 10. Individual families are allocated a score depending on their sensitivity to pollution (primarily organic pollution). Those taxa least tolerant, such as families of mayflies (Ephemeroptera) and stoneflies (Plecoptera), are given the highest scores, conversely pollution tolerant organisms such as chironomid larvae and tubificid worms are allocated low scores (see Table 1). The contributions of the individual families are then totalled to give a site biotic score.

A high overall biotic score is indicative of good water quality, while a lower score indicates pollution stress. A further measure, the Average Score Per

Taxon value (ASPT) is obtained by dividing the biotic score by the number of taxa present. This value indicates the relative contribution of high or low scoring macroinvertebrate taxa to the fauna as a whole. A high ASPT value shows that the fauna is composed of a high proportion of pollution sensitive taxa and water quality is good. Conversely a low ASPT value is typical of poorer biological quality (Extence & Ferguson 1989). An increasing number of biological surveys of rivers have used biotic scores to compare different sites (Manga et al 1983, Lucey 1987, 1991, Pinder & Far 1987 and Pinder et al 1987).

Macrophytes, like macroinvertebrates, are sensitive indicators of the conditions in which they live (Haslam 1978, 1990, Kelly 1989). They play a vital role in improving the quality of the river itself. During the day photosynthesis by the green submerged plants provides additional oxygen input in the river. M acrophytes also provide a surface on which bacteria can grow and it is the bacteria which breakdown organic pollution (Greg & Rose 1982). Therefore the greater the plant surface area available, the smaller the length of river that will be affected by a polluting inflow.

Macrophytes may offer a more convenient way of monitoring the quality of a river than macroinvertebrates since they remain stationary and cannot move over short periods of time. Their larger size and relative ease of identification enable one to make a reasonably rapid and comprehensive site appraisal (Caffery 1985, 1987).

Overlying the effects of pollution on macrophytes are the many natural characteristics of rivers, such as altitude, latitude, longitude, distance from source, substratum type, flow regime, current speed, depth and shading (Holmes 1983). These factors make it difficult to relate a particular macrophyte community to pollution conditions, unless neighbouring rivers with similar characteristics, but different loads of pollution are compared.

Water chemistry has the most influence in relation to the individual species which make up a river macrophyte community (Mason 1991). Indeed, Ellenberg (1973) found that macrophytes were related to water chemistry. Thus in rivers with continuous mild organic pollution or enrichment, the chemical composition of the water is altered. Macrophytes will survive and grow, but the species composition and abundance will be different to those characteristic of similar sites free from organic enrichment. There is an elimination or decrease of species most sensitive to pollution, a decrease in species composition and an increase in abundance, of species which are tolerant of pollution (Caffery 1985).

To date, little use has been made of macrophytic plants in the area of water quality assessment. However many biologists have long regarded macrophytes as important indicators of water quality, from the pioneering work of Butcher (1933) to the studies by Seddon (1972), Holmes & Newbold (1984) and Haslam (1987, 1990).

Haslam (1982) advocated the use of macrophytes in environmental assessment. She has also described standard methods for the use of macrophytes in the assessment of water quality that may be used to generate indices of a Plant Score (HMSO 1987). This is based on ascribing scores of between 1 to 10 (as in the BMWP score, see Table 2) to macrophytes found in surveys of defined river lengths. The scores are dependent upon their estimated tolerance to nutrient enrichment and/or organic enrichment. A Plant ASPT can also be derived, again along similar lines to that for BMWP scores. Philip Harding, a biologist working for the North West Water Authority, did the pioneering work in the early 1980's, using plant scores of macrophyte distribution, to assess 27 rivers in NW England (Harding 1981), and he found that plant scores correlate well with BMWP scores.

At about the same time, Nigel Holmes undertook a study for the Nature Conservancy Council to classifying British rivers according to their flora. His publication (Holmes 1983), summarizes river plant communities found in over 1000 sites in more than 150 rivers all over the UK. The report describes 56 different plant communities which were identified using TWINSPIN (Two-way Indicator Species Analysis), a computer programme which he used to classify those river plant communities having similar floristic characteristics.

Holmes's TWINSPAN analysis indicated, as expected that riverine plant communities in UK rivers could be divided into four main categories: lowland, enriched rivers with eutrophic plant assemblages, sandstone and limestone rivers with mesotrophic plant assemblages, upland or lowland rivers on tertiary sands or nutrient poor rocks with mesotrophic plant assemblages, and highland or lowland acid heathland rivers with oligotrophic plant assemblages (see Table 3).

Table 1: The BMWP score system.

Families	Score
Siphlonuridae Heptageniidae Leptophlebiidae Ephemerellidae Potamanthidae Ephemeridae Taeniopterygidae Leuctridae Capniidae Perlodidae Perlidae Chloroperlidae Aphelocheiridae Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	10
Astacidae Lestidae Agriidae Gomphidae Cordulegasteridae Aeshnidae Corduliidae Libellulidae Psychomyiidae Philopotamidae	8
Caenidae Nemouridae Rhyacophilidae Polycentropodidae Limnephilidae	7
Neritidae Viviparidae Ancylidae Hydroptilidae Unionidae Corophiidae Gammaridae Platycnemididae Coenagriidae	6
Mesoveliidae Hydrometridae Gerridae Nepidae Naucoridae Notonectidae Pleidae Corixidae Haliplidae Hygrobiidae Dytiscidae Gyrinidae Hydrophilidae Clambidae Helodidae Dryopidae Elminthidae Chrysomelidae Curculionidae Hydropsychidae Tipulidae Simuliidae Planariidae Dendrocoelidae	5
Baetidae Sialidae Piscicolidae	4
Valvatidae Hydrobiidae Lymnaeidae Physidae Planorbidae Sphaeriidae Glossiphoniidae Hirudidae Erpobdellidae Asellidae	3
Chironomidae	2
Oligochaeta (whole class)	1

Table 2: The Plant Score (After HMSO 1987).

ALGAE		MOSSES		MONOCOTYLEDONS		DICOTYLEDONS	
Batrachospermum sp(p)	7	*Amblystegium fluviatile*	6	*Agrostis stolonifera*	1	*Apium nodiflorum*	4
Blue-green mats	1	*Amblystegium riparium*	2	*Alisma plantago-aquatica*	3	*Callitriche sp(p)*	6
Cladophora spp	3	*Cinclidotus fontinaloides*	7	*Butomus umbellatus*	7	*Caltha palustris*	6
Enteromorpha sp(p)	3	*Fontinalis antipyretica*	4	*Carex sp(p)*	8	*Ceratophyllum demersum*	6
Hildenbrandia rivularis	7	*Fontinalis squamosa*	10	*Eleocharis sp(p)*	7	*Mentha aquatica*	6
Lemanea fluviatilis	8	*Hygrophypnum ochraceum*	10	*Elodea canadensis*	5	*Myosotis sp(p)*	5
Sigeoclonium sp(p)	1	*Racomitrium aciculare*	10	*Elodea nuttallii*	4	*Myriophyllum alterniflorum*	10
Vaucheria sp(p)	2	*Rhynchostegium riparioides*	6	*Glyceria maxima*	3	*Myriophyllum spicatum*	7
Other filamentous algae	—	*Sphagnum sp(p)*	10	*Glyceria other sp(p)*	4	*Nasturtium officinale agg*	7
		Other mosses (each)	10	*Iris pseudacorus*	3	*Nuphar lutea*	6
LIVERWORTS				*Juncus acutiflorus*	6	*Oenanthe crocata*	3
Chiloscyphus polyanthos	10	VASCULAR CRYPTOGAMS		*Juncus bulbosus*	6	*Polygonum amphibium*	3
Scapania undulata	10	*Equisetum fluviatile*	3	*Juncus bufonius*	6	*Polygonum sp(p)*	2
Solenostoma sp(p)	10	*Equisetum palustre*	3	*Juncus effusus*	4	*Ranunculus calcareus*	5
Other foliose liverworts (each)	10			Other *Juncus sp(p)*	4	*Ranunculus fluitans*	5
Pellia epiphylla	6			*Lemna sp(p)*	4	*Ranunculus hederaceus*	5
Other thallose liverworts (each)	6			*Phalaris arundinacea*	2	*Ranunculus omiophyllus*	10
				Potamogeton alpinus	10	*Ranunculus peltatus*	8
				Potamogeton berchtoldii	2	*Ranunculus penicillatus*	6
				Potamogeton crispus	4	Other *Ranunculus spp* (each)	6
				Potamogeton natans	3	*Rorippa amphibia*	4
				Potamogeton pectinatus	1	*Solanum dulcamara*	2
				Potamogeton perfoliatus	7	*Veronica beccabunga*	5
				Potamogeton polygonifolius	10	Other Dicotyledons	—
				Other *Potamogeton spp* (each)	7		
				Sagittaria sagittifolia	4		
				Scirpus sp(p)	5		
				Sparganium emersum	3		
				Sparganium erectum	2		
				Typha latifolia	4		
				Zannichellia palustris	5		
				Other Monocotyledons	—		

Table 3. A botanical classification of rivers in the UK, into 16 broad types (After Holmes 1990a)

GROUP	DESCRIPTION
A1	Enriched sand and gravel rivers
A2	Clay rivers
A3	Chalk rivers
A4	Lowland ditch communities
B1	Lowland rivers of NE Scotland
B2	Enriched lowland sandstone rivers
B3	Lowland sandstone rivers
B4	Western and upland rivers on sandstone or limestone
C1	Basic mesotrophic upland rivers
C2	Neutral oceanic western rivers
C3	Oligo-mesotrophic upland rivers in England & Wales
C4	Oligo-mesotrophic upland rivers in Scotland
D1	Oligotrophic mountain rivers
D2	Ultra-oligotrophic mountain rivers
D3	Oligotrophic moorland rivers
D4	Oligotrophic bog rivers

Table 4: The Macrophye Index Scheme
(After Harding 1981, Caffery 1987 and Hellawell 1986).

Sensitivity Groupings	*Macrophyes*	
Group A Sensitive	Callitriche spp. Ranunculus spp.	Hygrohypum ochrace. Scapania undulata
Group B Less sensitive	Alisma plantago-aqua Elodea canadensis Fontinalis antipyretica Rhynchostegium riparioides Rorippa nasturtium-aq	Apium nodiflorum Equisetum spp. Glyceria fluitans
Group C Tolerant	Iris pseudacorus Lemna spp. Nuphur lutea Polygonum amph. P. natans Typha latifolia	Juncus effusus Myriophyllum sp. Oenanthe crocata Potamogeton crispus Sparganium spp.
Group D More Tolerant *(Pollution-favoured species)*	Amblystegium riparium Cladophoda glomerata Potamogeton pectinatus	

Table 5: Water quality classes, sensitivity groupings and macrophyte relative abundance which characterise the water quality according to the Macrophyte Index Scheme (After Caffery 1987).

Water Quality Class	*Sensitive Grouping*	*Relative Abundance*
Q1 Bad Quality	Group A	Absent
	Group B	Absent
	Group C	Emergents sparse
	Group D	Dominant
Q2 Poor Quality	Group A	Absent
	Group B	Absent or sparse
	Group C	Abundant
	Group D	Dominant
Q3 Doubtful Quality	Group A	Absent
	Group B	Common
	Group C	Dominant
	Group D	Abundant
Q4 Fair Quality	Group A	Common
	Group B	Common or Abundant
	Group C	Common
	Group D	Some Algae
Q5 Good Quality	Group A	Dominant
	Group B	Abundant
	Group C	Sparse
	Group D	Absent

Wide variation in plant species composition, number of species present and total macrophyte cover are normally found within and between rivers with different trophic status (Holmes 1990b). Three distinct macrophyte zones can generally be distinguished according to the physical nature of the stretch of river being surveyed: in a river rising on hills the upper (swift flowing, rocky) reaches are usually dominated by submerged mosses and liverworts, the middle (fairly fast flowing, gravelly) reaches are dominated by rooted plants adapted to withstand fast flows, and the lower (deep, silted) reaches supported a community of submerged and emergent species similar to that of a lake or pond. Within each of these zones the distribution and abundance of different macrophytes are often markedly affected, and in a clearly defined manner by inputs of nutrients and/or organic material.

Plant community composition alters with the gradation from unpolluted to polluted waters (Kelly 1989). A knowledge of the trophic requirements and tolerances of important or conspicuous macrophyte species make it possible to infer the trophic status of a river on the basis of the macrophyte species present. Using these criteria Caffery (1985, 1987) proposed a scheme of water quality assessment in which the relative proportions of pollution "sensitive, less sensitive, tolerant and pollution-favoured species" were used to determine river water quality. This was based on macrophyte community analysis of over 140 sites on 27 rivers in the Irish Republic.

Caffery compressed this information into an easily understood form, by means of a five-point biotic index - the Macrophyte Index Scheme (MIS). For the purpose of this study, this was expanded using additional pollution sensitive and tolerance macrophyte species data from Harding (1981) and Hellawell (1986, p185) (see Table 4). The five water quality classes used were: Q1 - Bad quality, Q2 - Poor quality, Q3 - Doubtful quality, Q4 - Fair quality and Q5 - Good quality (see Table 5). Intermediate ratings (1-2, 2-3, 3-4, 4-5) can also be assigned to a site if the proportions of plant species in the sample do not indicate a distinct rating.

The growth of macrophytes in rivers is largely dependent upon light and nutrients (Van der Bijl et al 1989). Light is critical for photosynthesis and nutrients are needed for plant growth. In rivers with a natural scarcity of essential plant nutrients, especially nitrogen and phosphorus, and macrophyte densities are low. Such rivers are said to be oligotrophic, that is "underfed". By contrast, rivers with ample nutrients supporting profuse growths of macrophytes are eutrophic or "well-fed" (Mason 1991).

Organic matter in suspension is perhaps the most universal pollutant of rivers. Organic pollutants discharged into rivers supply plant nutrients especially for higher plants and algae, and when present in sufficient quantity lead to a stimulation of plant growth (Mason 1991). The effects of pollution on the plant communities of a river are often wide-ranging and long term.

Obvious signs that a river is suffering from organic pollution include the appearance of "sewage fungus" such as Sphaerotilus natans and various kinds of fungi and bacteria, though such effects may only be seen at the point of pollution (Hellawell 1986). Further down the river, abundant growths of filamentous algae, especially Cladophora glomerata are normally noted. As the nutrients on which these organisms feed are used up the fungi and bacteria decline in succession. Most macroinvertebrates and fish disappear or their populations become reduced through lack of oxygen and the blanketing effects of mats of "sewage fungus" (Seager & Maltby 1989).

Under these conditions certain macrophytes such as Canadian pondweed Elodea canadensis and fennel pondweed Potamogeton pectinatus and similar species which may blanket a river thrive, while other, pollution sensitive forms diminish in vigour. The entire flora of a river may be changed in this way. Where polluted conditions prevail, pollution tolerant plants grow vigorously, often to the exclusion of all other macrophyte species. In particularly severe cases, de-oxygenation and algal blooms may eradicate all aquatic plants as has occurred in certain Norfolk Broads (Mason 1991).

Newbold and Holmes (1987) and Barnes et al (1989) have propose the use of macrophytes alongside macroinvertebrate and chemical water quality assessment in environmental monitoring, and Schmedtje and Kohnmann (1987) used macroinvertebrates versus macrophytes as indicators of pollution to compare water quality assessment. This project tries to follow in their footsteps.

BACKGROUND

Northern Ireland covers an area of 5242 square miles. Of the population of 1.5 million, about one third live in the River Lagan catchment. A similar proportion live in towns with populations of upwards of 5000 and the remainder in smaller towns, villages and the countryside. Industry is generally centralised around the major population centres of Belfast, Londonderry, Lisburn and Ballymena (ISC 1992a).

Topographically it is composed as a series of uplands and mountains encircling a central lowland, much of which is occupied by Lough Neagh, the largest freshwater lake in the UK (see Figure 1).

Most rivers are subject to the same environmental forces, all having limited gradients, draining catchments essentially similar in underlying geology, land use and climate and particularly subject to the effects of drainage schemes and water-borne effluent disposal (Williams & Browne 1987).

The responsibility for consenting discharges to rivers, monitoring and policing pollution is in the hands of the Department of Environment (NI). Overall the water quality in most of Northern Ireland's rivers is good (DOE NI 1987). Although Northern Ireland has escaped the worst environmental degradation found in many industrialised countries, it has few, if any, areas of land or water which are not significantly influenced by man. Limited range in altitude, and a generally mild, damp, oceanic climate have resulted in almost all areas being subject to some modification especially for agriculture.

Indeed, agriculture is the single most important industry in Northern Ireland with over 8% of the population involved in farming and some 80% of the countryside in agricultural use. Most of the agricultural land is intensively managed for livestock and livestock products, with extensive use of inorganic fertilisers and regular dressings of slurry (ISC 1992a).

Widespread problems with farm waste discharges have been reported in Northern Ireland (Wilcock 1982). The most frequently reported causes are the release of animal slurry from stores, either deliberately or through structural failure, the discharge of silage effluents and run-off from farm yards, particularly during heavy rainfall. Farm wastes have both biochemical oxygen demand and ammonia concentrations many times those of sewage effluent and have caused widespread ecological damage in a number of rivers which were previously of good quality (DOE NI 1987, Withrington 1991).

STUDY AREAS

River Lagan -

The River Lagan has its source in the Dromara Hills in Co Down (Figures 1 and 2). It flows in a north-easterly direction, passing several major and small towns before finally discharging into Belfast Lough. The river is approximately 78km long, it rises at an elevation of 450m, and drains a small catchment area of 565km square. It has one major tributary, the River Ravernet. Physically the river can be divided into four sections:-

- A fast-flowing upper reach (where in approximately 20km the river falls over 370m).
- A broad flood plain.
- A relative faster flowing section between Lisburn and Stranmillis.
- A tidal reach below Stranmillis Weir.

Land use in the upper reach and flood plain is predominantly improved pasture sustaining livestock production. The lower reach is almost totally given over to industrial and residential development. Although the river drains a relatively small area, approximately 600,000 people live within its catchment and as a consequence the ratio of river flow to the volume of treated sewage and industrial effluent discharged is small, particularly during dry weather conditions (DOE NI 1987). This makes it difficult to maintain water quality in the river, particularly in the lower reaches. To try and improve this situation the DOE has recently spent close to £30 million on a number of sewage treatment works between Lisburn and Belfast, namely Dunmurry, New Holland and Newtownbreda (Environment Committee HOC 1990 p90).

Of previous studies done, Manga et al (1983) used macroinvertebrates to look the deterioration of biological conditions at seven sites spread out along the length of the Lagan. More recently, Webster (1991) makes a brief comment of finding water crowsfoot (Ranunculus penicillatus) in the upper reaches of the River Lagan.

Presently, the biological quality of the upper reaches of the river are described as good to moderate (Class A to B). Pollution from intensive farming in the middle reaches contributes to a decline in the biological quality. From Moira downstream, the river was banded as Class C. The middle and lower reaches are of poor quality as a result of both sewage and industrial discharges (ISC 1992a).

The latest major pollution incident, was in March of last year. When a large amount of detergent was spilled from a chemical factory just outside Lisburn, bringing about a marked deterioration in the macroinvertebrate fauna for a number of kilometres downstream from its point source (ISC 1992b).

Below Stranmillis Weir, the river is under tidal influence. This section of the river receives both domestic and industrial discharges from the densely populated area of Belfast, and is grossly polluted as manifested by the poor marine benthic fauna found, and gassing of the sediments (Manga et al 1983, DOE NI 1987).

The Environment Service DOE (NI) is currently (September 1992) asking for tenders from firms for a water quality management plan for the River Lagan catchment.

Ballinderry River

The main course of the river is approximately 37km long, with two principal tributaries, the Killymoon River and Lissan Water (Figures 1 and 3). The river rises at approximately 160m altitude on the south-east slopes of the Tyrone uplands and flows in a easterly direction into Lough Neagh. The catchment contains only one principal town, Cookstown, which is situated along the middle reach of the river. The town is sustained by a mixture of light industry, commerce and service industries. The hinterland of the river is predominantly improved permanent pasture, with forestry predominating in the upper catchment. Physically the river can be divided into two sections:-

- A shallow, fast-flowing upper reach.
- A sluggish lower reach, with long deep glide sections.

The surface geology of the upper reaches of the catchment is mostly sandy or gravelly beds derived from the underlying sandstone and a variable overburden of glacial drift. In the lower reaches the geology is dominated by clays of the Lough Neagh basin.

For most of its length, the river was banded as Class A, with the upper reaches being unclassified. The only major input to the river is from the Cookstown sewage treatment plant, although the river is slightly stressed from diffuse agricultural input (ISC 1992a).

There do not seem to have been any major surveys of the flora of the Ballinderry River in the past, although Harron and Rushton (1987) provide over 300 distribution maps of the 700 or so species recorded in the Flora of Lough Neagh. 41 relevant floristic records are mapped for the lower reach of the Ballinderry River.

Kilbroney River

This is a small fast-flowing river which rises in the Mourne Mountains, in south Down. It flows southwards to join Carlingford Lough at Rostrevor, which is situated near the mouth of the river and thus has relatively little influence on the river (Figures 1 and 4).

The solid geology of the catchment is tertiary granite, with silurian shales in the lower reaches of the Rostrevor valley. The upper reaches of the river are narrow (3-4m across), bordered by *Molinia* grass, with a backdrop of conifer forest. In the wider lower reach (5-7m), the river is lined, in parts by a mixture of *Alnus*, *Fraxinus* and *Sorbus*.

In the recent past, the middle reach of the river was effected by an industrial discharge from a dye factory. Above the factory the river was unclassified, downstream of the factory the river was banded as Class B (ISC 1992a). The situation has now been rectified, with the dye effluent being treated on-site, and the discharge being diverted to a sewer outside the small catchment.

Figure 1: Map of Northern Ireland Showing Surveyed Rivers

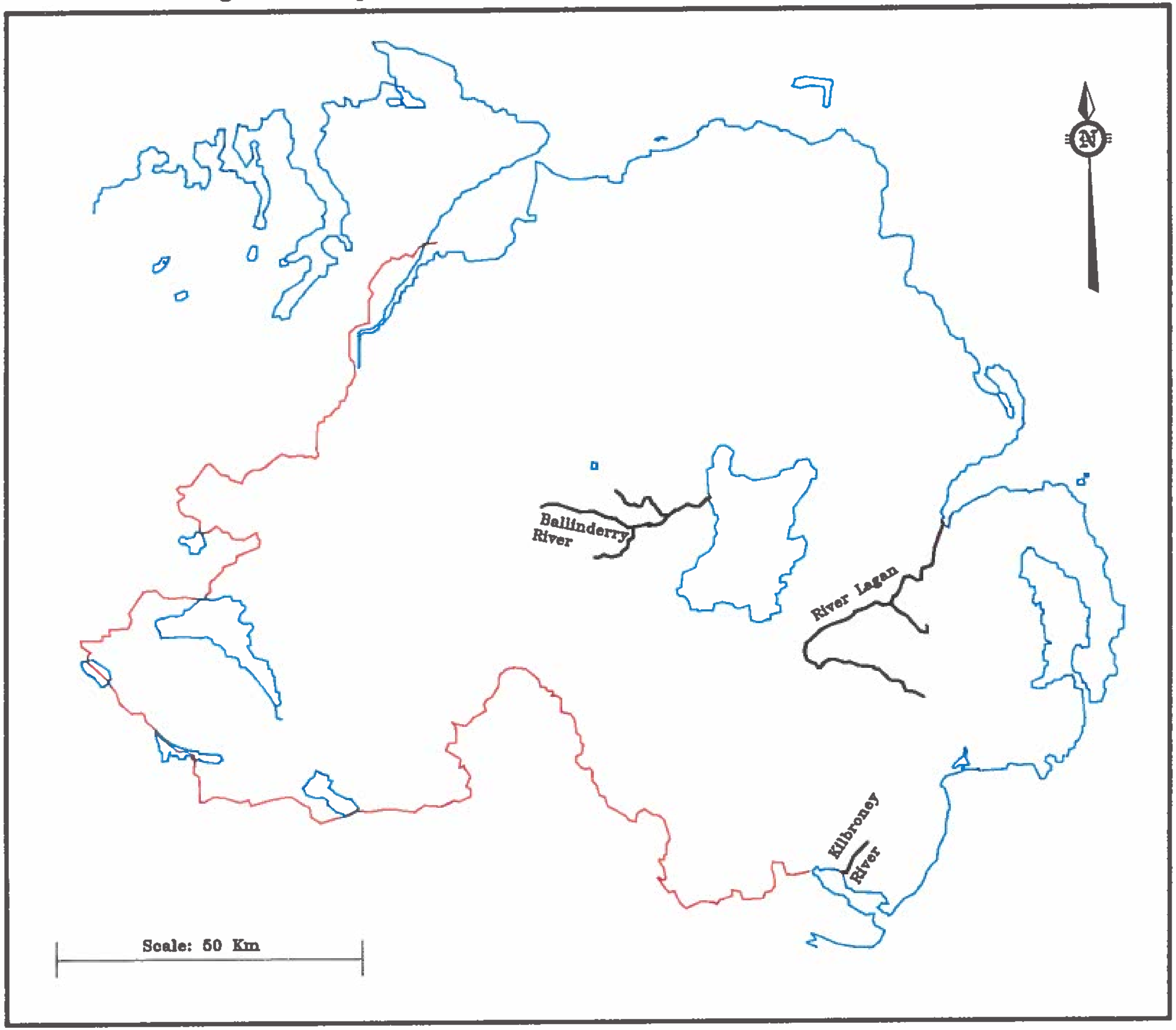


Figure 2: River Lagan Showing Sampling Sites

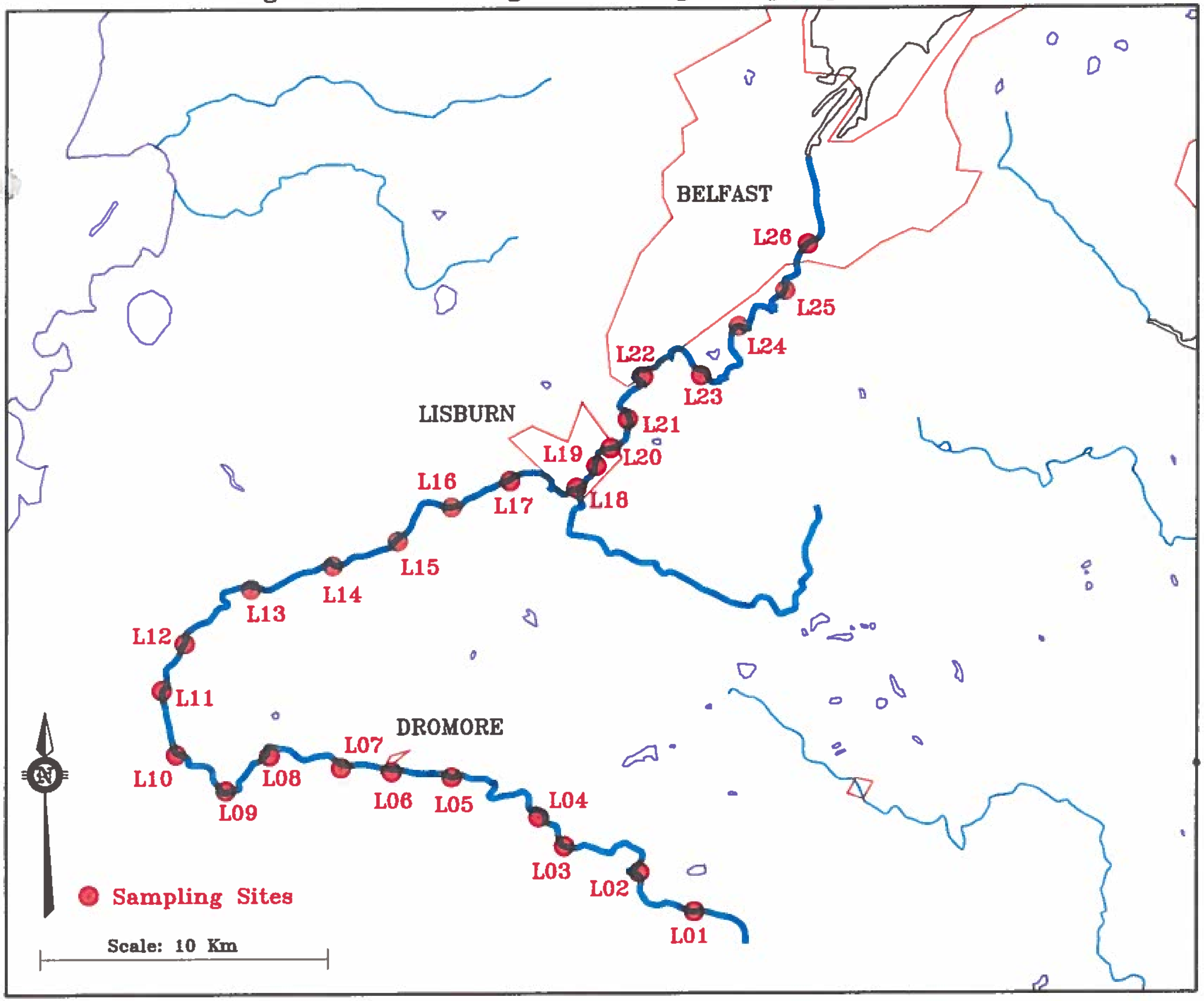


Figure 3: Ballinderry River Showing Sampling Sites.

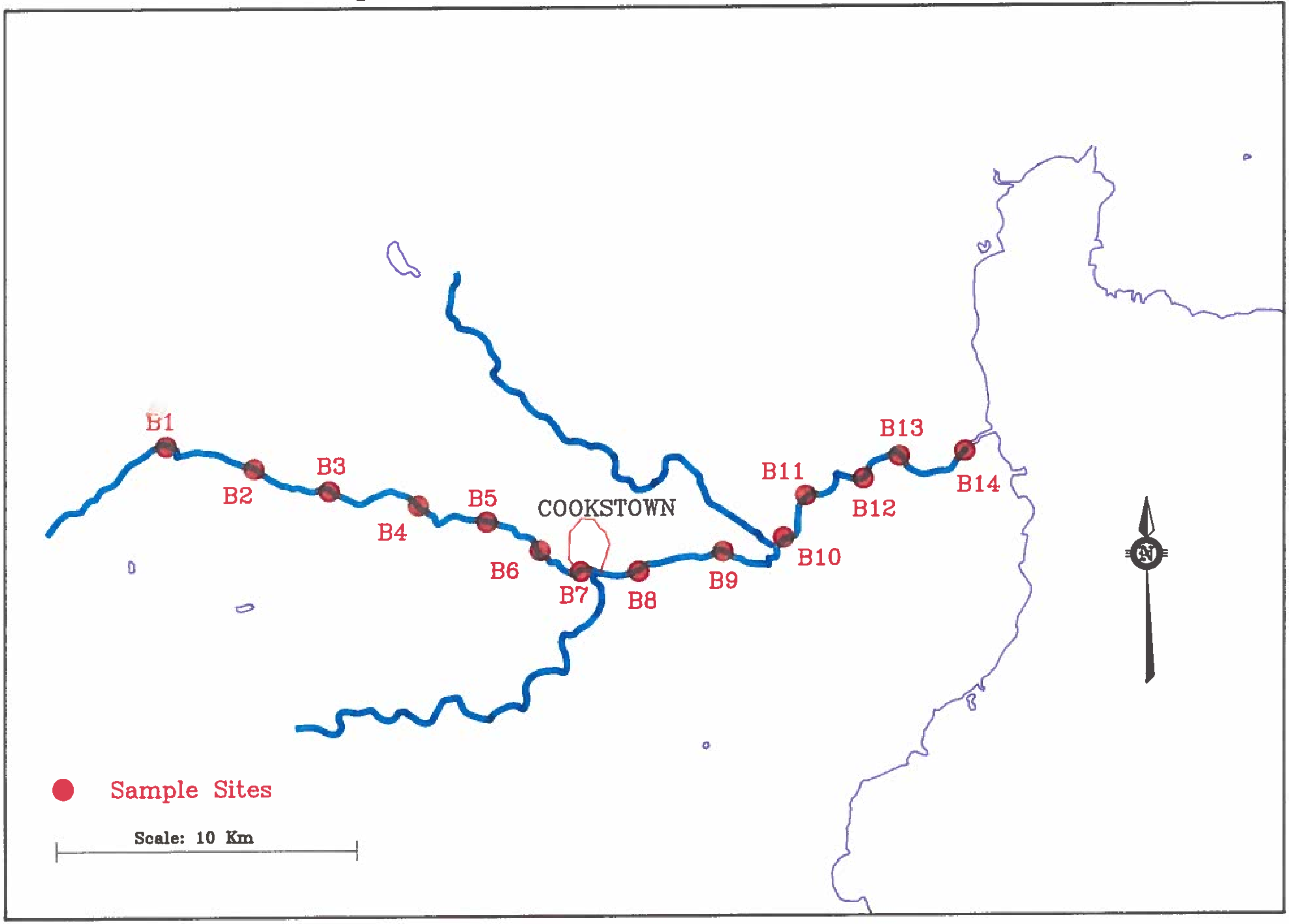
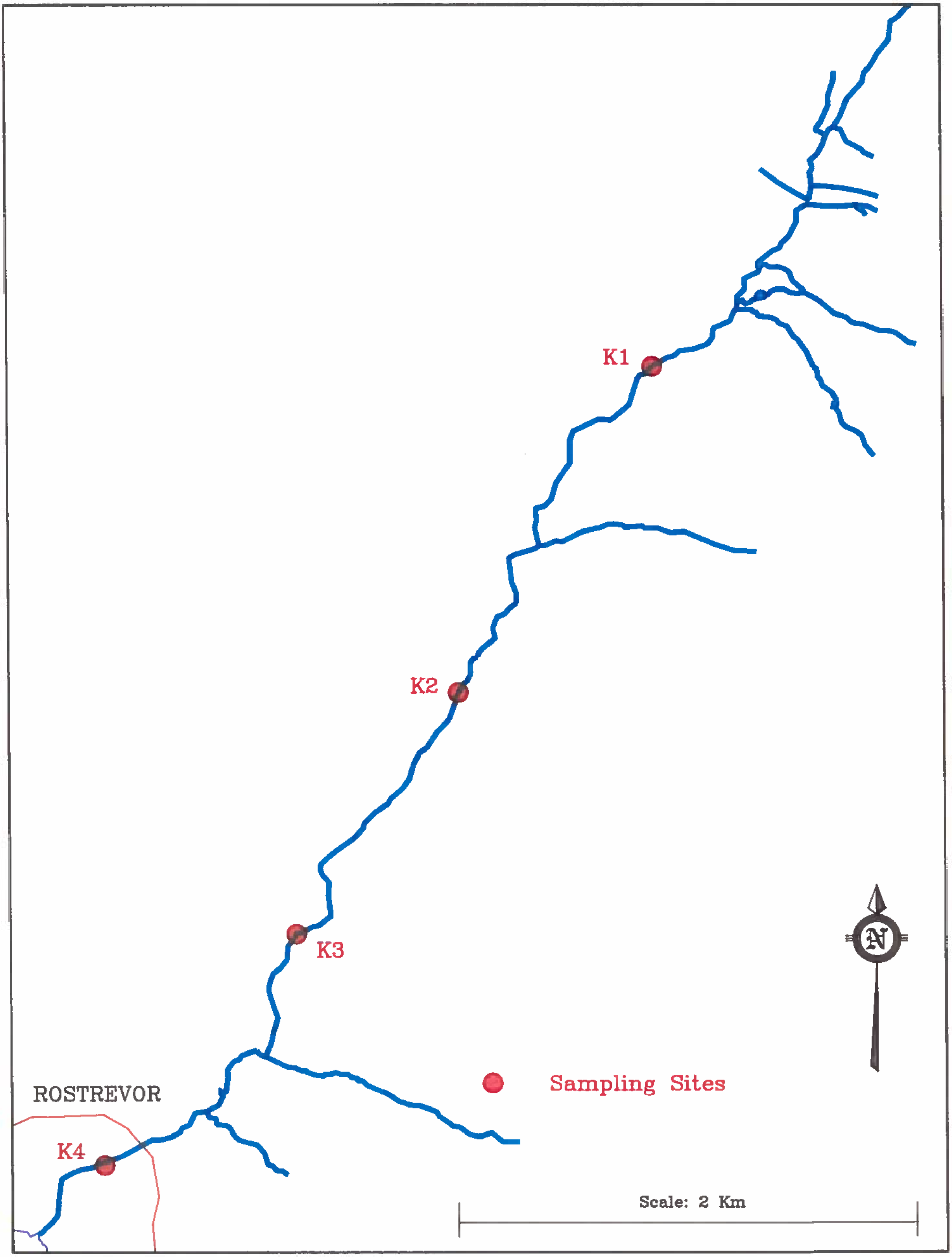


Figure 4: Kilbroney River Showing Sampling Sites



METHODS

Safety Aspect

All sites were surveyed by two people - chest waders, buoyancy vests and arm-length industrial rubber gloves were used throughout field-work. A safety rope and first-aid kit etc were at hand.

Number Of Sample Sites

26 sites were sampled along the River Lagan, 14 along the Ballinderry River and four along the length of the Kilbroney River (each site was around 3km apart, although some were chosen in relation to existing ISC RIVPACS monitoring sites). Exact six-figure Irish grid references of the mid-point of each site were recorded at the time of field work. Site codes, site names and the Irish grid reference of each sampling site on each of the three rivers are given in Tables 12, 13 and 14. Numbering of sites is subjective ie numbering starts from the upper-most site: River Lagan = L01 -> L26, the Ballinderry River = B01 -> B14 and the Kilbroney River = K01 -> K04.

Aquatic Macrophytes

The aquatic vegetation was surveyed during July and August of 1992 (the main growing season for river plants). Macrophyte surveys traditionally begin upstream working downstream to the river mouth, but the opposite policy was adopted for this survey because field work began in the last week of July and it seemed right to work upstream so that the expected richer downstream plant communities could be accurately and swiftly identified in their flowering and/or fruiting stages.

It was decided not to use the 100m survey length used by Caffery (1985, 1987), which was used to sample river macrophytes in a number of rivers, in the south of Ireland. Instead a standardised approach developed by HMSO (1987) was used. This used a survey length of 500m. The authors describe this length as being the "basic unit recommended for macrophyte assessment" and being "very well suited to providing broad, detailed descriptions of macrophyte communities".

Sites were sampled, by surveying 500m at each individual site. The standard method (Holmes & Whitton 1977) of wading in a zig-zag pattern along each 500m length was used. In a few cases, it was not possible to survey the entire length by the above method, such as in towns. An attempt was made to survey at least 100m in length, with the remainder, being surveyed by walking along the bank or by using bridges as observation points, and where possible re-entering the river. In deep sections a grapnel was used to sample submerged vegetation. With practice 4-6 lengths could be surveyed in one day.

Only aquatic plants (ie those associated with the river channel) were identified. It was decided not to survey adjacent bank-side vegetation, as this would have greatly increased the time taken to survey each site, but to solely concentrate on aquatic species, and also because generally bank-side vegetation does not reflect the pollution status of the river itself. Only plants that existed under the direct influence of water for more than 85% of the year (Holmes & Whitton 1977) were included in the species list. For this reason many of the marsh-dwelling or terrestrial grasses and sedges often included in macrophyte surveys carried out in the UK mainland (Holmes 1983), were excluded from the species lists.

Plant species where normally identified in the field, these were recorded on a standard survey sheet (a blank copy is included in the appendix), containing both a list of "selected species" (selected by Holmes 1983) and a selection for additional species. Any doubtful specimens were collected, for later identification. Bryophyte species were identified as much as possible in the field, but, further to this, all bryophytes were collected in plastic sample bags for identification back in the laboratory. An assessment of percentage cover of each species was made, using Scale A in Method B - The survey and assessment of macrophytes in watercourses, in HMSO (1987 p40).

The scale for percentage cover (the % of river or bed covered by individual species) was as follows:-

1 = <0.1% cover

2 = 0.1-1% cover

3 = 1-5% cover

4 = 5-10% cover

5 = >10% cover

Identification of plant species was carried out using Haslam et al (1982) and standard flora - Webb (1977) and Clapham et al (1989). Bryophyte species were identified using a 10x hand lens in the field and a 20x binocular microscope in the laboratory. Standard bryophyte flora keys were used - Watson (1968) and Smith (1978).

Macroinvertebrates

The macroinvertebrates were surveyed at the same sites as the macrophyte survey described above. At each site, sampling was carried out at approximately the mid-point of the 500m length. Sampling methodology followed that of Hellawell (1978). At most sites a three minute "kick sample" using a standard FBA long-handled pond net, was taken across the width of the river channel at each sampling site. Where possible, this was supplemented by one minute of "stone washing", where individual stones and rocks were washed by hand directly into the pond net. In areas of deeper water the pond net was swept along the margins of the river and under bank-side vegetation to gain an idea of marginal distribution.

The results of each sample were taken back to the laboratory in sealed plastic buckets for identification. Samples were sorted in the laboratory. Larger stones and fragments of vegetation were washed over a metal sieve and discarded. Shallow flat-bottomed white trays were used for sorting. Identification to family level was carried out on all samples using Macan (1959) and standard FBA fauna keys (Hynes 1977, Macan 1979, Edington & Hildrew 1981, Elliot & Humpesch 1983 and Wallace et al 1990).

Levels of relative abundance were recorded on a logarithmic scale as follows:

A = 1-9

B = 10-99

C = 100-999

D = 1000+

Additional Information

Physical characteristics of each site were recorded on a prepared survey sheet (see appendix sheet). Data was recorded for depth range, substrate types, channel width, habitat features, levels of shading and adjacent land-use.

Water Chemistry

Bi-monthly water chemistry data for 1990 and 1991 was obtained from the Environment Service of the Department of Environment (NI) for all three rivers (River Lagan - 9 sites, Ballinderry River - 4 sites (3 on the Ballinderry, and 1 from a tributary, the Killymoon River), Kilbroney River - 1 site).

The following key chemical parameters were used:-

% Dissolved Oxygen - The percentage saturation of dissolved oxygen is one of the most important indices of the purity of a river. A river containing a high proportion of organic pollution will have a much lower % dissolved oxygen than a river which is clean and pollution free. As well as indicating organic pollution the % dissolved oxygen is a critical factor when the suitability of a river for aquatic life is considered.

Ammoniacal Nitrogen - Ammonia arises as a rule from the aerobic or anaerobic decomposition of nitrogenous organic matter and if present in a river in appreciable amounts provides strong presumptive evidence of the presence of sewage or sewage effluent.

Total phosphate - Phosphorus occurs in natural waters and in waste water, mainly in the form of various forms of phosphate. It is an element which is essential to the growth of organisms especially macrophytes and algae and it can be the nutrient that limits the growth which a body of water can support.

Nitrate - This represents the final oxidation product of ammonia and therefore well treated sewage effluent can contain a high concentration of nitrate. Thus nitrate may well be useful for determining the operating efficiency of a sewage treatment works.

River Flow

Monthly flow data from 1990 and 1991 was obtained from the Water Hydrology Service of the Department of Agriculture (NI). At New Forge Lane (L25), for the River Lagan and at Ballinderry Bridge (B13) for the Ballinderry River. Flow data was not available for the Kilbroney River.

RESULTS

Aquatic Macrophytes

Macrophyte species lists, incorporating subjective estimates of the relative densities of individual plant species within the sites surveyed were compiled for each of the three rivers (Tables 7, 9 and 11). These enabled sites to be compared on the basis of abundance, species richness, Plant and ASPT Scores and also assessed into quality classes using the Macrophyte Index Scheme (MIS) (Tables 12, 13, 14, 16 and 17).

Approximately 47 macrophyte species were recorded in "river" habitats in the three rivers surveyed (see Table 15). Macrophytes almost always showed marked downstream zonation within each individual river, this zonation could be attributed to a combination of downstream physical changes and the effects of changing water quality.

River Lagan

A total of 45 macrophyte species were recorded (Table 7). The River Lagan could be divided into three zones based on the dominant macrophyte species: an upper zone dominated by *Ranunculus penicillatus* and *Fontinalis antipyretica*, a middle Potamogeton natans, Elodea canadensis and Sparganium emersum zone, and a lower Cladophora spp., Potamogeton pectinatus and Nuphur lutea dominated zone.

Cladophora and Elodea canadensis were also abundant at varying sections of the river. The upper and middle reaches were usually fringed by Alisma plantago-aquatica, Glyceria fluitans, Myostis scorpioides, Phalaris arundinacae and Oenanthe crocata. The moss Rhynchostegium riparioides and liverwort Pellia epiphylla were found within the upper reach. Moss species were rare in the lower part of the river. Fontinalis antipyretica was the only moss frequently encountered in the lower half of the Lagan. Apium nodiflorum was associated with Rorippa nasturtium-aquaticum in shallower water.

Myriphyllum alterniflorum and Potamogeton crispus were found at sites along the middle reach. Small amounts of Sphaerotilus natans and Enteromorpha algae were recorded in the middle and lower reaches. Lemna minor was only abundant in the lower reaches, Lemna polyrizha occurred in a similar distribution.

The plant score was a series of peaks and troughs (see Figure 6), slipping downwards from the upper to lower reaches of the river. The highest peak was at Ballyvicknacally (L06), just above Dromore, with a plant score of 91. A progression of small ups and downs, with minor peaks at Geehans Bridge (L12) and Moore's Bridge (L20) led to the lowest score at New Forge Lane (L25). The ASPT values followed a similar pattern, with a high peak at Woodford (L03), and a successive fall before a low point at Lisburn Weir (L21) (ASPT = 2.70), with a shallow climb in the lower reach sites.

The MIS split the Lagan up into four zones (see Table 12 and 16), the upper, middle and the start of the lower reaches, from Bell's Bridge (L01) to Hilden Bridge (L22) was a mixture of Q4 (fair quality) and Q3-4 (doubtful to fair quality), Ballyskeagh Bridge (L23) was classed as Q2-3 (poor-doubtful quality, Drum Bridge (L24) was an increase on the previous at Q3-4, while New Forge Lane (L25) and Stranmillis (L26) were classed as Q1-2 (bad-poor quality).

Ballinderry River

36 macrophyte species were noted (Table 9). Much of the river was dominated by Ranunculus penicillatus and Fontinalis antipyretica. Oenanthe crocata and Phalaris arundinacae, both bank-side marginal plants were widely found throughout the river course. Alisma plantago-aquatica, Callitriche spp., Iris pseudacorus and the algae Cladophora were recorded at scattered locations. Elodea canadensis, Lemna minor, Sparganium emersum and S. erecta were generally found scattered along the deep glides associated with the lower reaches. Potamogeton natans was found at sites in both the upper and lower

reaches. Nuphar lutea was found at only one site in the lower reaches. Myriophyllum alterniflorum and Potamogeton pectinatus were found only at the two lower-most sites.

The plant scores again peaked and troughed (Figure 8), with low scores found at Drumard (B06) and Doorless Bridge (B08). There was a steady climb in the score in the bottom sites, with the highest values recorded for the two lower most sites - Ballinderry Bridge (B13) and Lower Mullan (B14). The ASPT results showed low values for the first three sites, rising to a peak at Wellbrook Bridge (B04), with a slide down, between Doorless Bridge (B08) and Flood Lodge (B10), before a further small peak and trough towards the end.

The MIS (Table 17) classed the upper reaches of the river (B01 to B07) as a mixture of Q5 (good quality), Q4-5 (good-fair quality) and Q4 (fair quality). Doorless Bridge (B08) was classed as Q3 (doubtful quality), B09 to B12 were classed as Q4 (fair quality) and the bottom two sites as Q3-4 (doubtful to fair quality).

Kilbroney River

This river was dominated by bryophyte species. Ten species were recorded in all, six of them, bryophytes (see Table 11). Low abundances of the bryophytes Bryrum bicolor and Rhynchostegium riparioides, and the rush Juncus bulbosus were found at all four locations. Slightly larger quantities of *Fontinalis antipyretica* were found in all, bar the top most site. *Calliergon cuspidatum*, *Pellia epiphylla* and *Scapania undulata* were found at scattered locations. *Agrostis stolonifera*, *Callitriche* spp. and *Iris pseudacorus* were all recorded at the bottom site.

The plant score values (Table 14) for all four sites were low, between 33 and 40, ASPT values were high for the top three sites, reflecting high scoring pollution sensitive species, but dropped for the bottom site, Fairy Glen (see Figure 10). Species diversity was poor, as indicated by the small number of species recorded. The MIS (Table 17) classed all four sites as being Q5 (good quality).

Macroinvertebrates

Macroinvertebrate lists were also prepared for each of the three rivers (Tables 6, 8 and 10). These enabled sites to be compared on the basis of abundance, family richness, the presence/absence of certain families, BMWP and ASPT Scores.

River Lagan

The families and abundance levels of macroinvertebrates found at sites along the River Lagan are given in Table 6, where 41 taxa were found. The most common taxa at each site were generally similar: Gammaridae, Dytiscidae, Planariidae, Baetidae, Glossiphoniidae, Erpobdellidae, Asellidae, Chironomidae (found at all sites) and Oligochaeta.

Pollution sensitive families such as Heptageniidae, Ephemerellidae, Leutridae, Perlodidae and Leptoceridae were found at low levels of abundance along the upper and upper-middle reaches, apart from a small number of Heptageniidae and Ephemerellidae which were found at New Forge Lane (L25). Low abundances of Caenidae, Rhyacophilidae, Elmidae and Hydropsychidae were found at a handful of sites along the upper reaches of the river. Varying abundances of Ancylidae, Corixidae, Halipidae, Hydrophilidae, Simuliidae, Lymnaeidae, Planorbidae and Sphaeriidae were recorded at scattered intervals along the upper, middle and lower reaches of the river. Dendrocoelidae was found at sites in the middle and lower reaches.

There is a steady decline in the number of taxa found from the upper reaches to the lower reaches. An average of 23 taxa per site was found along the upper reaches of the river, Bell's Bridge (L01) to Clanmurry (L07), an average of 19 taxa per site in the middle reaches (L08-16) and an average of 16 taxa per site in the lower reaches (L17-26).

Gammaridae had extremely high levels of abundance between Clanmurry (L07) and Moygannon (L10), as did both, Simuliidae and Asellidae at sites L07 and L08 respectively. Ephemrellidae were found at reasonably high numbers at Woodford (L03).

The BMWP score shows a series of peaks and troughs, declining towards the start of the lower reach, with a shallow rise towards the bottom site (L26) (see Table 12 and Figure 5). The highest BMWP value (136) was recorded at Woodford (L03), with an unexpected sharp drop, down to 77, at Lappoges Bridge (L05). There was a peak in the middle reach at Spencer's Bridge (L16). The lowest scores of the river were recorded soon after, at Mazetown (L18) and Young's Bridge (L19), upstream from the town of Lisburn.

The ASPT values followed a similar pattern (Figure 5), with a series of peaks and troughs declining towards the start of the lower reach. Three peaks were noted at Woodford (L03), Ballyvicknacally (L06) and Thornyford Bridge (L09). From New Bridge (L17) to Hilden Bridge (L22), there was a progression of low ASPT values, before a late rise in the bottom few sites.

Ballinderry River

In all 36 taxa were recorded (Table 8). Ephemerellidae were found in abundance at all sites. Heptageniidae, Rhyacophilidae, Ancylidae, Gammaridae, Dytiscidae, Elmidae, Simuliidae, Baetidae and Hydrobiidae were found at scattered locations. Gammaridae were particularly abundant between Cookstown Bridge (B07) and Flood Lodge (B10). However, Chironomidae and Oligochaeta were found at all sites, generally in moderate quantities, Chironomidae were particularly abundant at Cookstown Bridge (B07) and Coagh Bridge (B11). Glossiphoniidae and Asellidae were recorded at a few sites.

The BMWP score (Table 13 and Figure 7), stayed relatively constant in the upper reaches of the river (between 70 to 90), with a slight rise at Cookstown Bridge, before moderately sloping down to the sampling site at Flood Lodge (B10), just after the confluence of the Lissan Water tributary. Coagh Bridge (B11) had the highest BMWP score, with the three bottom sites, B12 to B14 ranging between 82 and 96.

The ASPT values (Table 13), remained fairly constant in the upper reaches, with slight peaks at Corkill Bridge (B03) and Cookstown Bridge (B07), and two large dips at Doorless Bridge (B08) and Flood Lodge (B10), before levelling out in the bottom three sites.

Kilbroney River

The families and abundance levels of macroinvertebrates found at the four sites are given in Table 10. In all 21 taxa were recorded, six of those taxa were pollution sensitive indicator (ie scoring 10 on the BMWP system). The most common taxa across the four sites were Goeridae, Limnephilidae, Ancylidae, Dytiscidae, Baetidae, Chironomidae and Oligochaeta, however most were present only at low levels of abundance. Ephemerellidae and Dytiscidae were found at moderate levels of abundance. Newton Bridge (K03) was found to be the most taxon-rich and Fairy Glen (K04) had the greatest number of individuals.

For the upper reaches of the river, the BMWP score at Yellow Rock (K01) was very low (see Table 14 and Figure 9), the score rose steadily between the Valley Dyeworks site (K02) and Newton Bridge (K03), dipping sharply at lowest site (Fairy Glen K04). The ASPT values for the four sites were high (Table 14), with Yellow Rock (K01), the lowest at 5.64, and the three lower sites hovering near to or above a value of 6.00.

Water Chemistry

River Lagan

Data for water chemistry for a number of sites along the River Lagan were obtained. In the upper reaches (Figures 11 and 12), levels of ammoniacal nitrogen and total phosphate were generally low, although there was a small peak of total phosphate (1.65 mg/l) below Dromore STW (L08) during the summer months. There was an increase in nitrate at Bull's Brook (L04) in the autumn. At L08, there was a dip in both nitrate and % dissolved oxygen during the summer.

At Banoge (L11) and Magheralin Bridge (L14), Figures 13 and 14 respectively levels of ammoniacal nitrogen and total phosphate was low, apart for a huge total phosphate increase (16.9 mg/l) at Magheralin Bridge in December. At L11, % dissolved oxygen peaked in May at 128%, dropping to 72% in June. At L14, % dissolved oxygen was between 100-120% over the spring and early summer, before dropping to 65-75% in late summer/early autumn. At both sites, levels of nitrate stayed between 4-6 mg/l over the winter, falling during the summer.

In the lower-middle reaches, at Spencer's Bridge (L16) and Young's Bridge (L19) (Figures 15 and 16) levels of % dissolved oxygen and nitrate over the winter were high, becoming lower during the summer. Conversely total phosphate was low over the winter, with small peaks of between 1.7-2.35 mg/l in the summer. Ammoniacal nitrogen was found at low levels throughout the year at both sites.

In the lower reaches (L22 to L26, Figures 17, 18 and 19), levels of % dissolved oxygen and nitrate were relatively high throughout the year. Levels of total phosphate were low over winter, rising slowly during spring and summer to peak in September. Levels of ammoniacal nitrogen at Hilden Bridge (Figure 17) were low in the winter (0.4-0.6 mg/l), rising steadily in the spring and early summer to peak at 2.1 mg/l. Levels of ammoniacal nitrogen at the two lower most sites were correspondingly lower.

Ballinderry River

At all sites (Figures 20, 22 and 23) on the Ballinderry River and the one site on the Killymoon River tributary (Figure 21), levels of ammoniacal nitrogen and total phosphate were low. At Cookstown Bridge (B07) and Doorless Bridge (B08), levels of nitrate were moderately high throughout the year (3-4.5 mg/l). At the three sites along the Ballinderry River, % dissolved oxygen levels generally hovered between 85-100%, although there was a late summer peak at the Ballinderry Bridge site in the lower section of the river.

At the Prince of Wales Bridge, on the Killymoon River tributary, levels of nitrate were high in spring/early summer (3-5 mg/l), the % dissolved oxygen was high in late summer (140%), generally remaining between 90% to 105%.

Kilbroney River

Levels of ammoniacal nitrogen and total phosphate were relatively low across the year (Figure 24). % dissolved oxygen remained constant, between 95-105%. Nitrate levels peaked in February, decreasing over the spring and summer months, before rising again from October to December.

River Flow

The levels of nitrate in both the Lagan and Ballinderry Rivers seemed to follow that of river flow, both levels were moderately high in spring, decreasing to low levels in the summer months, before gradually increasing again over autumn and winter (see Figures 25 and 26).

Comparison Of BMWP Score With Plant Score

Comparing the values of plant scores with those of BMWP scores for all sites (Figure 27). The sites from the Ballinderry River were scattered in the central-left area of the graph, well mixed with a number of sites from the River Lagan. Sites along the Lagan showed up as outliers in both directions of the X-axis (BMWP score). The four sites from the Kilbroney River tended to cluster to the lower part of the graph.

Statistical Analysis

Correlation coefficient analysis was carried out, using a statistical computer program on the ORAC mainframe computer at ISC, on the biotic and plant scores and biotic ASPT and plant ASPT from each of the three rivers. As well as at all sites from the three rivers (biotic and plant scores, and biotic ASPT and plant ASPT).

There was a positive correlation between the BMWP and Plant scores for the River Lagan ($r = 0.646$, significant at $P<0.01$), as well as for the two ASPT values ($r = 0.652$, significant at $P<0.01$). The biotic and plant scores for the Ballinderry River indicated a poor correlation ($r = 0.270$, not significant). However the two ASPT values showed a positive correlation ($r = 0.650$, significant at $P<0.01$).

The two scores for the Kilbroney River showed a very weak relationship ($r = 0.212$, not significant), and the two respective ASPT values were negatively correlated ($r = -0.740$, not significant).

Correlation coefficients were also carried out on selected chemical data (% dissolved oxygen, ammoniacal nitrogen, total phosphate and nitrate) with river flow data, supplied by the Department of Agriculture (NI) for both the rivers Lagan and Ballinderry.

For the River Lagan at New Forge Lane, there was some relationship between river flow and nitrate ($r = 0.625$, significant at $P<0.05$). % dissolved oxygen seemed to be weakly related to river flow conditions ($r = 0.376$, $P<0.05$). Total phosphate and ammoniacal nitrogen were negatively correlated to river flow, with values of ($r = -0.839$, $P<0.001$) and ($r = -0.317$, $P>0.05$) respectively.

River flow data for the Ballinderry River at Ballinderry Bridge (B13) showed a strong positive correlation with nitrate ($r = 0.832$, highly significant at $P<0.001$) as did ammoniacal nitrogen ($r = 0.775$, significant at $P<0.01$), but was negatively correlated with both % dissolved oxygen ($r = -0.593$, $P<0.05$) and total phosphate ($r = -0.726$, $P<0.01$).

Correlation was also carried out to compare the values of plant score with values of BMWP score, and both biotic and plant ASPT. The biotic and plant score data was grouped together. The plant and biotic score showed a significant relationship ($r = 0.550$, $P<0.01$), as did the ASPT of both scores ($r = 0.684$, $P<0.01$).

Macrophyte, macroinvertebrate and all additional information, recorded from all sites is held on both file and mainframe computer ORAC RS1 filename BIO_STUDENT directory @Gregor at the Industrial Science Centre, Lisburn.

Table 6: Distribution Of Macroinvertebrate Taxa In The River Lagan.

M-I Taxa	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13
Heptageniidae	B	B	B		B	B	A		A	A			
Ephemerellidae	B	B	C	B		B	B	A	B	A	B	A	A
Leuctridae	A	A	A										
Perlodidae	A												
Leptoceridae			B	A		B						A	C
Agriidae													
Caenidae				A	B	B		B		A	A	A	
Rhyacophilidae			A			B	A		A	A			
Polycentropodidae		A	B										
Limnephilidae		A	B	B									
Ancylidae	B	B	B	B	B	B	B		B		B	B	B
Gammaridae	B	B	B	B	B	B	C	D	C	C	B	B	C
Coenagriidae				A								B	A
Hydrometridae									A				A
Gerridae	A	A	A				A						
Notonectidae		A											
Corixidan		A		A	B	B	A	B				B	C
Haliplidae	B	B		B		A	B	B	B				
Dytiscidae	B	B	B	B	B	B	B	C	A	A		B	B
Gyrinidae													
Hydrophilidae	B	C	B		B	B		C	B			B	B
Elimidae	B		B	B	B	B	B		B				
Hydropsychidae			B			A	A	A		B			
Tipulidae	A	A	A	A									
Simuliidae	B	B	B	B		B	D		B	B	B	B	
Planariidae		A	A	A	B	B	A	A	A	A	A	B	B
Dendrocoelidae							A	A	A	B	A		A
Baetidae	A	A	B	A	B	B	C	A	B	B	B		
Sialidae				A									
Piscicolae	A	A	A		A								
Valvatidae				A								A	
Hydrobiidae	B	B		B	A	B	A	A		B		B	C
Lymnaeidae	A	A		A		A					A	B	B
Physidae		A		A							A		A
Planorbidae		B	A	A	A	A					A	B	
Sphaeriidae		B	A	B		A					A	B	C
Glossiphoniidae	A	A	A	A	A		A	A	A	B	B	A	
Erpobdellidae						A		A		B	B	B	B
Asellidae		B	B	B	B	B	D	C	B	B	B	B	
Chironomidae	B	B	B	B	B	B	B	C	B	A	B	B	C
Oligochaeta	B	B	B	B	B	B	B	B	A	A	B		B
No. Taxa	20.00	27.00	25.00	26.00	17.00	24.00	21.00	18.00	18.00	17.00	17.00	20.00	19.00
BMWP	107	133	136	122	77.00	121	105	82.00	92.00	84.00	72.00	96.00	89.00
ASPT	5.35	4.93	5.44	4.69	4.53	5.04	5.00	4.55	5.11	4.94	4.24	4.80	4.68

Table 6 cont.: Distribution Of Macroinvertebrate Taxa In The River Lagan.

M-I Taxa	L14	L15	L16	L17	L18	L19	L20	L21	L22	L23	L24	L25	L26
Heptageniidae												A	
Ephemerellidae	A	A	A									A	
Leuctridae													
Perlodidae													
Leptoceridae	B		B										
Agriidae								B					A
Caenidae	A	A	A										
Rhyacophilidae													
Polycentropodidae													
Limnephilidae								B		A			
Ancylidae		B				B		B	A	B		B	
Gammaridae	B	C	B	B	B		A	B	B	C	B	C	C
Coenagriidae	A	A		A			B	B			A		A
Hydrometridae	A												
Gerridae											A		A
Notonectidae			A								A		A
Corixidan	B	B	B	B		B	A	A			B		B
Haliplidae			B	A	A	A	A	A			B		B
Dytiscidae	B	B	B		A	A	A	A		A			
Gyrinidae	A												
Hydrophilidae		B	B	B	A		A			A	A		
Elimidae	A		A										A
Hydropsychidae	B												
Tipulidae									A				
Simuliidae			B						A	B		B	
Planariidae	B	A	A	C	B	B	B		A	B	B	B	B
Dendrocoelidae					A	A			A	B	B	B	B
Baetidae			B					B	B	B		B	
Sialidae			B	A									
Piscicolae									A				A
Valvatidae			A			B							
Hydrobiidae	B			B		B	A	B				B	B
Lymnaeidae	B	B	B	B	B		C	B	B	C	C	B	C
Physidae		B		B				B					B
Planorbidae	B	B	B	B	B	B	B	B	A		B	B	C
Sphaeriidae		C	B	C	B	B	C	B	A	B		B	C
Glossiphoniidae	A		B	B			A		A	A	A		A
Erpobdellidae	B	B	B	B	B	B	B	B	A	B	B	B	B
Asellidae	B	C	B	C	B	B	B	B	B	C	B	C	C
Chironomidae	B	C	B	B	A	B	B	B	B	B	B	B	B
Oligochaeta	B	C	B	B		B	B	B	A	B		B	
No. Taxa	21.00	17.00	23.00	17.00	12.00	14.00	16.00	19.00	16.00	16.00	15.00	16.00	20.00
BMWP	98.00	76.00	105	63.00	48.00	52.00	61.00	81.00	61.00	66.00	64.00	72.00	85.00
ASPT	4.67	4.47	4.57	3.71	4.00	3.71	3.81	4.26	3.81	4.13	4.27	4.50	4.25

Table 7: Distribution Of Macrophytes Species In The River Lagan.

Spp	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13
Agro sto	1					1	1					1	1
Alis p-a			1	1	1	1				1	1	1	1
Apiu nod										1	2		1
Callitr	1		2	2	1	2	1	2		2	1	1	1
Calt pal	1												
Carex sp						5							
Eleo pal						1							
Elod can		5		3	3	2	2	3	2	1	2	3	2
Equi flu		1		1	2	2							
Equi pal													
Glyc max													
Glyc flu	1	1	1	1		1							
Iris pse						2				1		1	
Junc eff	1				1	1							
Lemn min		2		2	3	2	1	2	1	1	1	2	1
Lemn pol											1	2	2
Ment aqu							1				1		
Myos sco	1	1		1	1	1	1			2			
Myri alt												4	4
Nuph lut		5		4	3		1	4	1		1	2	3
Oena cro	3	1	2	2	2	2	1	1	2	2	2	1	1
Phal aru	2	2	1	2	1	2	1	1		1	1	1	2
Poly amp				1									
Pota cri				1		2	2	2	1	3	1	2	2
Pota nat		4		3	3	1		4	1			3	
Pota pec												1	
Pota obt												2	1
Ranu pen	1	4	5		3	4	2	2	3	3	2		
Rori n-a										1	1		
Spar eme		2		2	2	2	2	4	2	2	1	2	
Spar ere		1		2		2	2	2	1		1	1	
Typh lat					2	1							
Vero bec													
Ambl rip				1	1	1					1		
Cladopho	3	3	1	2	4	1	2	3	1	2	2	4	3
Enteromo													
Font ant	4	3	4	4	5	3	3	2	3	4	3	2	3
Fw sponge			1	1	1								
Lema flu			1										
Liverwort	1	1											
Pell epi	1	1	1	1	1								
Rhyn rip	1	1		1									
Spha nat													
Vaucheri													
Oth moss	1		1		1								

Table 7 cont.: Distribution Of Macrophyte Species In The River Lagan.

Spp	L14	L15	L16	L17	L18	L19	L20	L21	L22	L23	L24	L25	L26
Agro sto				1				1					
Alis p-a	1	1	1			1	1						
Apiu nod	1						1						
Callitr	1	3	1	2	1	1	1	1	1		1		
Calt pal						1							
Carex sp													
Eleo pal													
Elod can		3	3	3	2	3	3				2		4
Equi flu		1		1									
Equi pal													
Glyc max													
Glyc flu							2						
Iris pse							1	2					
Junc eff													
Lemn min	1	1	1	2	1	3	4	5	2	2	2	2	3
Lemn pol	1	1	2	1	2	1		2	1	2	2		
Ment aqu													
Myos sco		1											
Myri alt	4	3											
Nuph lut	2	2	4	2	3	5	4	2	1	1	1		3
Oena cro	1		1					1		1			
Phal aru	1		1	2		1	1	1					
Poly amp													
Pota cri	1	1	2	1	1		2	1	1	3		3	1
Pota nat		2	3	5	3	5	5	3	1	3	1		2
Pota pec		3	2	3	2	2	2	2	2	3	2	2	3
Pota obt		1											
Ranu pen	2						1						
Rori n-a	1		1										
Spar eme	4	3	3	4	4	2	3	3	2	2	3	2	2
Spar ere	1	2	1	1							1		
Typh lat													
Vero bec				1									
Ambl rip													
Cladopho	5	4	5	2	5	2	2	2	5	5	1	5	5
Enteromo								1	1		1	1	
Font ant	2							1	2	2			
Fw sponge		1			1								
Lema flu	1												
Liverwort													
Pell epi													
Rhyn rip													
Spha nat	3							1		1			
Vaucheri				1		1							
Oth moss													

Table 8: Distribution Of Macroinvertebrate Taxa In The Ballinderry River.

M-I Taxa	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13	B14
Heptageniidae	A	A	A	A	A	A	A				A	A		
Ephemerellidae	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Ephemeridae								A						
Leuctridae		B	A		B		A				A	A	A	
Leptoceridae							A		A	A	A		A	A
Goeridae				A										
Lepidostomatidae						A								
Sericostomatidae							A							
Caenidae	A													
Rhyacophilidae	A				B	B	A		B		A	A	A	A
Polycentropodidae			A	A		A						A		A
Limnephilidae			A	A	A	A		A						A
Ancylidae		A	A	B	A	A	B		B		A	A	A	A
Gammaridae	A	B	B			B	C	C	C	C	B	B	B	B
Corixidae								A		A	A			A
Haliplidae								A	A	A	B			B
Dytiscidae	A	A	A	B		B		B		B	B	B	B	B
Hydrophilidae	B						A	B		B				
Elmidae	B	B	A	A		B	B		B	B	B	B	B	B
Hydropsychidae			A			A	A					B	B	B
Tipulidae												A		
Simuliidae	B	B	A	B	B	A	B		B			A	B	
Planariidae				A				A						
Dendrocoelidae											A			A
Baetidae	B	B	B	B	B	B	C		B		A	A	A	A
Piscicolidae	A							A						
Hydrobiidae	B	B		A	B	B	B	C	B	B	B			
Lymnaeidae	B	A												
Physidae										A				
Planorbidae					A					A	A	A		
Sphaeriidae								B			A	A	A	
Glossiphoniidae	A				A			A		A	A			A
Erpobdellidae				B										A
Asellidae								A		A	A		A	
Chironomidae	B	B	A	B	B	B	C	B	B	B	C	B	A	A
Oligochaeta	B	B	A	A	B	B	A	B	B	B	B	B	A	A
No. Taxa	16.00	13.00	15.00	15.00	13.00	16.00	16.00	17.00	14.00	15.00	22.00	17.00	15.00	18.00
BMWP	80.00	70.00	90.00	83.00	71.00	93.00	99.00	83.00	74.00	69.00	116	94.00	82.00	96.00
ASPT	5.00	5.38	6.00	5.54	5.46	5.81	6.19	4.88	5.29	4.60	5.27	5.53	5.47	5.33

Table 9: Distribution Of Macrophyte Species In The Ballinderry River.

Spp	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13	B14
Agro sto	1	1			1		2	1	1	1		1	1	1
Alis p-a			1							1				1
Apiu nod					1						1			
Callitr	3	2	1		1		1		1	1	1			
Calt pal													1	
Elod can					1		1	5	3	5	1	1	3	3
Equi flu	2													
Equi pal				1										
Glyc flu	2		1				1					1		1
Iris pse					1		1	1		1	1			1
Junc eff														1
Lemn min								1		1	1		1	1
Ment aqu	1		1											
Myos sco	1						1					1	1	1
Myri alt													1	1
Nuph lut										2				
Oena cro	1	1		2	2	2	2	2	1	1	1	2	1	1
Phal aru	1	1		2	1	2	2	2	2	1	2	2	1	1
Phra aus									1					
Pota cri									3				1	
Pota nat	2	3	1							2			1	2
Pota pec													1	2
Ranu pen	4	3	4	3	4	4	5		4	1	3	5	3	2
Spar eme		2							2	1	1	1	1	1
Spar ere	2		1					1	2	1	1	1		2
Ambl rip											1	1	1	
Cladopho	2	2		1	3	3	3	3	3	5	4	1	1	3
Font ant	2	2		3	3	2	2	1	3		2	2	2	3
FW sponge									1					
Hygr och				1										
Lema flu			1		1									
Liverwort			1	2		1	1	1						
Pell epi	1	1	1											
Rhyn rip		1	1	1										
Spha nat							1				1			
Oth moss		1		1	1	1			1		1	1	1	1

Table 10: Distribution Of Macroinvertebrate Taxa In The Kilbroney River.

M-I Taxa	K01	K02	K03	K04
Heptageniidae		A		
Ephemerellidae		A	B	B
Leuctridae	A			B
Chloroperlidae			A	
Goeridae	A	A	A	A
Sericostomatidae		A	A	
Nemouridae	A			
Rhyacophilidae		A	A	A
Limnephilidae	A	A	A	A
Ancylidae	A	A	A	A
Gammaridae			A	
Dytiscidae	A	B	B	B
Gyrinidae		A		
Elmidae	A	A	A	
Hydropsychidae			A	
Tipulidae	A		A	
Simuliidae		B	A	
Baetidae	B	A	A	B
Hydrobiidae			A	
Chironomidae	A	A	A	A
Oligochaeta	A	A	A	A
No. Taxa	11.00	14.00	17.00	10.00
BMWP	62.00	87.00	101	62.00
ASPT	5.64	6.21	5.94	6.20

Table 11: Distribution Of Macrophyte Species In The Kilbroney River.

Spp	K01	K02	K03	K04
Agro sto				1
Callitr				1
Iris pse				1
Junc bulb	1	1	1	1
Byru bic	1	1	1	1
Call cus		1		
Font ant		2	2	2
Pell epi	1	1		
Rhyn rip	1	1	1	1
Scap und	1		1	

Table 12: BMWP And MI ASPT, Plant Score And Plant ASPT, MIS Quality For Sites Along The River Lagan.

Site No.	IGR	Location	MI BMWP Score	MI ASPT	No. Taxa	P Score	P ASPT	P Spp No.	Plant MIS
L01	J288486	Bell's Br	107	5.35	20	63	4.50	14	Q4
LO2	J286497	Dromara	133	4.93	27	79	4.65	17	Q4
LO3	J277504	Woodford	136	5.44	25	59	5.36	11	Q4
LO4	J252517	Bull's Brook	122	4.69	26	83	4.37	19	Q4
L05	J236535	Lappoges Br	77	4.53	17	74	4.35	17	Q4
L06	J214531	Ballyvicknacally	121	5.04	24	91	3.80	24	Q3-4
L07	J187533	Clanmurry	105	5.00	21	60	4.00	15	Q4
L08	J177538	Below Dromore STP	82	4.55	18	51	3.40	15	Q3-4
L09	J157541	Thornyford Br	92	5.11	18	49	3.77	13	Q3-4
L10	J139526	Moygannon	84	4.94	17	55	3.92	14	Q4
L11	J123538	Banoge	72	4.24	17	57	3.56	16	Q4
L12	J122565	Geehans Br	96	4.80	20	70	3.68	19	Q3-4
L13	J129581	Newforge	89	4.68	19	62	4.13	15	Q3-4
L14	J137586	Magheralin	98	4.67	21	60	3.75	16	Q3-4
L15	J164598	Newmill Br	76	4.47	17	65	3.82	17	Q3-4
L16	J183604	Spencer's Br	105	4.57	23	45	3.21	14	Q3-4
L17	J202613	New Br	63	3.71	17	48	3.20	15	Q3-4
L18	J221624	Mazetown	48	4.00	12	35	3.50	10	Q3-4
L19	J233630	Young's Br	52	3.71	14	42	3.50	12	Q3-4
L20	J263629	Moore's Br	61	3.81	16	57	3.80	15	Q3-4
L21	J273644	Lisburn Weir	81	4.26	19	46	2.70	17	Q3-4
L22	J282656	Hilden Br	61	3.81	16	37	3.36	11	Q3-4
L23	J285668	Ballyskeagh Br	66	4.13	16	35	3.18	11	Q2-3
L24	J306671	Drum Br	64	4.27	15	36	3.60	10	Q3-4
L25	J331692	New Forge Lane	72	4.50	16	18	3.00	6	Q1-2
L26	J342704	Stranmillis	85	4.25	20	28	3.50	8	Q1-2

Table 12: BMWP And MI ASPT, Plant Score And Plant ASPT, MIS Quality For Sites Along The River Lagan.

Site No.	IGR	Location	MI BMWP Score	MI ASPT	No. Taxa	P Score	P ASPT	P Spp No.	Plant MIS
L01	J288486	Bell's Br	107	5.35	20	63	4.50	14	Q4
LO2	J286497	Dromara	133	4.93	27	79	4.65	17	Q4
LO3	J277504	Woodford	136	5.44	25	59	5.36	11	Q4
LO4	J252517	Bull's Brook	122	4.69	26	83	4.37	19	Q4
L05	J236535	Lappoges Br	77	4.53	17	74	4.35	17	Q4
L06	J214531	Ballyvicknacally	121	5.04	24	91	3.80	24	Q3-4
L07	J187533	Clanmurry	105	5.00	21	60	4.00	15	Q4
L08	J177538	Below Dromore STP	82	4.55	18	51	3.40	15	Q3-4
L09	J157541	Thornyford Br	92	5.11	18	49	3.77	13	Q3-4
L10	J139526	Moygannon	84	4.94	17	55	3.92	14	Q4
L11	J123538	Banoge	72	4.24	17	57	3.56	16	Q4
L12	J122565	Geehans Br	96	4.80	20	70	3.68	19	Q3-4
L13	J129581	Newforge	89	4.68	19	62	4.13	15	Q3-4
L14	J137586	Magheralin	98	4.67	21	60	3.75	16	Q3-4
L15	J164598	Newmill Br	76	4.47	17	65	3.82	17	Q3-4
L16	J183604	Spencer's Br	105	4.57	23	45	3.21	14	Q3-4
L17	J202613	New Br	63	3.71	17	48	3.20	15	Q3-4
L18	J221624	Mazetown	48	4.00	12	35	3.50	10	Q3-4
L19	J233630	Young's Br	52	3.71	14	42	3.50	12	Q3-4
L20	J263629	Moore's Br	61	3.81	16	57	3.80	15	Q3-4
L21	J273644	Lisburn Weir	81	4.26	19	46	2.70	17	Q3-4
L22	J282656	Hilden Br	61	3.81	16	37	3.36	11	Q3-4
L23	J285668	Ballyskeagh Br	66	4.13	16	35	3.18	11	Q2-3
L24	J306671	Drum Br	64	4.27	15	36	3.60	10	Q3-4
L25	J331692	New Forge Lane	72	4.50	16	18	3.00	6	Q1-2
L26	J342704	Stranmillis	85	4.25	20	28	3.50	8	Q1-2

Table 13: BMWP And MI ASPT, Plant Score And Plant ASPT, MIS Quality For Sites Along The Ballinderry River.

SITE No.	IGR	Location	M-I BMWP SCORE	M-I ASPT	M-I Taxa	P Score	P ASPT	P Spp No.	Plant MIS
B01	H682807	Mill Br	80	5.00	16	48	3.70	13	Q4-5
B02	H704800	Dunamore Br	70	5.38	13	47	4.27	11	Q4
B03	H734793	Corkill Br	90	6.00	15	66	4.40	15	Q5
B04	H749792	Wellbrook Br	83	5.54	15	45	5.00	9	Q4-5
B05	H768782	Kildress Br	71	5.46	13	51	4.25	12	Q4
B06	H794777	Drumard	93	5.81	16	29	4.14	7	Q4
B07	H812765	Cookstown Br	99	6.19	16	53	4.08	13	Q4
B08	H835764	Doorless Br	83	4.88	17	33	3.33	10	Q3
B09	H864772	Ardtrea Br	74	5.29	14	49	3.50	14	Q4
B10	H885776	Flood Lodge	69	4.60	15	47	3.36	14	Q4
B11	H891788	Coagh Br	116	5.27	22	57	3.80	15	Q4
B12	H912795	Lanaglug	94	5.53	17	60	4.29	14	Q4
B13	H927798	Ballinderry Br	82	5.47	15	69	4.31	16	Q3-4
B14	H947805	Lower Mullan	96	5.33	18	73	3.84	19	Q3-4

Table 14: BMWP And MI ASPT, Plant Score And Plant ASPT, MIS Quality For Sites Along The Kilbroney River.

SITE No.	IGR	Location	M-I BMWP SCORE	M-I ASPT	M-I Taxa	P Score	P ASPT	P Spp No.	Plant MIS
K01	J209222	Yellow Rock	62	5.64	11	36	7.20	5	Q5
K02	J197206	Valley Dyeworks	87	6.21	14	40	6.66	6	Q5
K03	J189192	Newton Br	101	5.94	17	34	6.80	5	Q5
K04	J181183	Fairy Glen	62	6.20	10	33	5.50	6	Q5

Table 15: Macrophytes Found Across All Three Rivers.

Species	River Lagan	River Ballinderry	Kilbroney River
Agro sto	#	#	#
Alis p-a	#	#	
Apiu nod	#	#	
Callitri	#	#	#
Calt pal	#	#	
Carex	#		
Eleo pal	#		
Elod can	#	#	
Equi flu	#	#	
Equi pal	#	#	
Glyc flu	#	#	
Glyc max	#		
Iris pse	#	#	#
Junc bul			#
Junc eff	#	#	
Lemn min	#	#	
Lemn pol	#		
Ment aqu	#	#	
Myos sco	#	#	
Myri alt	#	#	
Nuph lut	#	#	
Oena cro	#	#	
Phal aru	#	#	
Phra aus		#	
Poly amp	#		
Pota cri	#	#	
Pota nat	#	#	
Pota pec	#	#	
Pota obt	#		
Ranc pen	#	#	
Rori n-a	#		
Spar eme	#	#	
Spar ere	#	#	
Typh lat	#		
Vero bec	#		
Ambl rip	#		
Bryu bic			#
Call cus			#
Cladopha	#	#	
Enteromo	#		
Font ant	#	#	#
Hygr och		#	
Lema flu	#	#	
Pell epi	#	#	#
Rhyn rip	#		#
Scap und			#
Spha nat	#	#	
Fw spong	#	#	
Vaucheri	#		
Oth live	#	#	
Oth moss	#	#	

Figure 5: Biotic Scores And MI ASPT Values At Sites Along The River Lagan.

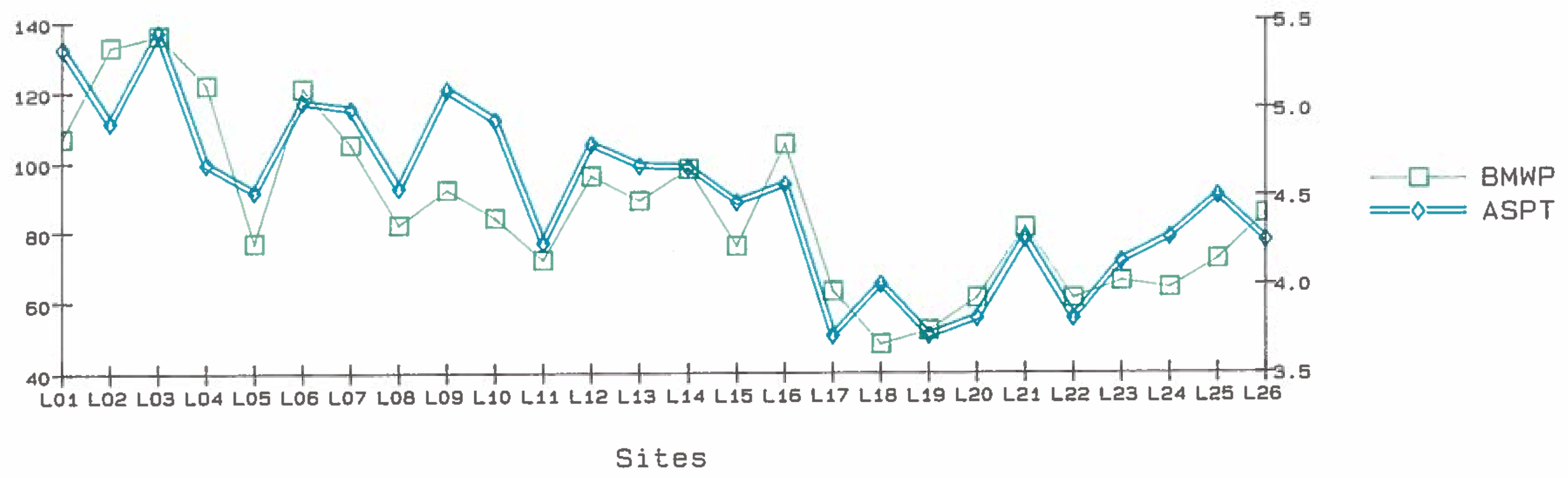


Figure 6: Plant Scores And Plant ASPT Values At Sites Along The River Lagan.

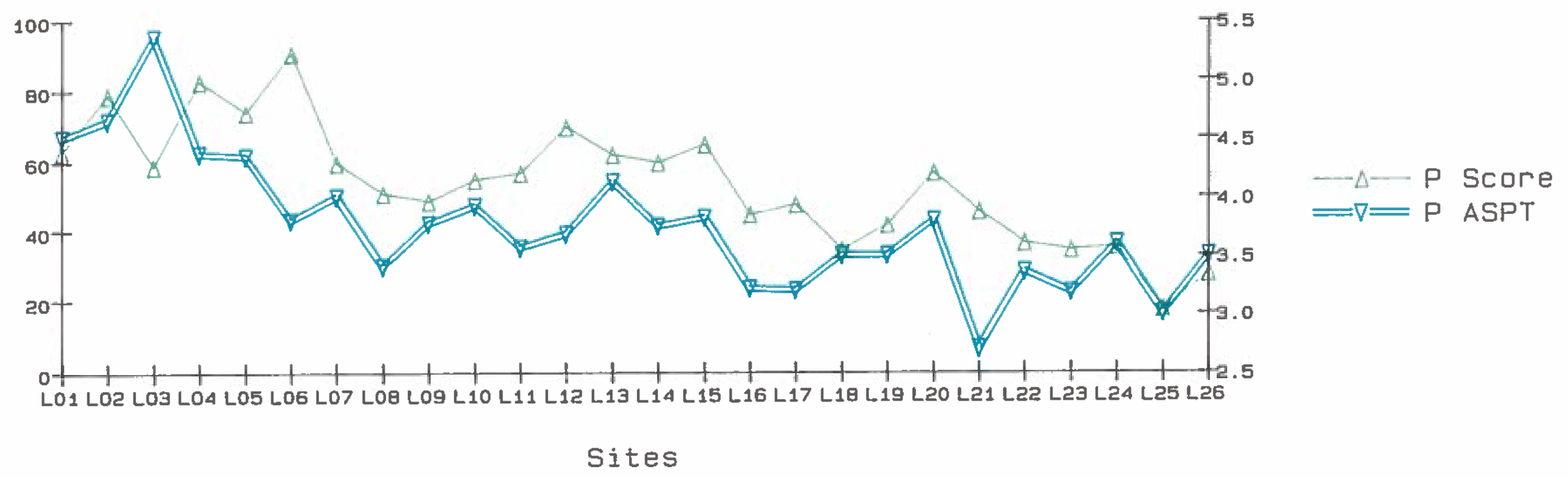


Figure 7: Biotic Scores And MI ASPT Values At Sites Along The Ballinderry River.

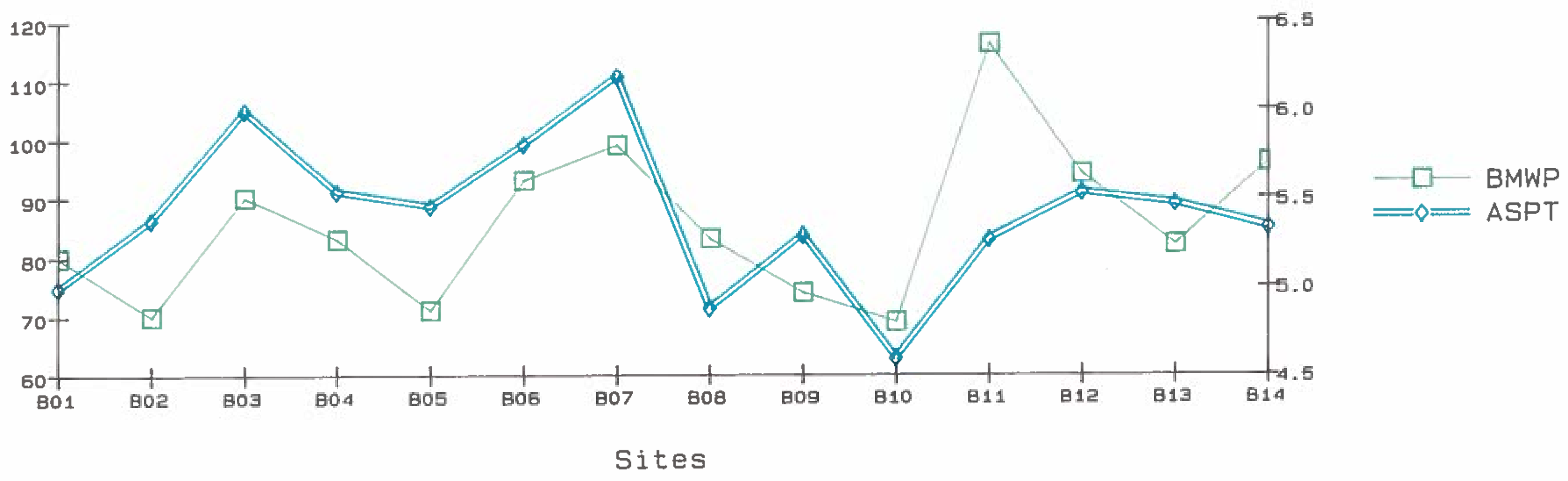


Figure 8: Plant Scores And Plant ASPT Values At Sites Along The Ballinderry River.

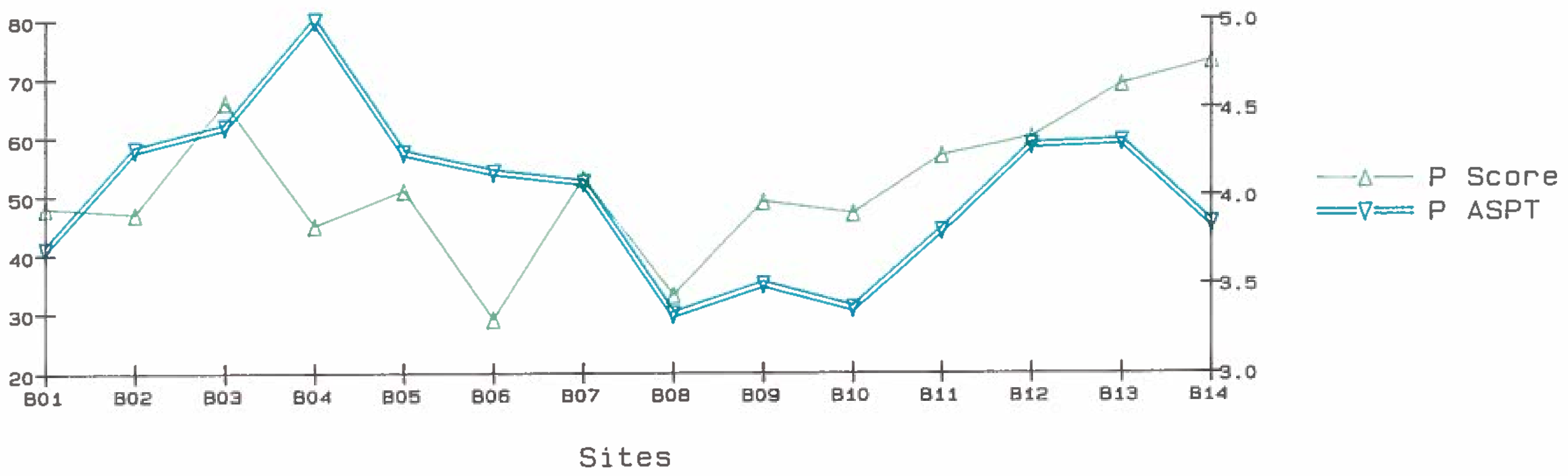


Figure 9: Biotic Scores And MI ASPT Values Along The Kilbroney River.

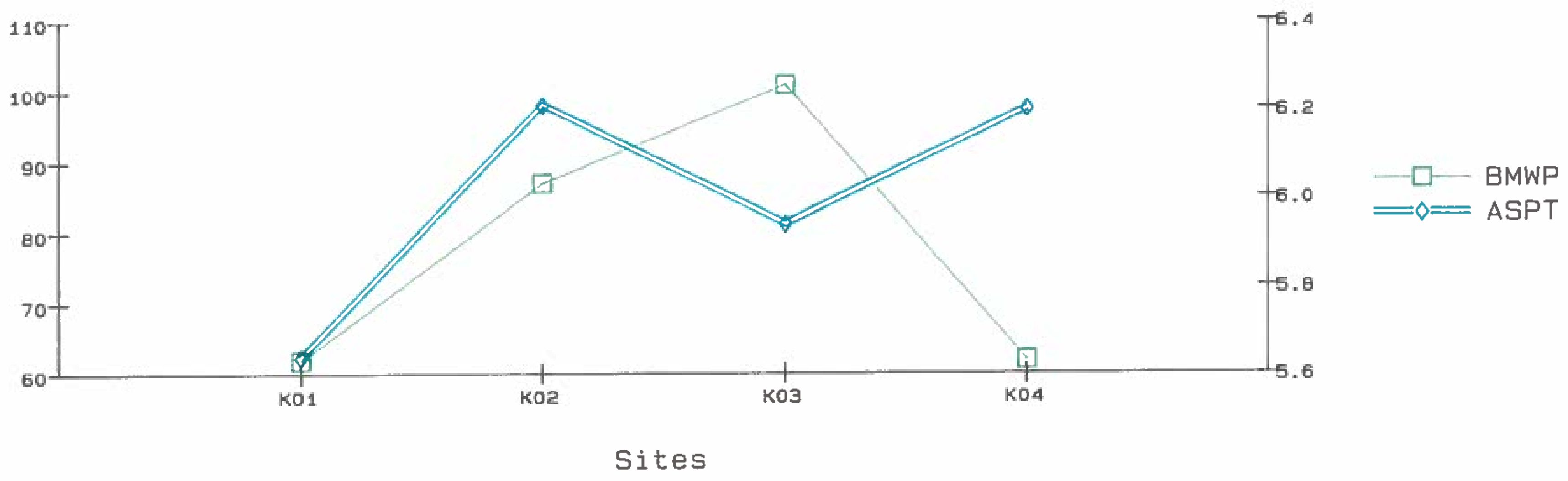


Figure 10: Plant Score And ASPT Values At Sites Along The Kilbroney River.

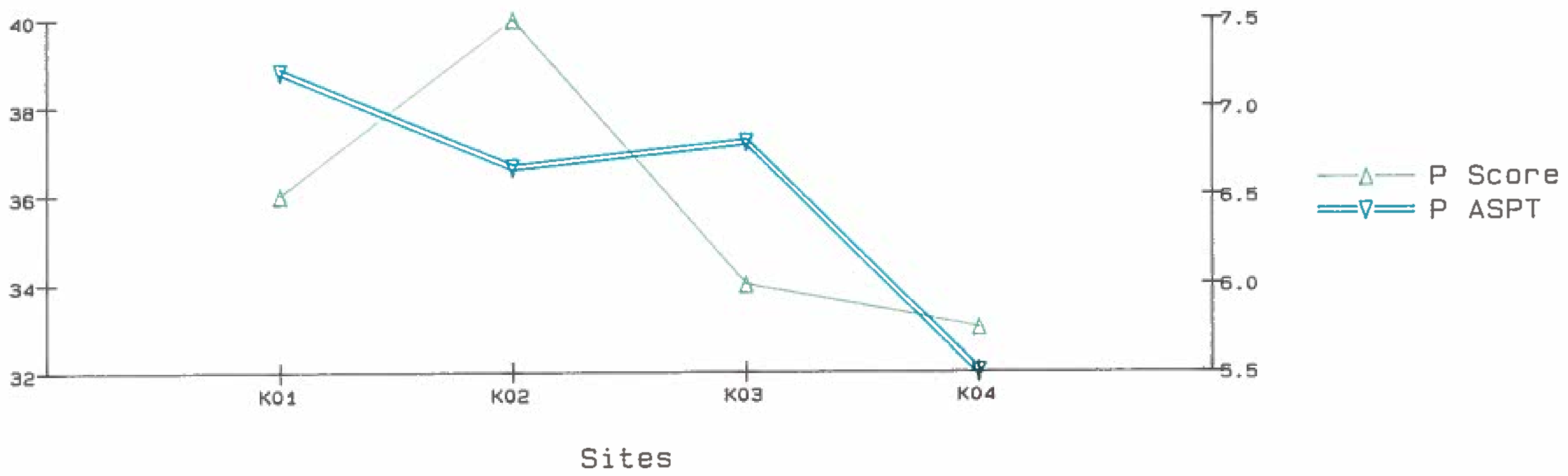


Table 16: Water Quality Classes At Sites Along The River Lagan According To The Macrophyte Index Scheme (Showing Numbers Of Species Found In Each Grouping).

Site No.	Group A	Group B	Group C	Group D	Plant MIS
L01	2	3	2	1	Q4
LO2	1	5	6	1	Q4
LO3	2	3	1	1	Q4
LO4	1	5	8	2	Q4
L05	2	4	7	2	Q4
L06	2	5	9	2	Q3-4
L07	2	2	6	1	Q4
L08	2	2	8	1	Q3-4
L09	1	2	7	1	Q3-4
L10	2	5	5	1	Q4
L11	2	5	7	2	Q4
L12	1	3	10	2	Q3-4
L13	1	4	6	1	Q3-4
L14	2	4	8	2	Q3-4
L15	1	3	7	2	Q3-4
L16	1	3	8	2	Q3-4
L17	1	2	7	3	Q3-4
L18	1	1	6	2	Q3-4
L19	1	2	6	3	Q3-4
L20	2	4	6	2	Q3-4
L21	1	1	8	2	Q3-4
L22	1	1	6	2	Q3-4
L23	0	1	7	2	Q2-3
L24	1	2	6	2	Q3-4
L25	0	0	3	2	Q1-2
L26	0	1	5	2	Q1-2

Table 17: Water Quality Classes At Sites Along The Rivers Ballinderry And Kilbroney According To The Macrophyte Index Scheme (Showing Numbers Of Species Found In Each Grouping).

Site No.	Group A	Group B	Group C	Group D	Plant MIS
B01	2	3	3	1	Q4-5
B02	2	2	5	1	Q4
B03	2	3	2	0	Q5
B04	2	3	1	1	Q4-5
B05	3	3	2	1	Q4
B06	2	1	1	1	Q4
B07	2	3	2	2	Q4
B08	0	3	4	1	Q3
B09	2	2	4	1	Q4
B10	2	2	7	1	Q4
B11	2	3	5	2	Q4
B12	1	3	3	2	Q4
B13	2	1	7	3	Q3-4
B14	1	4	8	1	Q3-4
K01	1	1	0	0	Q5
K02	1	2	0	0	Q5
K03	1	2	0	0	Q5
K04	1	2	1	0	Q5

Figure 11: Monthly Changes In Water Chemistry
At Bull's Brook L04 On The River Lagan.

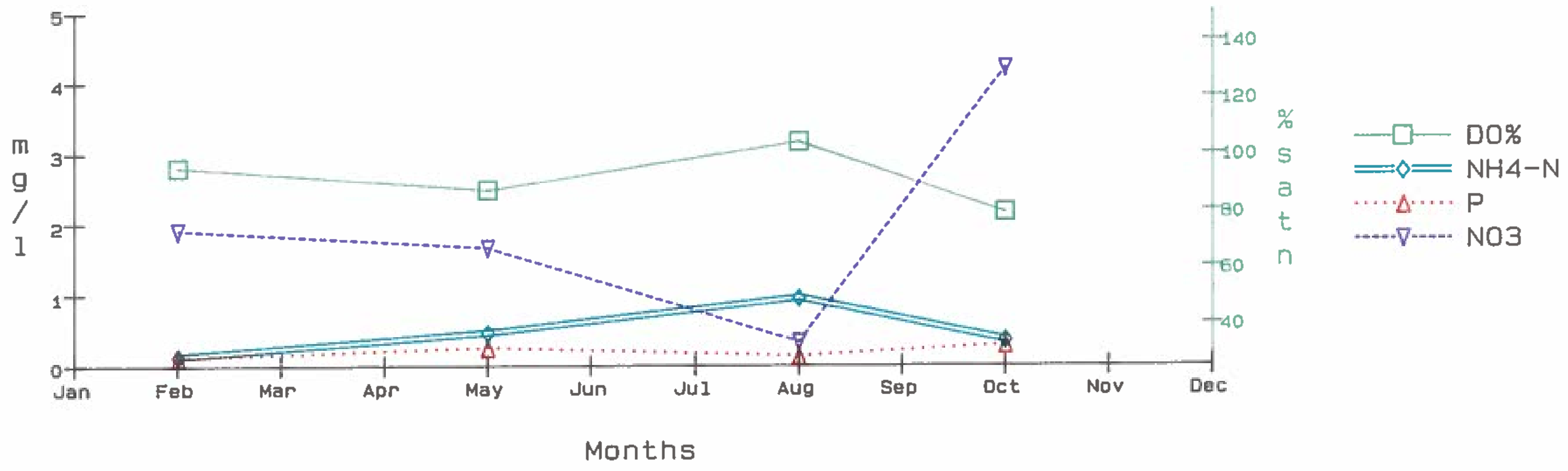


Figure 12: Monthly Changes In Water Chemistry
Below Dromore STW L08 On The River Lagan.

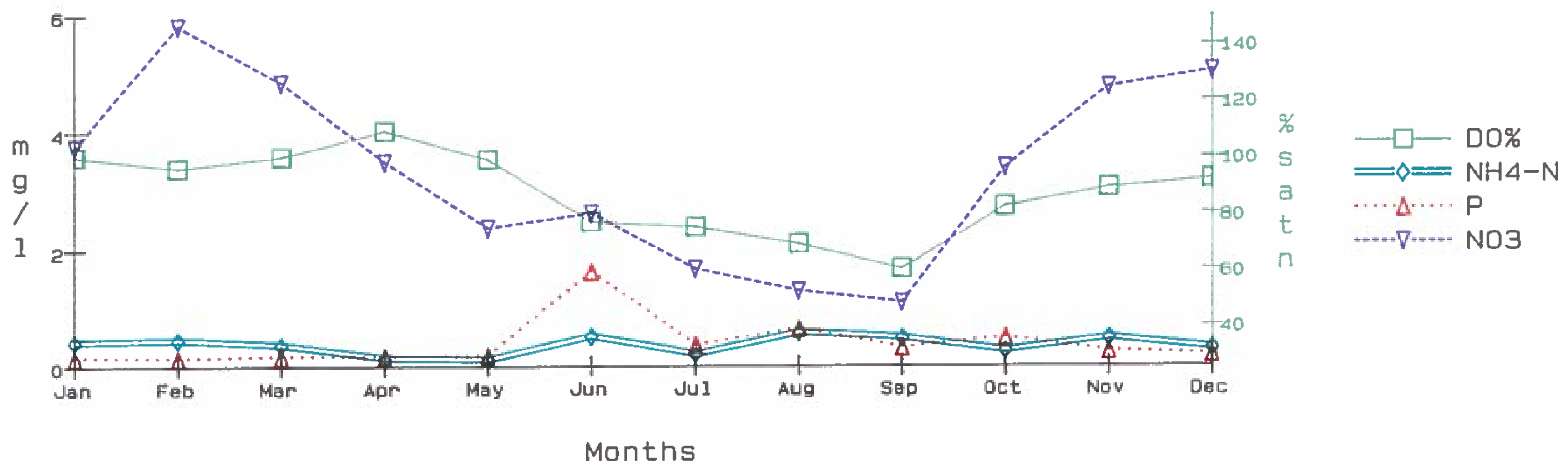


Figure 13: Monthly Changes In Water Chemistry
At Banoge L11 On The River Lagan.

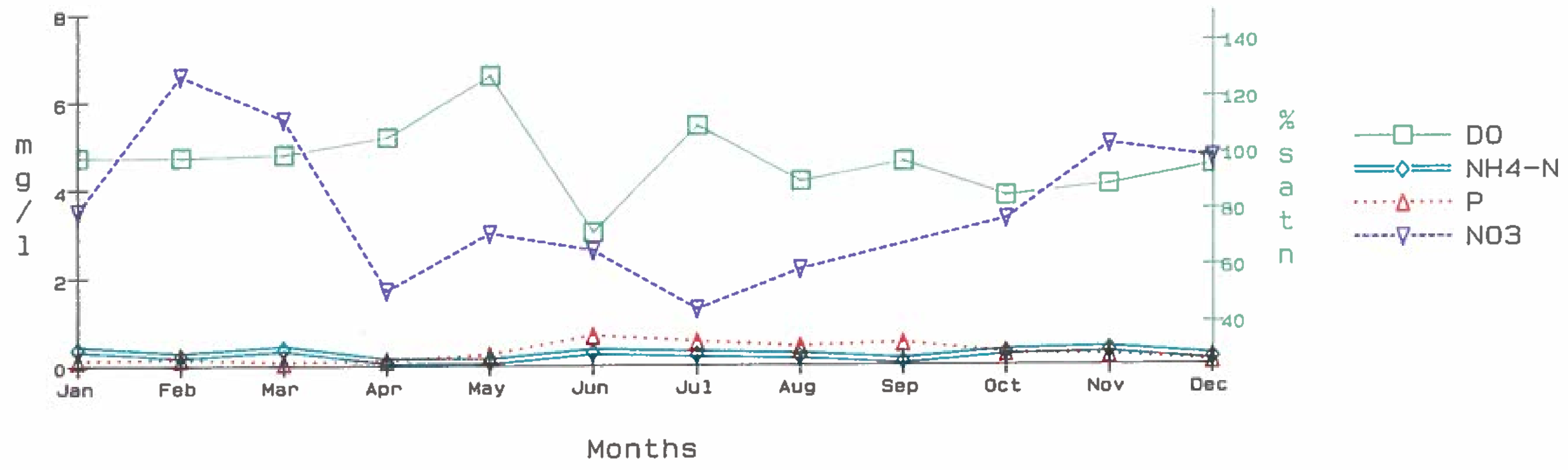


Figure 14: Monthly Changes In Water Chemistry
At Magheralin Bridge L14 On The River Lagan.

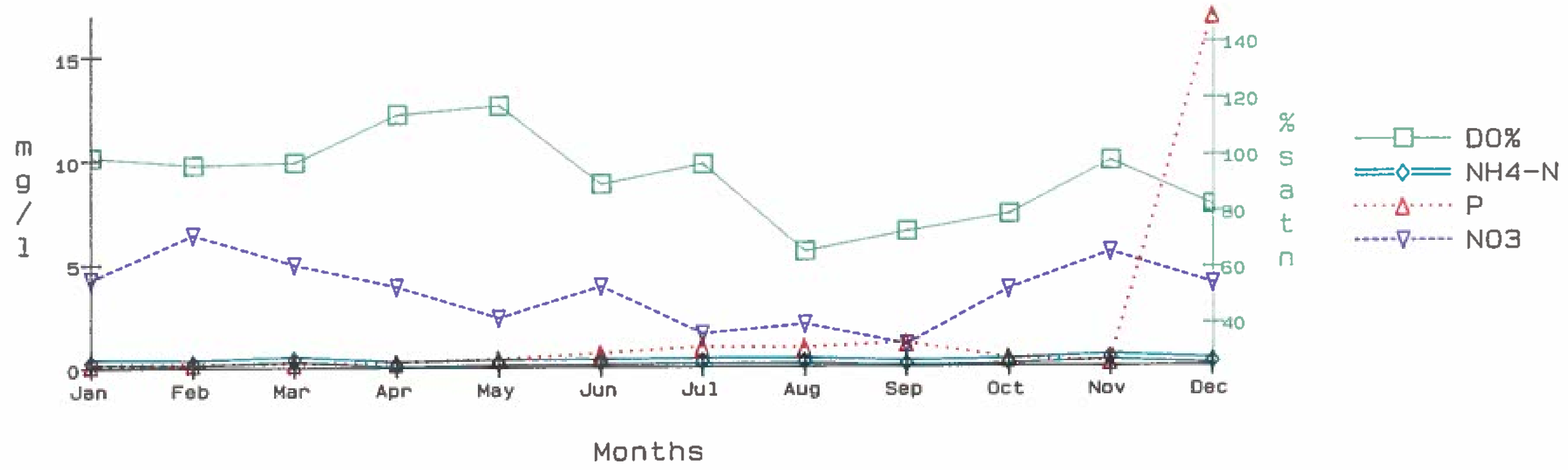


Figure 15: Monthly Changes In Water Chemistry
At Spencer's Bridge L16 On The River Lagan.

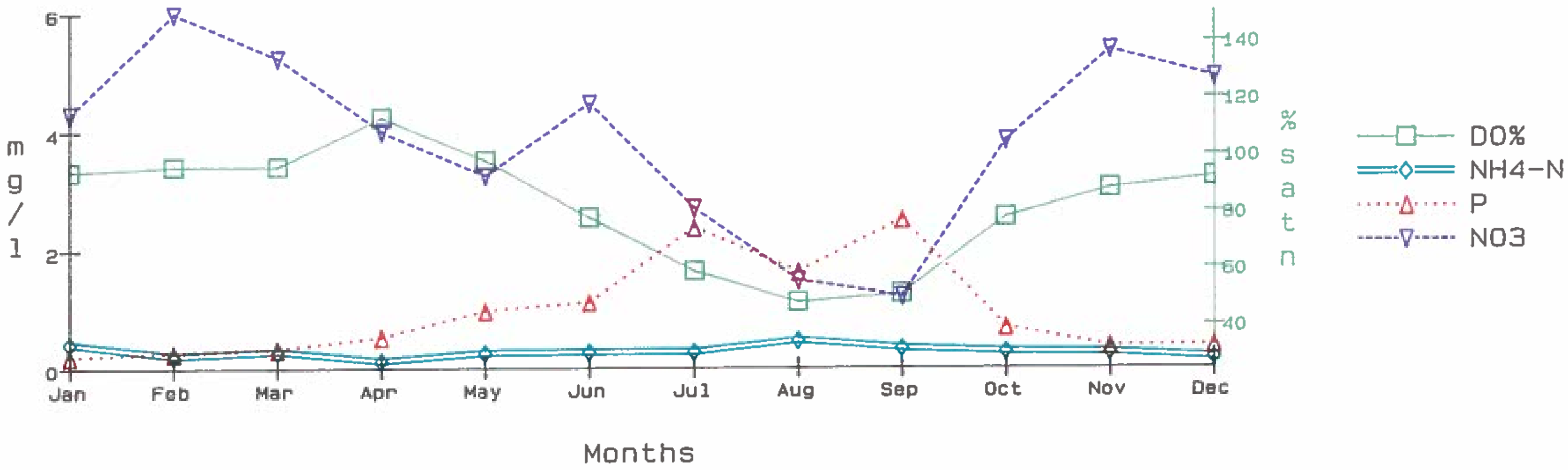


Figure 16: Monthly Changes In Water Chemistry
At Youngs Bridge L19 On The River Lagan.

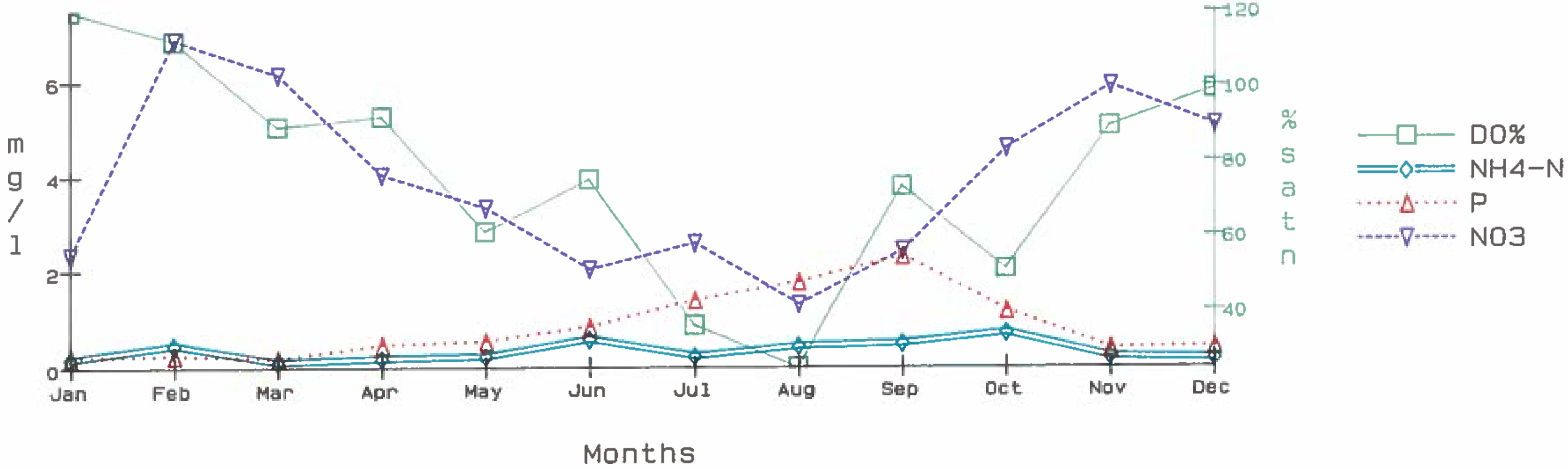


Figure 17: Monthly Changes In Water Chemistry
At Hilden Bridge L22 On The River Lagan.

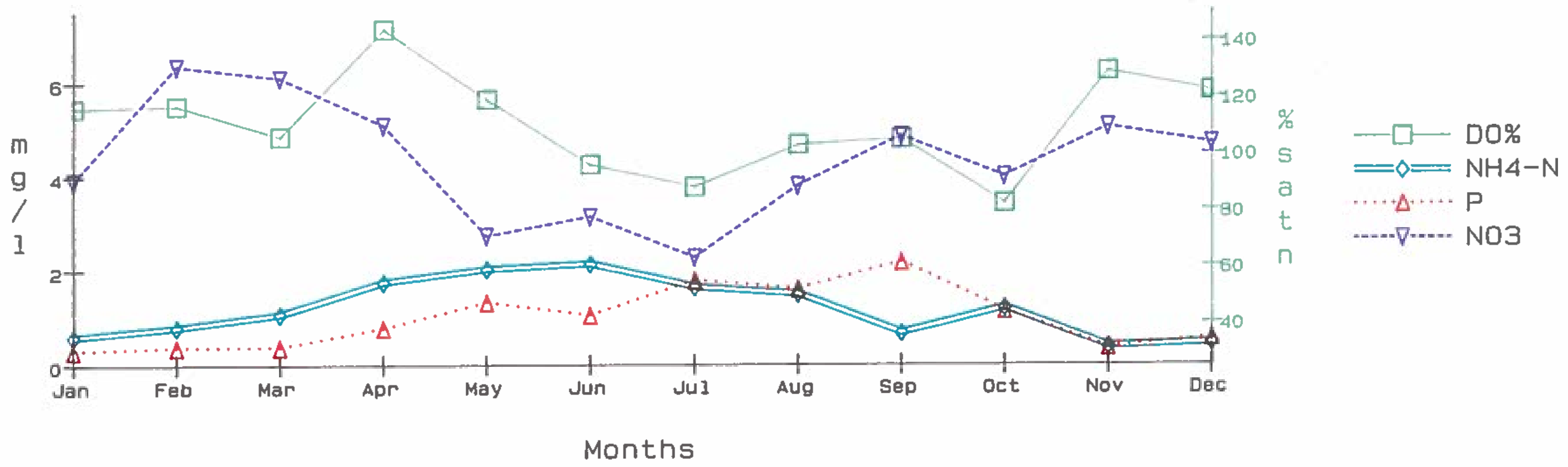


Figure 18: Monthly Changes In Water Chemistry
At New Forge Lane L25 On The River Lagan.

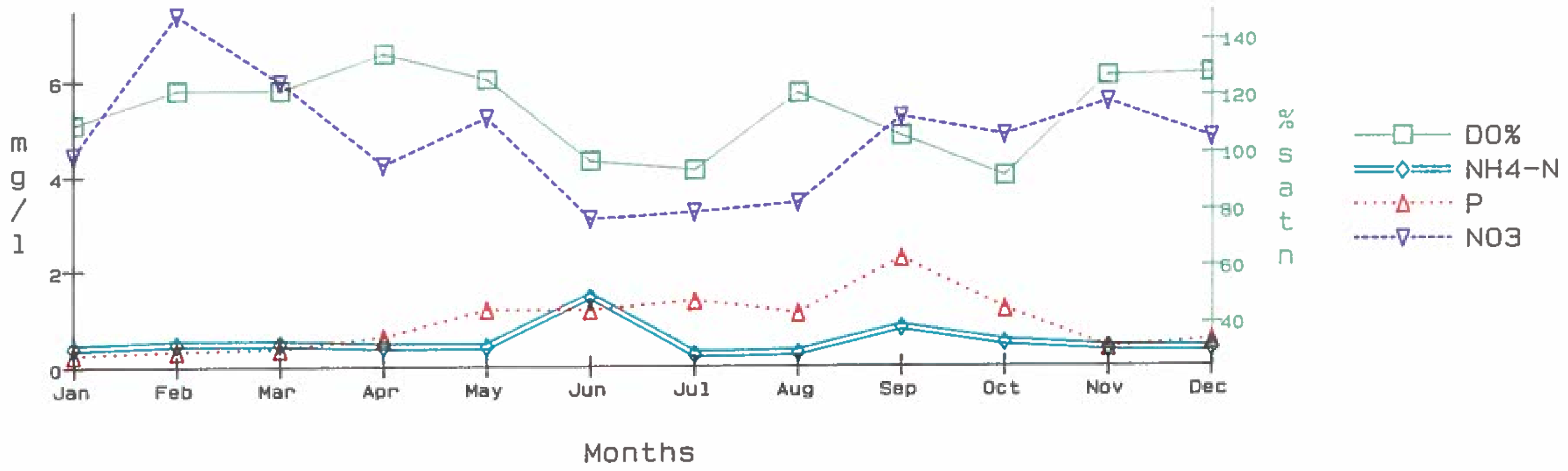


Figure 19: Monthly Changes In Water Chemistry
At Stranmillis L26 On The River Lagan.

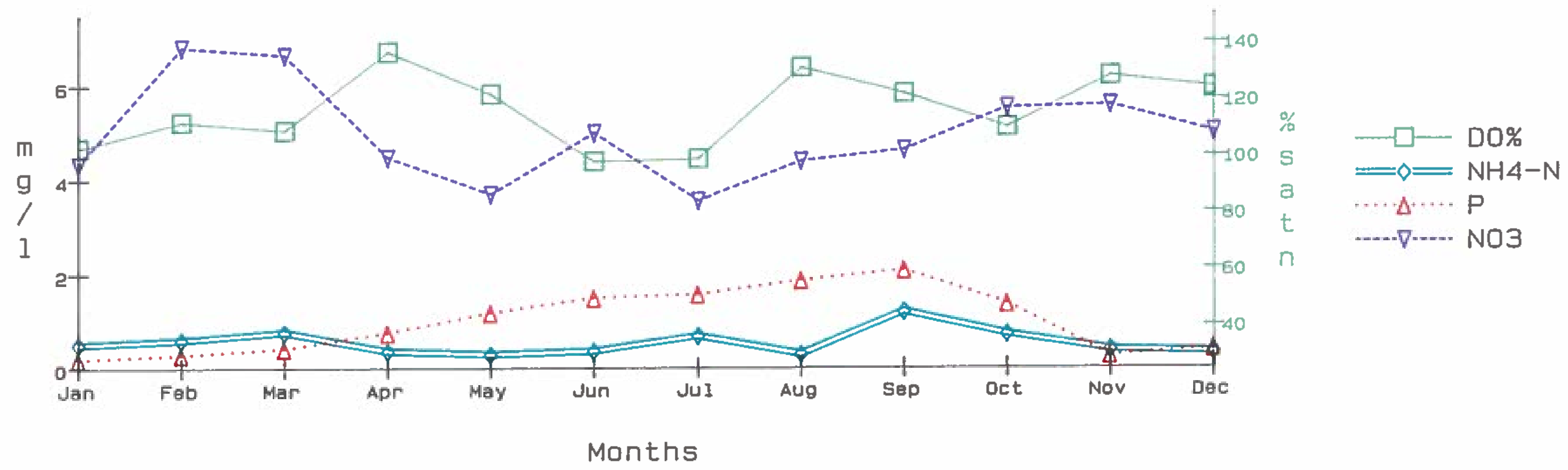


Figure 20: Monthly Changes In Water Chemistry
At Cookstown Bridge B07 On The Ballinderry River.

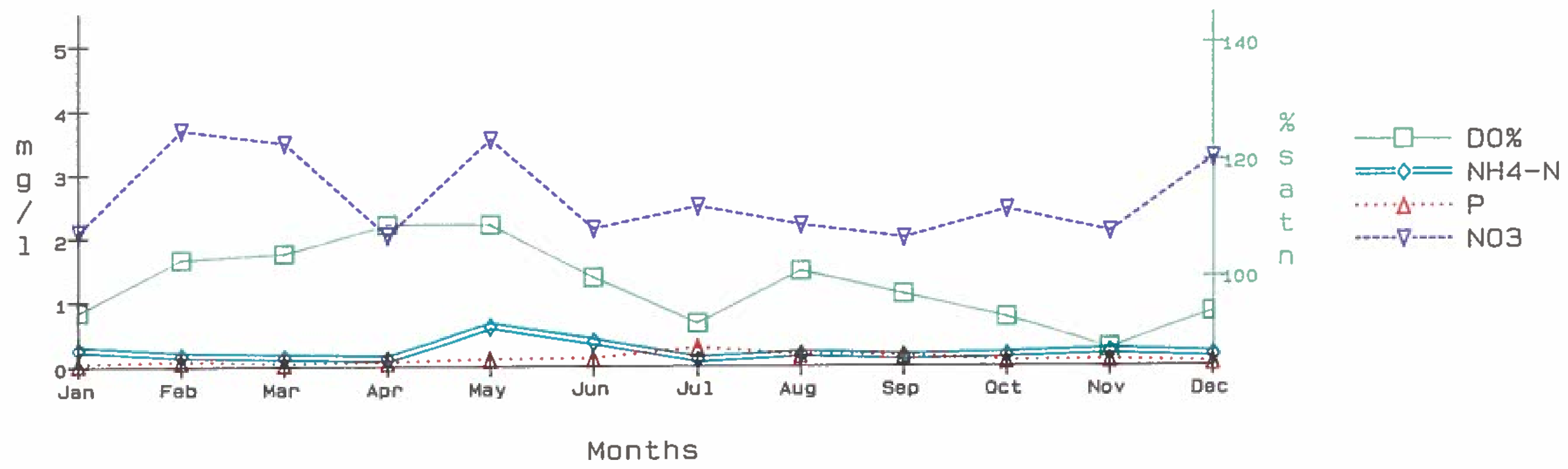


Figure 21: Monthly Changes In Water Chemistry At Prince Of Wales Bridge, On The Killymoon River, A Tributary Of The Ballinderry River.

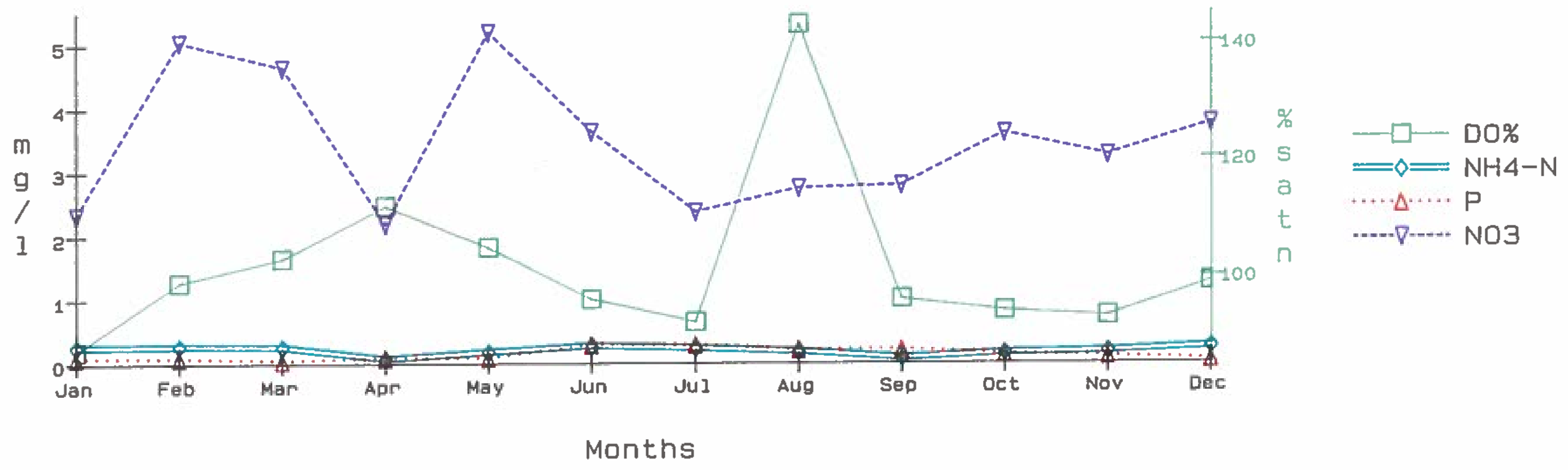


Figure 22: Monthly Changes In Water Chemistry At Doorless Bridge B08 On The Ballinderry River.

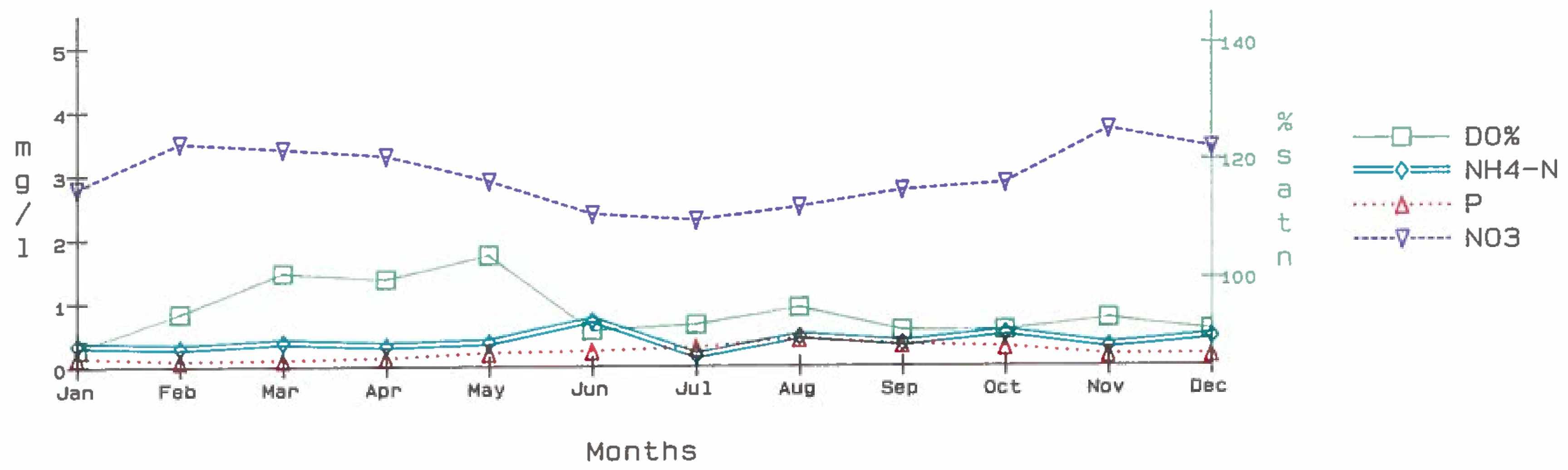


Figure 23: Monthly Changes In Water Chemistry
At Ballinderry Bridge B13 On The Ballinderry River.

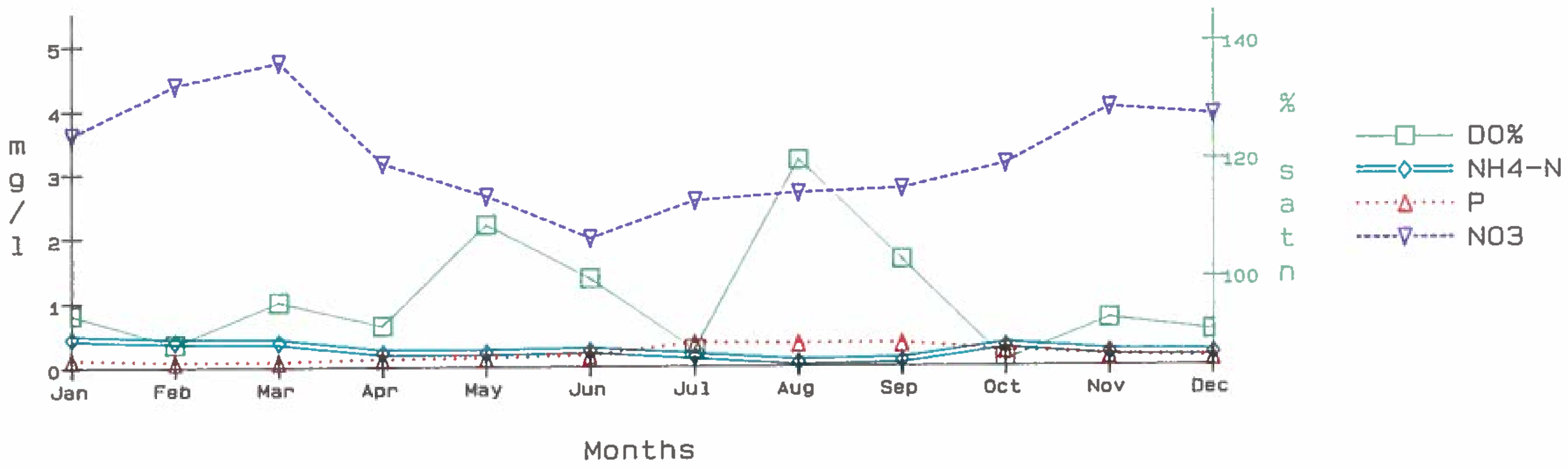


Figure 24: Monthly Changes In Water Chemistry
At Newton Bridge K03 On The Kilbroney River.

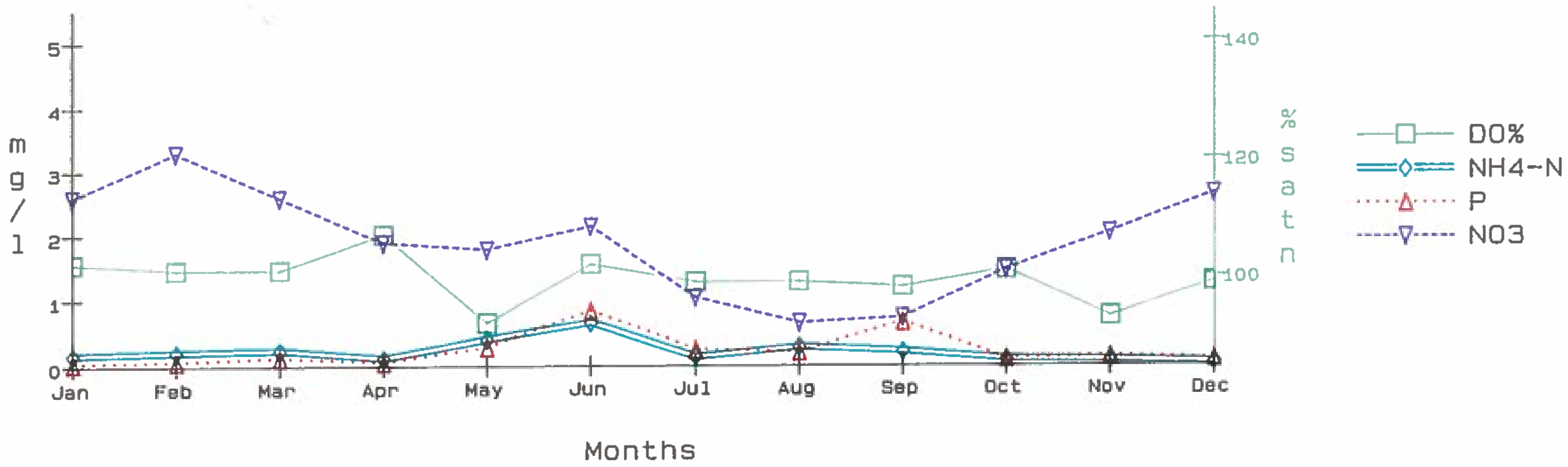


Figure 25: Monthly River Flow With Nitrate Levels At New Forge Lane L25 On The River Lagan.

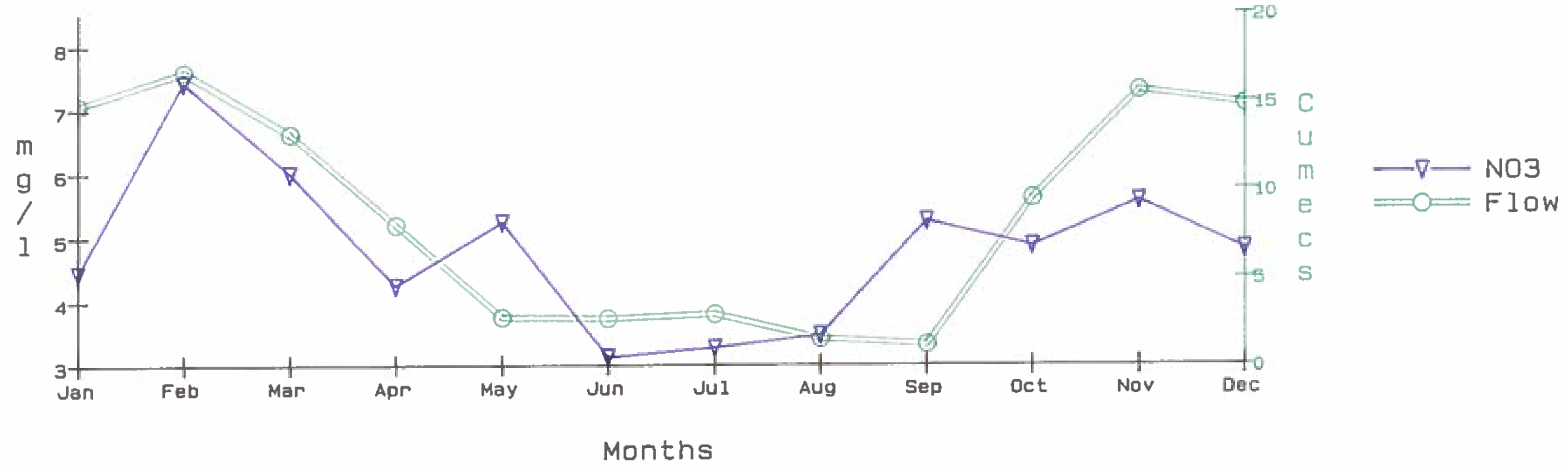


Figure 26: Monthly River Flow With Nitrate Levels At Ballinderry Bridge B13 On The Ballinderry River.

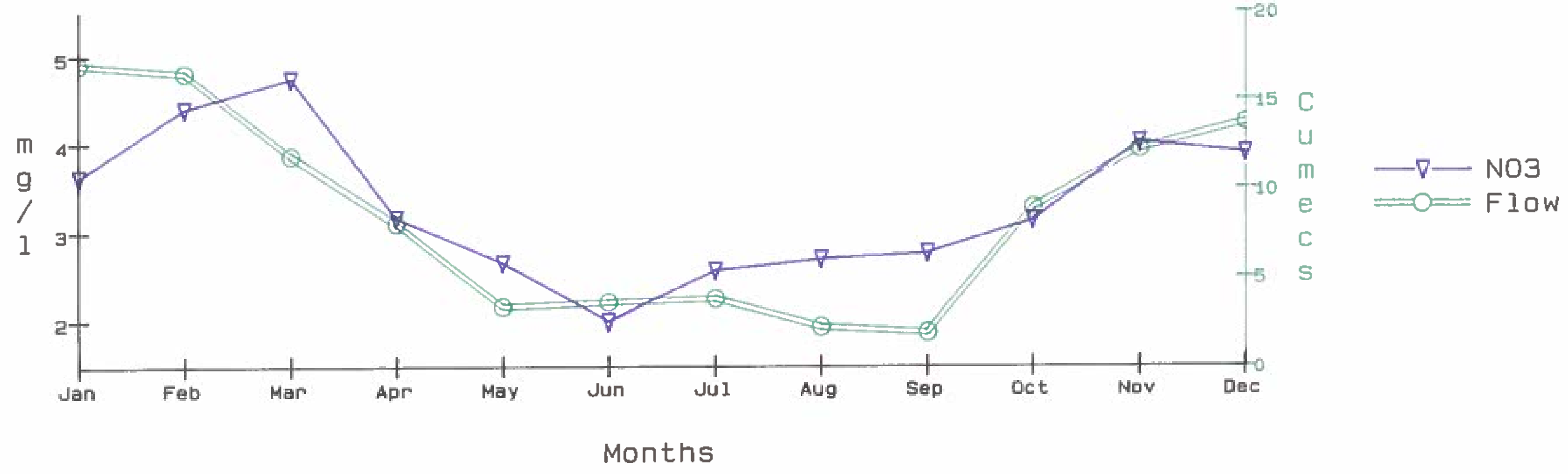
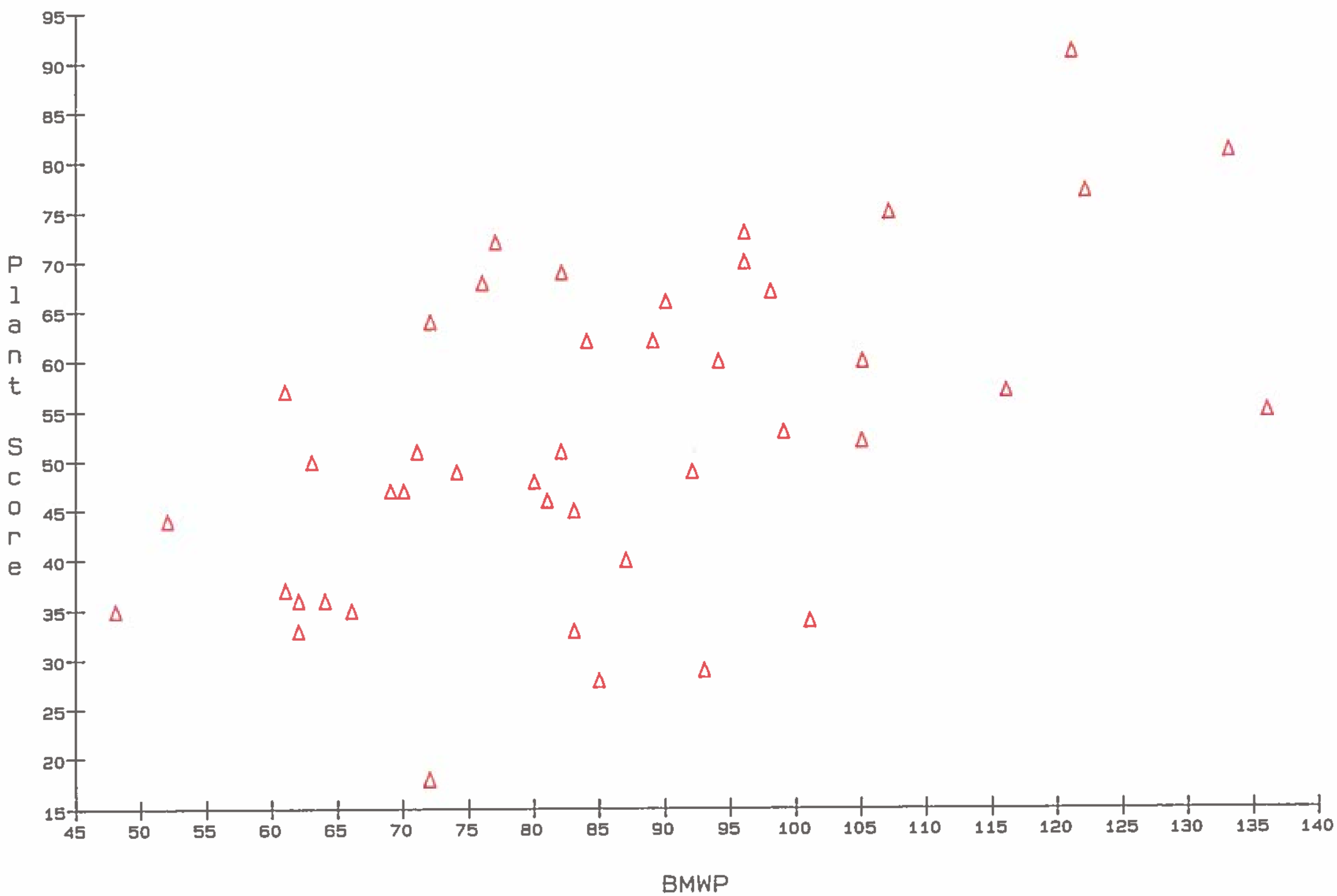


Figure 27: Comparison Of Plant Score Against BMWP Score.



DISCUSSION

River Lagan

The upper five sites (L01 to L05) group together in a macrophyte community dominated by *Fontinalis antipyretica*, *Oenanthe crocata*, *Pellia epiphylla*, *Potamogeton natans Ranunculus penicillatus*. These species suggest a meso-oligotrophic status (Haslam 1982). Bryophyte species are noted to be common in part, where the substrate was typically rocky and the river flow moderate to fast.

Sites L06 to L15 are characterised by *Elodea canadensis*, *Nuphur lutea*, *P. crispus*, *P. natans* and *Sparganium emersum*, with scattered *Cladophora* and *R. penicillatus*. This grouping would generally indicate semi-eutrophic conditions (Haslam 1982).

In the lower-middle reaches, where the flow is sluggish and there is prolific macrophyte growth, such as *E. canadensis*, *N. lutea* and *P. natans*, it would be likely that this could be responsible for the drop in % dissolved oxygen noticed at Spencer's Bridge and Youngs Bridge. This could lead to a de-oxygenation of the water in this section of river during the summer months, possibly causing fish kills.

De-oxygenation problems with rivers with excessive amounts of macrophyte growth, have been well documented (Pokorny et al 1984, Carpenter & Lodge 1986, Sand-Jensen et al 1989). Primarily these relate to huge swings in dissolved oxygen and pH as photosynthetic and respiratory processes change in response to night and daylight. Changes in oxygen levels have been quoted to vary between 50 to 150% saturation depending on the time of day.

In the middle reach the relative lack of turbulence would limit scope for physical re-oxygenation during periods of low oxygen levels and conversely retain high oxygen levels when photosynthetic activities are at a maximum. The potential for excessive swings in oxygen concentration, might thus be considerable. If this is the case, then it might also explain the poor macroinvertebrate diversity and biotic score between New Bridge (L17) and Moore's Bridge (L20).

From L16 to L21, the macrophyte community indicated semi-eutrophic conditions, this was re-enforced by the MIS quality rating (Table 16). Downstream from this, the river was eutrophic, as defined by the pollution tolerant species, the abundance of particular species, namely P. pectinatus, Cladophora spp., and Nuphur lutea, reduced species diversity and also by the bad-poor MIS quality rating.

This decrease in species diversity in the lower reaches, with the loss of those species most sensitive to pollution, and a corresponding increase in the abundances of species favoured by pollution, is typical of eutrophic conditions. The only species whose range appeared to be increased by organic pollution was *P. pectinatus*, described by Haslam (1990) as very tolerant. Small patches of semi-tolerant species such as Lemna minor, Sparganium emersum and S. erecta were able to survive at the river margins.

This series of succession in the lower reaches of a river, is typical of rivers affected by organic pollution in the English Midlands, such as the Rivers Etherow and Weaver (Harding 1981, Harding et al 1981). Holmes and Newbold (1984) described the impoverished macrophyte community found in the lower reaches of the Lagan as characteristic of "polluted or at least considerably enriched" water.

To show the effects of broad influences on the distribution of individual species, one could look at the contrasting distributions of pollution sensitive species such as *Ranunculus penicillatus* and *Rhynchostegium riparioides*, against pollution tolerant species such as *Potamogeton pectinatus*. These species mirror broad quality changes within the river quite accurately. Large beds of *R. penicillatus* was found in abundance in the upper and middle reaches, and *R. riparioides* was restricted to the four upper most sites. Dense beds of *P. pectinatus* was recorded from Spencer's Bridge (L16) downstream.

The use of agricultural fertilizers and slurry spreading of fields, has been shown as a major contributor to the nitrate loading in rivers (Mason 1991). For the River Lagan, this was also shown to be the case. The concentration of nitrate in the river followed closely that of the river flow (Figure 25). Levels of nitrate are low, during the summer months because there is little downward movement of water in the soil, due to lower levels of rainfall and high rates of evaporation. With an increase in rainfall, and surface water run-off, nitrate is leached from the soil and levels in the river rise. Increases in the nutrient levels in the river, bring about increases in plant productivity.

Large quantities of the sewage fungus Sphaerotilus natans were noted along the river bed, below the creamery waste-processing plant at Magheralin Bridge (L14). When field work was carried out, disturbance of the river bed released a sulphide smell from the black amorphous matter which blanketed the river bed for some distance (50-125m) downstream of the creamery discharge point. The accumulation of what appears to be anaerobic deposits within the river bed matrix must exert an appreciable impact on the river community. Pollution tolerant macrophyte species, such as Cladophora and Sparganium emersum were shown to predominate.

The upper reaches of the river were relatively unpolluted as indicated by the high BMWP scores and ASPT values. The upper reaches of the river (L01-06) supported a rich macroinvertebrate community, dominated by Heptageniidae, Ephemeridae, Leuctridae, Perlodidae and Leptoceridae. The biotic score at Woodford (L03) of 136 (ASPT 5.44) would be representative of that expected in an relatively unpolluted situation.

Water quality began to deteriorate downstream of Dromore. The most polluted stretch occurred between New Bridge (L17) and Moore's Bridge (L20). Rather surprisingly there was, a relatively gradual increase in both the biotic score and ASPT in the lower reaches of the river, from Lisburn (L21) to Stranmillis (L26). The biotic score and ASPT at Hilden Bridge (L22) 61 and 3.81 respectively is the only hiccup in this gentle increase. The bottom two sites New Forge Lane and Stranmillis had a small abundance of pollution sensitive fauna. This marginal improvement in both biotic and ASPT scores perhaps heralds the beginning of the recovery phase in the lower reaches, and possibly shows the improvement in water quality brought about by the upgrading of two sewage treatment works in the bottom stretch of river.

Ballinderry River

The upland sites (B01 to B03) exhibit a distinctive macrophyte community, indicated by *Callitriche* spp., *Pellia epiphylla* and *Potamogeton natans*. The three suggest a meso-oligotrophic status according to Haslam (1982). From sites B04 to B07, again a reasonably distinctive macrophyte community can be deduced, indicated by Fontinalis antipyretica, Oenanthe crocata, Phalaris arundinacea and Ranunculus penicillatus also suggesting meso-oligotrophic status (Haslam 1982).

Downstream of Wellbrook Bridge (B04), bryophytes, such as Pellia and Rhynchostegium were seen to die out, possibly because of their inability to tolerate increasing nutrient loadings from suspected agriculture run-off and farm drainage. Of the lower reaches (B08 to B12) E. canadensis, O. crocata, R. penicillatus and the two Sparganium spp. are representative of mesotrophic to semi-eutrophic conditions (Haslam 1982).

The two bottom sites on the river, before it enters Lough Neagh, are probably best indicated by E. canadensis, Myriophyllum alterniflorum and P. pectinatus. These macrophyte species indicate a community typical of mesotrophic to semi-eutrophic water quality (Haslam 1982). This restricted grouping could be caused by reduced species diversity, coupled with a degree of intermittent canopy shade from bank-side trees. As these species are not bank-side forms which could be shaded out by the tree canopy, but macrophytes typically found in the main channel flow.

The MIS worked well (Table 17), in that it was easy to interpret and to apply. It grouped the three upper most sites as Q4-5, of being of good to fair quality. Sites B04 to B07 it also grouped as being Q4-5. It grouped Doorless Bridge (B08), which is immediately downstream of the Killymoon River confluence, as Q3, (doubtful quality). Water chemistry data for the Killymoon River (Figure 21), suggests a seasonal input of high levels of nitrate into the main river. Rippey (1987) suggests that there have been problems in the past in the lower reaches of the Ballinderry, caused by the effects of agricultural run-off. The MIS also clearly picked out the two lower most sites as being Q3-4, fair to doubtful quality, which was mirrored in the macrophyte species above.

There seems to be suppression of macroinvertebrates in the upper most reaches. The most obvious source of this stress is the upper afforested catchment. Conifer planting and forestry practices have been shown to exert both physical and chemical influences on rivers, especially increases in acidification, nutrient run-off, particularly phosphorus and sediments (Hellawell 1986). Increased sedimentation, as a result of forestry practices may smother both macrophytes and macroinvertebrates, and when in suspension reduce light penetration and cause increased scouring of bottom-dwelling organisms. However further sampling and analysis would be necessary to prove unequivocally that this is the case.

The recovery of the upper reach from the possible stress appears to occur over a relatively short distance, with Corkill Bridge (B03) supporting a fauna typical of a "high quality" reach. The waste water effluent discharge from Cookstown sewage treatment works, and the entering of the Killymoon confluence below B07 appears to be responsible for the poor biological condition of the river between Doorless Bridge (B08) and Flood Lodge (B10).

Indeed, the Killymoon River confluence may have a subtle impact on the biological quality of the middle reach, as noted in the reduced MIS quality rating (see Table 17). Pollution tolerant macroinvertebrate taxa were more numerous below the confluence, as indicated by the lower ASPT value, as far as macrophyte species were considered, there was a high abundance of E. canadensis. It would seem that the macroinvertebrate and macrophyte community of the reach below the Killymoon confluence was depressed in terms of pollution sensitive taxa and in the number of macrophyte species, this was reflected in the water chemistry data for the Killymoon confluence, showing peaks and troughs of nitrate levels as well as a peak of supersaturated % dissolved oxygen, this is most likely caused by increased levels of photosynthetic production (Figure 21).

Although, for Doorless Bridge, there may be other factors, to explain the poor biological quality. The substrate was very poor and sandy, which possibly leads to a lack of many rooted macrophyte species, as they cannot become established on a unstable substrate. There would also be loss of certain taxa due to a loss of habitat, and overall a reduction in shelter for macroinvertebrate taxa as well as being susceptible to the smothering effect of accumulating sand.

Rather surprisingly there is an increase in the lower reaches, with the highest biotic score (116) for the river recorded at Coagh Bridge (B11). This, taken in conjunction with an ASPT of 5.27, would normally be representative of a moderately unpolluted river. However, a high abundance of pollution tolerant Chironomidae were found, suggesting that the site has been stressed for a considerable time. Indeed there is a sewage treatment works at Coagh, and this could be responsible for the biological stress. The high scoring biotic taxa could possibly be caused by drift (Hellawell 1986). This may over estimate the biological quality of this stretch of river.

In the lower reach of the river, just before it enters Lough Neagh, it supports a macroinvertebrate fauna which is more typical of an "unpolluted" reach, this does not correspond with the MIS quality rating and the semi-eutrophic status as indicated by the dominant macrophyte community. This could primarily be, because of changes in habitat type from riffle to a moderately deep glide, which would bring about slightly change the macroinvertebrate fauna and macrophyte community found.

On the chemical side, the low ammoniacal nitrogen and total phosphate levels, can possibly be explained, by the fact that most sewage treatment works on rivers that enter Lough Neagh, have tertiary treatment plants added to remove the majority of phosphorus contained in the sewage, in an effort to reduce the external loading of nutrients entering the lake. In the past, Lough Neagh have suffered from a high degree of eutrophication from both agricultural and domestic sources within its catchment area (Smith 1977).

Kilbroney River

Mosses are the dominant aquatic group, notably Fontinalis, Rhynchostegium and Scapania. The presence of Pellia epiphylla indicates a lack of nutrient enrichment (Watson 1968), and this associates with the fact that the upper catchment would be fed by nutrient-poor streams and the coarse gravel river bed would hold few nutrients. There was an absence of many higher aquatic plants. The only higher aquatic plants to occur are the opportunists Callitriche sp. and Juncus bulbosus.

Of the small macrophyte community found at the four sites sampled along the the short course of the Kilbroney, Holmes (1983) describes almost all, as being indicators of oligotrophic conditions. The aquatic species recorded also would class the river as oligotrophic to semi-oligotrophic according to the trophic banding in Haslam (1982).

The primary factors responsible for limiting the growth of macrophytes in the upper and middle reaches of the river, seems to be a lack of plant nutrients, the fast current velocity and the possible susceptibility to the scouring nature of the gravel substrate. The abundance of mosses and liverworts such as the genera Scapania, Bryum, Calliergon and Fontinalis illustrate that both solid rock and gravel were common. Holmes and Whitton (1975a, 1975b) also describe similar bryophytes as being the dominant macrophytic taxon in the upper, gravelly reaches of the River Tweed in Scotland.

Macroinvertebrate diversity in the Kilbroney River is generally low probably as a result of a number of interacting natural phenomena. The short length of travel of the river from it source in the Mourne Mountains to the sea, coupled with its generally fast flowing and turbulent nature all serve to restrict the availability of nutrients available to stimulate primary food production. This, in turn will directly limit the macroinvertebrate abundance in the river. In addition the physical nature of the river limits the variety of ecological niches available for macroinvertebrate colonization, which ultimately will reduce diversity.

Low species diversity would be anticipated as a natural feature of the river. Furthermore many of the colonizing macroinvertebrates would be strongly influenced by seasonal factors. For example, a number of families of stonefly and mayfly nymphs (ie high scoring BMWP taxa) would be naturally absent for part of the summer months due to the normal emergence patterns of the adult insects. Given the timing of field work (mid-summer), it is reasonable to expect macroinvertebrate diversity to be naturally relatively low.

However the high ASPT values at all of the four sites reflected a high occurrence of pollution sensitive higher scoring taxa and are typical of those expected in a clean upland river. The ASPT value of 6.20 obtained at Fairy Glen (K04) is virtually identical to that derived from the Valley Dyeworks in the upper reach of the Kilbroney River, and clearly reflects a benthic fauna dominated by pollution sensitive taxa, with stonefly nymphs being particularly well represented.

The BMWP score derived from sites K01 and K04 were relatively lower than expected (Table 14). Yellow Rock (K01) can be possibly explained by the seasonal absence of species and lack of nutrients, discussed above. This lack of nutrients is reinforced by the absence of Pellia epiphylla, which is an indicator species for lack of nutrient enrichment, downstream of the Valley Dyeworks (K02).

The biotic score and invertebrate diversity is seemingly impaired below Newton Bridge (K03). However the abundance of Chironomidae and Oligochaeta are at normal background levels for that expected in a healthy river. Ephemerellidae and Leutridae were found to be relatively abundant, although this could possibly be the effects of downstream drift.

Perhaps the most plausible explanation for the impaired macroinvertebrate data produced for the lower reaches of the Kilbroney, would be that the reach has been stressed at some point in the recent past. As water quality conditions improves, the reach would be expected to re-colonize.

The Kilbroney seems to remain oligotrophic for almost its entire length. This may be because the upland catchment area of the Kilbroney river is sparsely populated and farmed. The small town of Rostrevor, which lies at the mouth of the Kilbroney, has few if any major industries, rather it is a small commuter town for the near-by Newry and Warrenpoint.

It would be reasonable to assume that only a small amount of organic enrichment enters the river, probably from septic tanks in the upper and middle catchment and in the lower catchment, or possible isolated incident of storm overflow at Rostrevor STW. This could possibly explain the small pulse of ammoniacal nitrogen and total phosphate observed in Figure 24, the rest of the year, the two values were so close to zero they could be ignored. Indeed, almost all domestic sewage from houses in Rostrevor is piped to a local sewage treatment works, before being discharged to the sea (Eamon Hagan, Environment Service, DOE, NI, Personnel Communication).

CONCLUSION

River Lagan

The macrophyte community in the upper reach of the river, indicate meso-oligotrophic conditions, and in the middle reach, the macrophyte grouping indicates semi-eutrophic. The lower-middle reaches indicate semi-eutrophic to eutrophic conditions. The lower reach has macrophyte species which would indicate eutrophic conditions.

This would mean that under article 5 of the EC Directive concerning urban waste water treatment (EC/91/271), the lower reaches, and possibly the lower-middle reach, of the river would be classified as "sensitive", because of its eutrophic status, and that a higher standard of sewage treatment would be needed to reach certain nitrogen and phosphorus chemical standards.

In the middle reaches of the river, during periods of low flow and high water temperatures, wide fluctuations in levels of % dissolved oxygen, caused by photosynthetic and respiratory processes during night and day. Such short-term changes in oxygen levels would perhaps be expected to detect as gross changes in the macroinvertebrate fauna of the river reach affected.

The macroinvertebrate fauna in the lower reaches of the River Lagan deteriorate, and then begin to show a degree of improvement in their BMWP scores in the bottom two sites, this could be as a result of the recent upgrading of the New Holland and Newtownbreda sewage treatment works, downstream from Hilden Bridge.

Ballinderry River

The macroinvertebrate data derived from the Ballinderry River are generally of a magnitude indicative of good water quality conditions. However there was obvious suppression at Doorless Bridge (B08) below both the Cookstown STW and the Killymoon River confluence, where doubtful quality conditions are indicated. These two sources of pollution were also picked up, by an abundance of E. canadensis, indicative of semi-eutrophic conditions (Haslam 1982).

There is a noticeable decline in the macroinvertebrate fauna of the river at Flood Lodge (B10). In the lower reaches of the river, there was an abundance of E. canadensis and P. pectinatus, suggesting nutrient enrichment.

Kilbroney River

The river had a diverse macroinvertebrate fauna, however there was suppression, possible due to natural factors. The macrophyte community was dominated by bryophytes, indicative of oligotrophic conditions.

The survey of the Kilbroney River, suggests that macrophytes may be more effective than macroinvertebrate communities in indicating the relatively subtle changes in nutrient status.

The overall conclusion of this project is that macrophytes respond to spatial and temporal changes in river quality in a sensitive and clearly defined manner. They could accordingly be used by river biologists to monitor river quality in a similar manner to macroinvertebrates. However, there would be little point in appending macrophyte survey work to existing biological monitoring programmes if macrophytes told exactly the same story as macroinvertebrates.

Data on macroinvertebrate communities has played an increasingly important role in river monitoring programmes, since they provide a much more integrated picture of changing quality than chemical data, and therefore in many cases offer a more effective means of detecting significant changes. Macrophytes, whilst responding with great sensitivity to spatial and long-term changes in river quality, are less sensitive than macroinvertebrates to short-term pollution. They offer an even more integrated and reliable basis for the classification of overall river quality. A combination of macrophyte and macroinvertebrate surveys may draw attention to problems which might be missed or under-estimated if either technique was used in isolation.

Macrophytes could therefore have an important part to play in future river monitoring work. However, there would seem little point in attempting to survey river plants throughout Northern Ireland on an annual basis, since they would be expected to remain relatively stable in the face of the short-term pollution events that are detected though present macroinvertebrate monitoring.

The most logical approach, would be to include detailed macrophyte surveys of major rivers in any environmental monitoring programme carried out by ISC river biologists, under the direction of the Environment Service, DOE (NI). In this way, problem rivers could be surveyed on a repeating basis every 4-5 years, allowing data on macrophytes to strengthen the conclusions of macroinvertebrate monitoring and aid the detection of problems which might otherwise be overlooked.

RECOMMENDATIONS

River Lagan

Carry out an assessment of agricultural activities within the River Lagan catchment, along the lines of the study by Schofield et al (1990), to assess the pollution contribution from agricultural sources including the storage and spreading of animal slurry, silage leachate, farm-yard washing and run-off.

Carry out a study to see if the influence of rainfall and specific farming practices affect the chemical and biological quality of the river.

Develop a nutrient budget for phosphorus and nitrogen for the catchment as a whole, with particular emphasis on the lower reaches, with estimates of contributions from sewage effluents, industrial discharges and agricultural sources, to comply with the EC Urban Waste Water Treatment Directive (EC/91/271).

In the middle reaches of the river, such as Spencer's Bridge (L16) and Youngs Bridge (L19), use oxygen meters to analysis the 24 hours cycles of pattern of night-time plant respiration, particularly under low flow conditions.

Ballinderry River

The biological condition of the upper reaches, merits more detailed examination in an attempt to establish where the source of the problems lie.

Kilbroney River

The biological condition of the upper reaches, merits more detailed examination in an attempt to establish where the source of the problem lies.

Evaluation Of Macrophyte Survey Method

Analysis of the macrophyte data for each of the three rivers, by the computer package TWINSPAN, may have split up the macrophyte zonation of the various reaches of rivers in a slightly different manner.

Barnes et al (1989), took two days/per site (plus extra time for site write-up), to do a detailed survey of both the river channel and bank-side vegetation along the Six-Mile Water in Co Antrim. This sort of detailed botanical survey of all 44 sites would have been far too time consuming for the present study.

In hindsight, it may have proved helpful to have included a sampling site on each major tributary, prior to its confluence with the river being studied, as this may have helped to determine whether changes downstream of the entry of the tributary were due to chemical changes or to the input of fresh species from the tributary.

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Appendix

River Macrophytes
Site Length: 500 m Scale A

River ______________ **Site** ______________ **Recorder** GW/______

IGR ______________ **Date** __/__/92

Scale A: 1 = <0.1%, 2 = 0.1-1%, 3 = 1-5%, 4 = 5-10%, 5 = >10%

Higher Plants

Agrostis stolon 1 [ ]
Alisma pl-aquat 3 [ ]
Apium nodif 4 [ ]
Berula erecta [ ]
Butomus umbe 7 [ ]
Callitr hamula 6 [ ]
Callitr hermap - [ ]
Callitr platycar - [ ]
Callitr stagnalis - [ ]
Caltha palustris 6 [ ]
Carex sp 8 [ ]
Ceratophyll dem 6 [ ]
Eleocharis sp 7 [ ]
Elodea canadens 5 [ ]
Equisetum flu 3 [ ]
Equisetum pal 3 [ ]
Glyceria maxim 3 [ ]
Other Glyceria 4 [ ]
Hippuris vulg [ ]
Iris pseuda 3 [ ]
Juncus acutiflor 6 [ ]
Juncus articu [ ]
Juncus bulb 6 [ ]
Juncus effusus 4 [ ]
Other Juncus sp 4 [ ]
Lemna gibba 4 [ ]
Lemna minor - [ ]
Lemna polyrhiz - [ ]
Lemna trisulca - [ ]
Mentha aquat 6 [ ]
Menyanthes trif [ ]
Myosotis sp 5 [ ]
Myriophyll alt 10 [ ]
Myriophyll spic 7 [ ]
Nasturtium off 7 [ ]
Nuphar lutea 6 [ ]
Oenanthe croc 3 [ ]
Phalaris arundin 2 [ ]
Phragmites aust [ ]
Polygonum amp 3 [ ]
Other Polygonu 2 [ ]
Pot alpinus 10 [ ]
Pot berchtoldii 2 [ ]
Pot crispus 4 [ ]
Pot filiformis 7 [ ]
Pot natans 3 [ ]
Pot pectinus 1 [ ]
Pot perfolia 7 [ ]
Pot polygonif 10 [ ]
Pot pusillus 7 [ ]
Other Pot sp 7 [ ]
Potentilla pal [ ]
Ranunc circinatu 6 [ ]
Ranunc flamm 6 [ ]
Ranunc hedera 5 [ ]
Ranunc peltatus 8 [ ]
Ranunc penicil 6 [ ]
Ranunc sceleratu 6 [ ]
Ranunc trichopi 6 [ ]
Other Ranunc sp 6 [ ]
Rorippa amphi 4 [ ]
Rumex hydro [ ]
Sagittaria sag 4 [ ]
Scirpus sp 5 [ ]
Solanum dulcam [ ]
Sparganium eme 3 [ ]
Sparganium erec 2 [ ]
Typha latifolia 4 [ ]
Veronica an-aqua [ ]
Veronica becca 5 [ ]
Zannichellia pal 5 [ ]

Lower Plants

Batrachospermu 7 [ ]
Blue-green mats 1 [ ]
Cladophora spp 3 [ ]
Enteromorpha 3 [ ]
Sphaerotilus nat - [ ]
Fontinalis anti 4 [ ]
Sphagnum sp 10 [ ]
Liverwort sp ? [ ]
Other mosses ? [ ]
Other fila algae - [ ]

Others

[ ]
[ ]
[ ]
[ ]
[ ]
[ ]

Plant score:
ASPT score:
No. of spp:

Habitat Features

River ______________ **Site** ____________ **Recorder** GW/______

IGR ______________ **Date** __/__/92

Physical records *(Record 1, 2 or 3 in brackets below, where 1 = <5% of total, 2 = 5-25% of total, 3 = >25% of total)*

Width (m) <1 [ ] 1-5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

Depth (m) <0.25 [ ] 0.25-0.5 [ ] 0.5-1.0 [ ] >1.0 [ ]

Substrate Bed rock [ ] Boulders [ ] Cobbles [ ] Pebbles [ ]

Gravel [ ] Silt/mud [ ] Clay [ ] Peat [ ]

Habitats Pools [ ] Slacks [ ] Riffles [ ] Fast deep water [ ]

Shading Left Bank: None [ ] Slight [ ] Moderate [ ] Dense [ ]

Right Bank: None [ ] Slight [ ] Moderate [ ] Dense [ ]

Obvious signs of pollution (wide-spread/localised, name)

Trophic status (circle) oligo meso semi-eutroph eutroph

Adjacent land-use (name)

Other possible forms of damage (wide-spread/localised, circle & name)

Trampling by livestock Trampling by humans Herbicide application

Man-made structures Canalization Shade Boats

Roadworks Dredging Cutting

Other notes: