Toxicological, behavioural and morphological studies on *Daphnia longispina* O.F. Müller in relation to ferric toxicity

A thesis submitted for the degree of
Doctor of Philosophy

Selena Jane Randall M.Sc.

University of Leicester

January 1998

Plate I Rutland Water viewed from the main basin

Toxicological, behavioural and morphological studies on *Daphnia longispina* O.F. Müller in relation to ferric toxicity

Selena Jane Randall

Rutland Water in Leicestershire, UK, has been dosed with ferric sulphate for eutrophication control through phosphorus inactivation, since 1990. Iron concentrations between 1990 and 1994 were generally <0.5mg Fe l^{-1} (maximum 17.5mg Fe l^{-1} recorded). Examination of the long-term data (collected since 1980) showed that phophorus has declined in the water column since 1990. Iron and phosphorus have accumulated in the sediments around the pumped inlet through which iron was added. Algal biomass (measured by chlorophyll *a*) has declined since 1990 although cyanobacterial blooms have still occurred.

Laboratory studies established that growth of the Chlorophyte *Chlorella vulgaris* was inhibited at concentrations >50mg Fe l^{-1} and cellular aggregation occurred at concentrations >150mg Fe l^{-1}. When the Cladoceran *Daphnia longispina* was exposed to concentrations >11mg Fe l^{-1} over 48 hours, significant deaths occurred. 30 second exposure to concentrations >0.5mg Fe l^{-1} caused a reduction in feeding rate. Exposure to >3mg Fe l^{-1} over 21 days resulted in a reduction in population growth rate. Over this time-span the filtering area of daphnid thoracic limbs increased significantly in concentrations of iron >9mg Fe l^{-1}. A safe limit of 1.69mg Fe l^{-1} was determined from toxicity tests, below which field populations would suffer no harmful effects.

There was no evidence of any impact of ferric dosing on daphnid numbers in the reservoir. However, the filtering area of the third thoracic limb in daphnids from around the inlet were significantly greater than in daphnids elsewhere in the reservoir, which may have been a consequence of long-term exposure to sub-lethal concentrations of iron. The observed decline in the size of daphnids in the reservoir since 1980, suggests predation by fish has been a significant force in the reservoir.

The success and implications of ferric dosing for eutrophication control in Rutland Water, and elsewhere are discussed, and future strategies considered.

CONTENTS

PLATES

FIGURES

TABLES

Acknowledgements

There are many people I would like to thank for their time and for the advice given to me whilst completing this work. I am especially grateful to the National Rivers Authority (now the Environment Agency) in Anglian Region for funding this work and for the provision of data - particularly Dr Bill Brierley and Dr Chris Extence.

I could not have completed this work without the help and encouragement of Dr David Harper who has kept me pointed in the right direction and read endless drafts tirelessly.

In the early days many people helped me with method development, to whom I am very grateful - Dr Colin Reynolds (IFE), Dr Steve Marshall (Unilever), Dr Pauline Jowett (NRA), Dr Denis Ratcliffe (University of Leicester), and Dr Neil Radford (University of Leicester).

I would like to thank Professor Josef Hrbacek, Professor Vladimir Korinek, Dr Jaromir Sed'a, Dr Jiri Machacek, and Martina Hronesova of the Czech Republic and Professor Jim Green of the UK for teaching me about *Daphnia.*

I am very grateful to my fellow cell-mates Jan Krokowski, Jo Walker and Rory Sanderson for assistance with sampling, their moral support and most important for helping me maintain my sense of humour.

Finally, I would like to thank my husband Chris for having such patience with me over the past few years

For Chris

'One may not doubt that somehow, good
Shall come out of water and of mud;
And sure, the reverent eye must see
A purpose in liquidity.'

Rupert Brooke 'Heaven' (1915)

Chapter One - The control of Eutrophication

1.1 Introduction to the problem

The effects of eutrophication - chiefly, accelerated algal growth and high biomass - have caused problems for water supply undertakings in developed countries for at least fifty years. These problems were initially, in the UK at least, largely contained through the use of progressive advances in technology in water treatment plants. In the last twenty years however, the belief that eutrophication was a minor problem in the UK confined to wetland areas such as the Cheshire/Shropshire Meres and the Norfolk Broads (where the Broads Authority has supported a wide range of research projects), has been dispelled as a result of the widespread appearance of troublesome growths of algae (Phillips & Moss, 1994).

The ecological consequences of eutrophication came to a head in the UK in 1989 when outbreaks of toxic cyanobacteria (accentuated by the long hot summer) occurred throughout the country. These outbreaks were particularly severe at Rutland Water, and the reservoir has been treated with ferric sulphate as a means of precipitating algae and sequestering phosphate since 1990.

The ecological consequences of the use of a large quantity of ferric sulphate in the aquatic environment have never previously been studied, and so in 1991 the National Rivers Authority (NRA) initiated a programme to study several aspects of the effects of ferric dosing. This study addresses the direct and indirect effects on plankton.

1.2 The nutrients which cause eutrophication

Eutrophication is a natural process by which lakes and reservoirs become enriched in nutrients (particularly nitrates and phosphates), and is enhanced by anthropomorphic activities within the catchment (Welch, 1980; Vollenweider & Kerekes, 1982; Moss, 1988). Eutrophication is caused by the ingress of phosphates from sewage treatment works and organic effluents from animal units and fish farms, and by run-off of nitrates and ammonia (and to a lesser extent phosphates), which form the basis of fertilisers, from arable catchments. There is mounting evidence that phosphorus loadings from agricultural sources (ie. diffuse sources) are increasing for a number of reasons: association with soil particles in erosion (Sharpley & Smith, 1990); increased stocking rates (Wilson *et al.*, 1993); run-off of applied animal derived slurry; and saturation of soil-binding capacities through continuous use of fertilisers (Sharpley *et al.*, 1994).

Both nitrogen and phosphorus are vital for sustaining plant and animal life, in and out of water. Nitrogen is a major component of proteins, nucleic acids and chlorophyll. Phosphorus is a component of adenosine triphosphate, nucleic acids and cell membranes. In most UK lakes phosphorus is the nutrient limiting primary production, but for short periods of time in spring when phosphorus has raised production above background levels silicon may be limiting, whilst in summer nitrogen and light may be limiting (Hecky & Kilham, 1988; Moss, 1988; Harper, 1992). Removal of phosphorus from point sources or recipient ecosystems will increase the probability that nitrogen becomes limiting. The cycles of these nutrients in the aquatic environment have been extensively reviewed, a summary is presented here.

The majority of phosphorus from agricultural sources enters lakes primarily in particulate form, adsorbed onto inorganic silt and clay particles, and in organic detritus (Imboden, 1974; Stumm & Morgan, 1981; Froelich, 1988; Holtan *et al.*, 1988). Products from domestic catchment sources, such as sewage effluent, enter water as dissolved phosphate, which is rapidly incorporated into organic forms inside planktonic algal and bacterial cells (Hooper, 1973; Welch, 1980; Holtan *et al.*, 1988). Zooplankton graze algal, bacterial and detrital particles, recycling, in dissolved form, around 50% of ingested phosphorus in their excretion (DeAngelis, 1980; McQueen & Post, 1986). There is a slow loss of phosphorus to the sediment, with rate determined by the degree of mixing, depth, retention time and particle size, where it accumulates bound to iron (III) and clay particles (Imboden, 1974; Kirchner & Dillon, 1975). Whether it remains in the sediment or not depends on the redox potential of the sediment surface and the interstitial water (Böstrom *et al.*, 1988). The surface sediments, usually aerobic if oxygen can diffuse or be mixed into them from overlying water, form a crust of insoluble ferric and other metal complexes over a brownish-black anaerobic sediment (Davison & Tipping, 1984). Phosphate release occurs however, when the overlying water becomes depleted in oxygen, such as during summer stratification, and insoluble ferric is reduced to soluble ferrous iron (Davison & Tipping, 1984). In lakes where there is high algal growth there is a steady supply of easily decomposable phosphate-rich organic matter on the sediment surface; bacterial decomposition releases soluble phosphates which become available to the upper waters following wind mixing (Klotz, 1985; McQueen & Post, 1986).

The cycling of nitrogen is more complicated, since there are many organic and inorganic complexes formed, along many more pathways than occur in the cycling of phosphorus. Elemental nitrogen is relatively unreactive and available from the atmosphere only to nitrogen fixers. Nitrogen is converted to utilisable compounds by atmospheric lightning, ultraviolet radiation, and by biological nitrogen fixers such as cyanobacteria (Sprent, 1987; Harper, 1992). Nitrates and ammonia, which are highly soluble, enter reservoirs in run-off from terrestrial sources such as fertilisers, animal excretion and afforestation (van Kessel, 1977; Heathwaite *et al.*, 1993). Organic nitrogen, in forms such as urea (from bird and fish faeces, and decaying algae and zooplankton cells) are utilised directly, other forms become adsorbed onto carbonate particles which may be oxidised and sedimented by microbes. Throughout the growing season ammonia and nitrate decline within the epilimnion as bacterial and algal biomass increase. Grazing zooplankton rapidly recycle nitrogen as ammonia which is generally taken up in preference to nitrate by algal and bacterial cells. Decaying algal cells and zooplankton faeces sink to the sediments where decomposer action by aerobic bacteria leads to an accumulation of ammonia in the interstitial water. This may then be mixed into the upper waters in aerobic conditions or become denitrified by bacteria under anaerobic conditions. Denitrification, the reduction of nitrate ions during respiration by bacteria in the absence of oxygen, is the major nitrogen loss mechanism in most lakes (Myers, 1972; Moss, 1988).

1.3 Water management problems

1.3.1 Drinking water quality

In eutrophic lakes where both phosphorus and nitrogen are in abundance, phytoplankton growth may become prolific, obscuring light from submerged aquatic plants, leading to their decline. Increased phytoplankton crops result in more costly treatment for public supply. In summer some cyanobacteria fix atmospheric nitrogen supplementing the nitrogen pool. These cyanobacteria may form unsightly and toxic scums which affect the aesthetic value of the lake or reservoir and may increase the costs of water treatment (Collingwood, 1977; Harper, 1992).

High levels of sedimenting organic matter cause increased bacterial decomposition, depleting oxygen from the hypolimnion which may make water unsuitable for public supply. In addition, secretion of organic substances, which in the case of cyanobacteria may include substances toxic to mammals and fish (NRA, 1990; Codd & Beattie, 1991) and may lead to unpleasant taste and odours (Collingwood, 1977; Moss, 1988). Increased amounts of organic material passing through the filters at the water treatment plant supports communities of bacteria, nematodes, sponges, hydrozoans and insects in the distribution system, which require costly and inconvenient treatment (Collingwood, 1977; Moss, 1988). Dissolved organic matter secreted into the water by algae leads to an increase in the amount of chlorination and granulated activated carbon (GAC) treatment required which removes such organics, but are costly.

In eutrophic lakes the typical algal succession is as follows: diatom growth during spring and early summer depletes the nutrient pool. Early in spring, algae such as *Asterionella, Fragilaria, Scenedesmus* and *Cryptomonas* dominate. During early summer, *Eudorina* and *Volvox* appear. In late summer *Aphanizomenon, Anabaena, Asterionella* and *Ceratium* dominate, with *Microcystis* appearing later (Harper, 1992).

Many cyanobacteria have developed mechanisms to inhibit grazing by zooplankton, such as indigestible cell walls and large cell size (Benndorf and Henning, 1989). As a result, the presence of cyanobacteria may alter the zooplankton community. George & Edwards (1974) showed that the cladoceran *Daphnia* became more abundant and the calanoid copepod *Eudiaptomus* less abundant as eutrophic species of algae increased in Esthwaite Water in the Lake District. This supported the idea that those zooplankton able to digest cyanobacteria are more likely to survive than those that cannot with a consequence on the invertebrate and vertebrate predators able to persist in the water (McQueen & Post, 1986).

1.3.2 Problems for fisheries

In the summer, temperature stratification through the water column may divide the lake into layers (stratification) - the epilimnion (warm, oxygenated surface layer) and hypolimnion (cooler, possibly oxygen-limited lower layer) - which do not readily mix. This stratification may eventually cause differences in water chemistry and redox potential with depth (DeAngelis, 1980; Moss, 1988). Deoxygenated hypolimnetic waters provide unfavourable conditions for fish, especially salmonids. Salmonids depend on cool well-oxygenated hypolimnia for their survival in summer and are intolerant of high temperatures in the epilimnion. Where lakes or reservoirs support a commercial or recreational fishery this situation may result in serious financial loss. In addition, restricted growth of marginal plants in eutrophic waters leads to loss of fish spawning grounds and loss of habitats for invertebrates. As a consequence of this diminished ecosystem fish and plant-eating birds may decline (Phillips & Moss, 1994).

1.4 Methods of eutrophication control

There are two approaches to management of eutrophication - by treating either the causes (elevated nutrient fluxes from land) or the effects (higher nutrient concentrations in lakes leading to prolific algal growth and poor water quality).

1.4.1 Catchment management of nutrient levels

There are several schemes and practices currently operating within England and Wales which aim to preserve diverse habitats and reduce nutrient losses from diffuse sources (primarily agriculture). Farm management techniques are evolving due to increasing awareness of the impact of agricultural inputs on the environment and due to increased consumer demands for quality control and product accountability. Farmers supplying major supermarkets for example, are required to audit their management systems (livestock management, planting techniques, cropping regimes, fertiliser and pesticide applications, fuel consumption, waste disposal) through schemes such as 'Integrated Crop Management' and the LEAF audit (Linking Environment And Farming). The intended results of these audits, in terms of diffuse inputs, are more appropriate applications of agrochemicals and organic fertiliser and reduced pollution, with financial savings to the farmer with no loss of yield.

The Ministry of Agriculture Fisheries and Food (MAFF) promote Good Agricultural Practice through codes designed to protect the major media air, soil and water (MAFF,1991). MAFF also support a number of schemes, such as Set-Aside and the Countryside Stewardship Scheme, which have the benefit of reducing the area of cropped land, reducing leaching of nutrients which generally occurs between drilling and crop emergence. Significant habitats (eg. wetlands) are protected through schemes such as Environmentally Sensitive Areas.

Landowners are encouraged to use these schemes to create and preserve hedgerows, headlands, wetlands and buffer zones, which all have the benefit of reducing nutrient runoff to surface waters in some way. Buffer zones, vegetated areas extending from the waters edge for the purpose of protecting water quality, remove up to 100% nitrate before they reach a watercourse (Jordan *et al.*, 1993, Vought *et al.*, 1994). The efficiency of buffer zones for removal of phosphorus depends on the adsorption capacity and P-saturation of the soil. Retention is achieved by the filtering effect of vegetation, and reduction of the surface flow velocities, reducing surface run-off and enhancing nutrient retention in soil (Muscutt *et al.*, 1993).

The observation that natural wetlands act as sinks, transformers and sources of chemicals (Boyt, 1977; Nichols, 1983), has led to their artificial construction as a means to treat waste-water. Wetlands are areas with a high water table, with vegetation ranging from trees, through emergent marsh vegetation to open water with a mixture of emergent and submerged vegetation. They intercept surface and sub-surface run-off. Plant biomass is the main storage component, with plant nutrient uptake the primary removal mechanism (Breen, 1990) and adsorption a secondary one. Harvesting of plants is a means of permanent removal of nutrients from a wetland. Nichols (1983) found wetlands to be 70% efficient at removing both nitrogen and phosphorus.

Removal of phosphates from detergents by manufacturers for household consumers may reduce phosphates in raw sewage by up to 50% (Klapper, 1991). A more efficient technique is to eliminate phosphates collected in the sewerage system. That is from domestic sewage and industrial effluents and from road run-off, by removal as a tertiary treatment stage at sewage treatment works.

In the UK, limited control of nitrates and ammonium levels is currently being implemented by the designation of Nitrate Sensitive Areas (NSAs) and Nitrate Vulnerable Zones (NVZs). NSAs are those areas where it is desirable to reduce nitrate levels in groundwater supplies, and are designated under the Drinking Water Directive (80/778/EEC). In these areas farmers voluntarily reduce their use of nitrate-rich fertilisers, for which they receive monetary compensation. NVZs are designated under the Nitrates Directive (91/676/EEC) as groundwaters and surface waters where public supplies are polluted by nitrates from agriculture. Mandatory restrictions will be placed on agricultural practices within these zones for which compensation is not given. Additionally, under the Urban Waste Water Treatment Directive (91/271/EEC) some surface waters are designated as Sensitive Areas (Nitrate) and large sewage treatment works (> 10,000 p.e) must introduce measures to reduce nitrate in effluent (similar measures are also in place to reduce phosphorus). Whilst the limitation of the use of nitrates in these Vulnerable Zones and Sensitive Areas is a step forward in nutrient control, the area covered by such designations is small.

1.4.2 In-lake management of nutrients

Reduction of nutrient concentrations by physico-chemical removal at the river input or within the lake is often possible. The reduction of only one nutrient - that which is actually or potentially limiting - should be sufficient to reduce the algal crop of a lake (Moss, 1988). Phosphorus is the nutrient most readily controlled, since its major source is sewage input to rivers from which it enters lakes. The compounds of nitrogen are too soluble for easy control and enter waterways from many diffuse sources, such as surface run-off and river inflows as well as having a potential supply in the atmosphere.

Control of the release of nutrients from sediments has achieved some success. Temporary drawdown is a technique limited to water-bodies in catchments with high reliable inflows, such as reservoirs on major rivers in Poland (Zalewski *et al.*, 1995). The resultant drying of sediments induces compaction which persists once the water body is flooded again reducing nutrient release (Rijsdijk, 1994). Drawdown provides an opportunity to remove fish where this is desired. The main advantage of this technique however, is the decreased costs of complementary eutrophication control measures. Sediment covering, involves the creation of a physical barrier above the sediment-water interface to prevent the exchange of nutrients and inhibit the internal loading process. Artificial substrates such as plastics are usually employed (Cooke *et al.*, 1993; Rijsdijk, 1994). The cost of the materials usually confines the technique to small water bodies.

Sediment removal techniques rely on the presence of sediment with low phosphorus content beneath the sediments extracted. The top sediment is removed by a suction dredger and pumped into a settling pond. This technique is generally used in conjunction with chemical precipitation techniques (Bjork, 1985 & 1994). Sediment conditioning involves the extraction of ancient deposits from the lake which are returned to cover the recent sediment. The purpose of the technique is to increase the sediment-phosphorus binding capacity. Klapper found that simultaneous precipitation of phosphorus and algae was achievable using phosphorus coagulants (Klapper, 1991).

The methods for removal of phosphorus by chemical means have been extensively reviewed by the OECD (1971) and Klapper (1991). Not all of the methods examined are appropriate for use in water storage reservoirs. For example, chemical precipitation of phosphates by chalk is highly efficient, but requires a high pH and a large amount of chemical which may have deleterious effects on faunal assemblages. It also produces a large amount of sludge which may be difficult to remove from a reservoir (Klapper, 1991).

In USA and Germany precipitation of phosphates by aluminium sulphate is a commonly used technique in reservoirs (OECD, 1971; Klapper, 1991). The aluminium loss which accompanies precipitation only amounts to about 0.75% of the quantity of precipitating agent used. Phosphate adsorbed on the resulting aluminium hydroxide complex may be eliminated as calcium phosphate and the remaining aluminium recovered as sodium aluminate. The use of aluminium in public water supply systems is not supported in this country due to the possible links with poor health (Harper, 1992).

Techniques have been pioneered in the Netherlands for precipitating iron phosphates by means of ferric salts, which have great affinity for phosphate ions and polyphosphates (Knudsen, 1975). Ferric binds with the phosphate and settles to the sediment. An additional product ferric hydroxide is formed as a red-brown gelatinous mass. The settled floc should prevent phosphate in the substrate returning to the overlying waters, by binding with any phosphate released from the interstitial waters (See 1.6). This latter technique was applied to Rutland Water in 1990 following successful use by Anglian Water in smaller reservoirs elsewhere in their region.

1.4.3 In-lake management of nutrient enrichment effects

In-lake techniques for management of algal problems are in the short-term cheaper than treating the causes (Harper, 1992). Artificial destratification and aeration techniques mix and circulate water between the aerobic epilimnion and potentially anaerobic hypolimnion. The principles of mixing regimes are that phytoplankton abundance is reduced by increasing the time spent by photosynthesizing cells below the compensation depth (Steel, 1975; Oskam, 1994) and that prevention of anoxia in the hypolimnion inhibits nutrient release from anaerobic sediments (Burns, 1981: Klapper, 1991; Verner, 1994). This may be achieved by the introduction of compressed air through a perforated pipe (eg. 'Helixor'), so that fine bubbles released entrap hypolimnetic water and carry it to the surface (epilimnion); or by mechanical pumping from the bottom; or in the case of pumped inflows, by 'jetting' the inflowing water under pressure.

Preliminary investigations suggest that control of cyanobacteria by the introduction of parasites, diseases and predators could be successful, although studies have not been conducted on a large scale (Parr & Clarke, 1992; Cooke *et al.*, 1993). Natural toxins have been found, although not yet identified, in decomposing barley straw and similar materials (Ridge *et al.*, 1994; Newman & Barrett, 1993). The mechanisms by which the decaying material inhibit algal growth are unclear at present.

It has been observed that maintenance of populations of large bodied grazing cladocera is a management technique which reduces algal biomasses. Zooplankton need protection from consumption by small fish. Several authors and reviewers have observed the value of macrophyte beds in shallow lakes as refuges and alternative food resources for zooplankton (Moss, 1990; Irvine *et al.*, 1990; Phillips & Moss, 1994). In water supply reservoirs, an alternative supply of food is rarely required due to high inputs of allochthonous food during periods of low phytoplankton biomass (McQueen & Post, 1986). Artificial planting of macrophytes would probably be unsuccessful in a reservoir due to sharp rise and fall of the water level in response to supply and demand of water.

In the absence of macrophyte refuges, zooplankton biomass and diversity may be maintained by reduction of spawning by cyprinids (eg. roach) through netting regimes, or the removal of cyprinids by the introduction of a piscivorous predator. This practice, known as biomanipulation, aims to enhance the biomass of larger zooplankton, such as *Daphnia* (highly efficient algal grazers), and it has received considerable attention in recent years (McQueen & Post, 1984; Faafeng & Braband, 1990; Leventer & Teltsch, 1990; McQueen, 1990). However, many reservoirs earn valuable revenue for water companies from angling, and so the removal of fish from the water body may not be acceptable.

1.5 Management techniques used in Rutland Water

1.5.1 Management of effects of eutrophication

Rutland Water in Leicestershire, is the largest potable water supply reservoir in the UK by area. It is eutrophic due to the high nutrient status of its pumped river inflows and water quality is managed in a variety of ways. Features to counter problems of algal blooms and reduction of water quality were included in the reservoir design (figure 1.1) (Harper, 1978). A grid of twelve 'Helixor' airguns was constructed on the bed of the deepest part of the main basin, through which compressed air is pumped into the water column in order to prevent stratification in the reservoir.

Rutland Water is 'U'-shaped, as a result of the filling of two neighbouring valleys. River water is pumped into the reservoir through four jets inclined at 22.5° to the horizontal, westwards into the south arm. This optimises the likelihood that by the time water reaches the primary outlet shaft located at the eastern end of the main basin it has been well mixed, and has been in the reservoir for some months. A secondary draw-off tower was built in the north arm, since water in the north arm would be subjected to a longer period of retention and thus be of higher quality. To maintain this quality, treated sewage effluent from Oakham sewage treatment works which originally discharged into the north Gwash, was diverted to the south arm of the reservoir through a tertiary treatment grass plot followed by the reed beds of the nature reserve lagoons prior to release into the reservoir.

1.5.2 Management of causes of eutrophication

After the filling period of 1976-1978, the algal biomass in Rutland Water, as measured by chlorophyll *a*, did not exceed 25μgl^{-1}, but after 1985 spring and summer peaks in excess of 45 and 55μgl^{-1} occurred annually, until late summer of 1989 (65μgl^{-1}). In this year, the reservoir was closed to public use following the deaths of sheep and dogs after contact with the water during a *Microcystis* bloom (NRA, 1990). Toxins are commonly released from cyanobacteria, some of which affect mammals (Codd & Beattie, 1991). The implied risk to public health meant the problem has had a high media and political

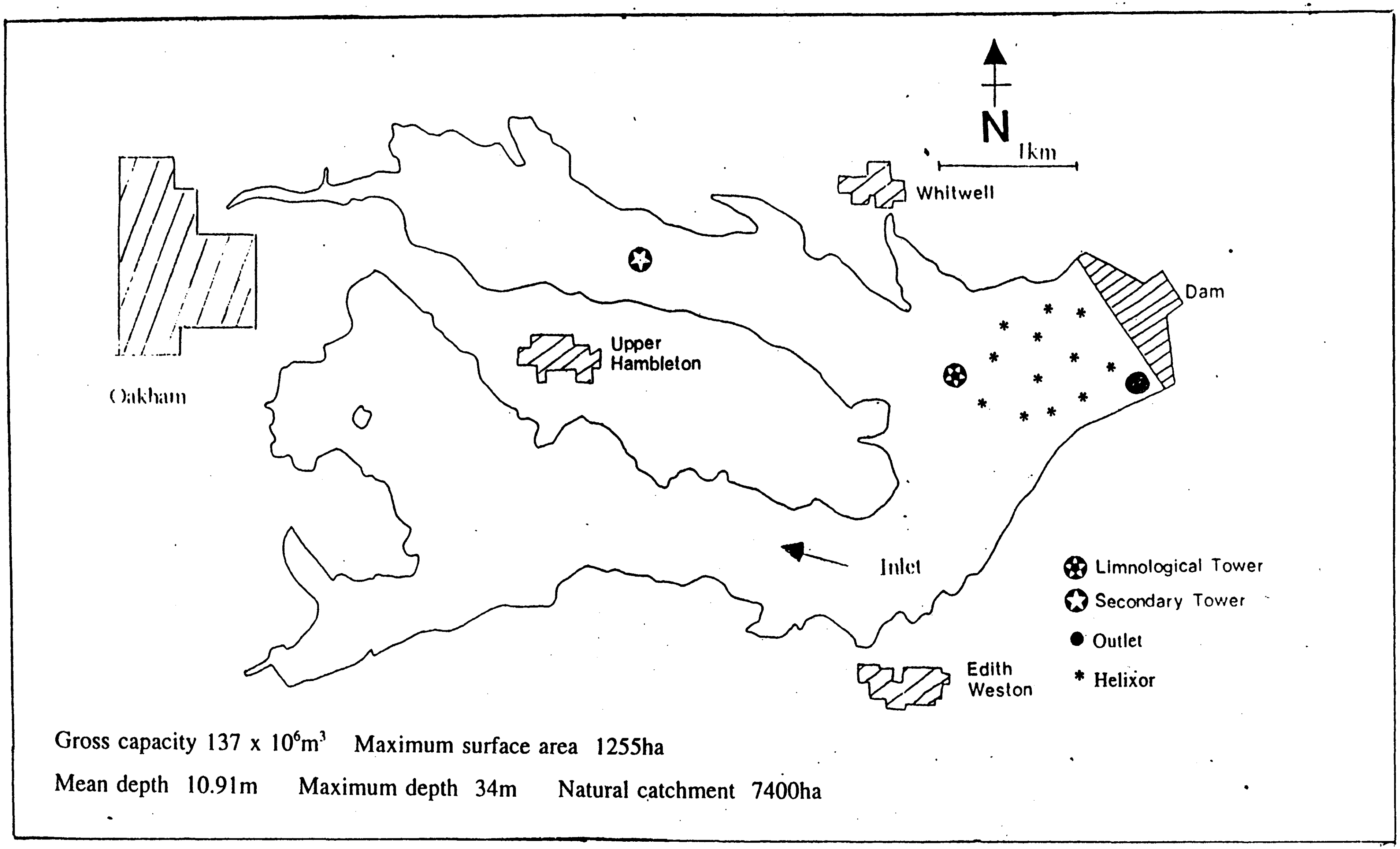


Figure 1.1 Management features in Rutland Water

profile.

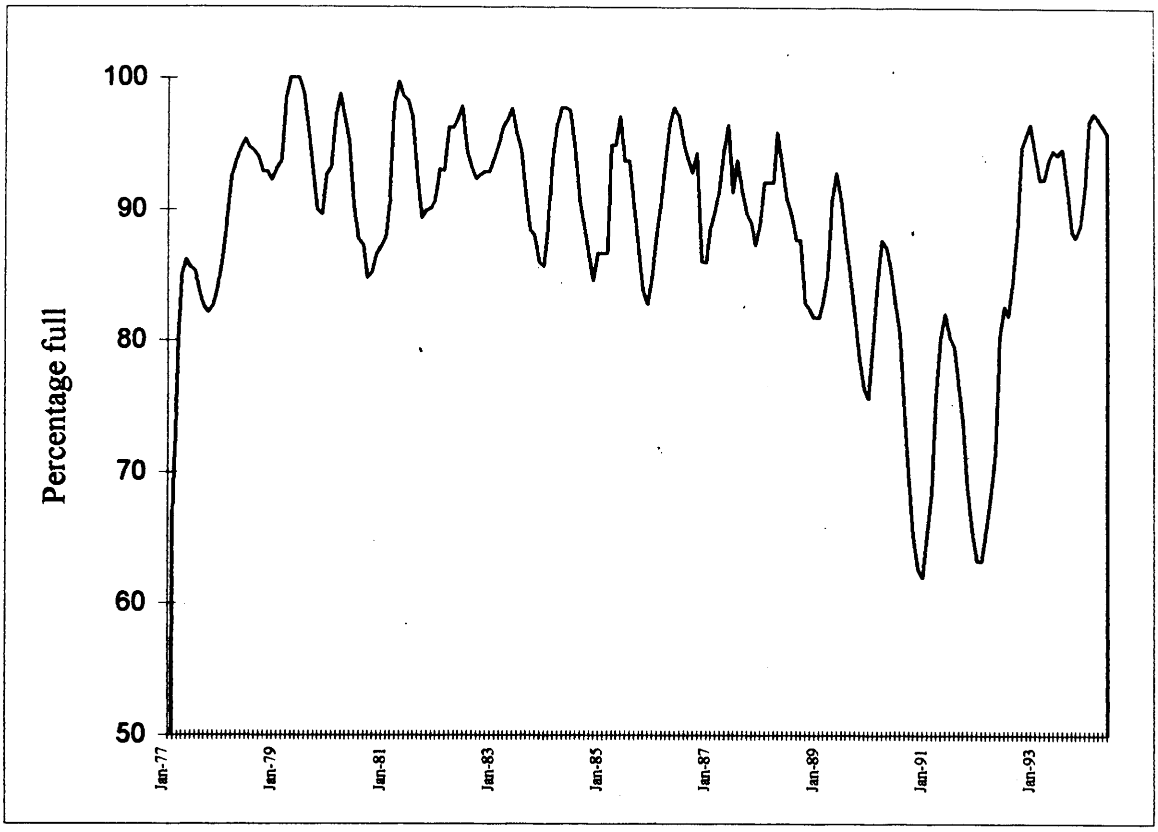
Anglian Water Services plc implemented a programme of directly dosing the reservoir with ferric sulphate in June 1990, following its closure in September 1989. The aim of ferric dosing was to reduce orthophosphate concentrations below 10μg l^{-1}. This was the level which supported a diverse algal species composition and low overall algal biomass at Foxcote reservoir (Young *et al.,* 1988). A blanket of ferric hyroxide on the sediment surface was believed to prevent release of phosphorus under anoxic conditions.

Initially, ferric sulphate was added to the reservoir in chosen areas such as close to the outlet, and over the inlet pipe, from a barge. Following modification of the pipeline, ferric was added to the river waters (R. Welland and R. Nene) at Empingham pumping station, and entered the reservoir through the inlet. Initially a level of 20:1 iron to orthophosphate based on the previous week's analysis of the orthophosphate levels was used. Latterly, a phosphorus monitor was installed at the pumping station which ensured automatic dosing at a ratio of 15:1 iron to orthophosphate (P. Daldorph, pers comm.).

The addition of ferric sulphate to the reservoir was dependent on two factors: a) that there was enough water in the rivers to enable abstraction; and b) that the chemical suppliers A & E West (who obtained ferric sulphate from the titanium dioxide industry) could maintain sufficient supplies to meet their demands. However, both of these factors varied, resulting in fluctuations in the amounts of ferric sulphate entering the reservoir monthly, weekly and even daily. The actual daily amounts of ferric sulphate used are not available from AWS. However, figure 1.2 illustrates the fluctuations in the addition of ferric sulphate in tonnes per month, and its relation to water level.

Rutland Water is greatly buffered by its alkalinity (150-180mgl^{-1} as calcium carbonate) and has a pH of approximately 8 (NRA data). Precipitation of ferric colloids and the hydrous oxide occurs quickly. An obvious plume of particulate iron was visible in the water column when dosing with ferric was taking place through the inlet in 1992 and 1993. The levels of iron at this time may have temporarily exceeded the WRc recommendation of 2mgl^{-1} for total iron (Mance & Campbell, 1988).

a) Monthly fluctuations in Rutland Water capacity



b) Monthly inputs of ferric sulphate to Rutland Water

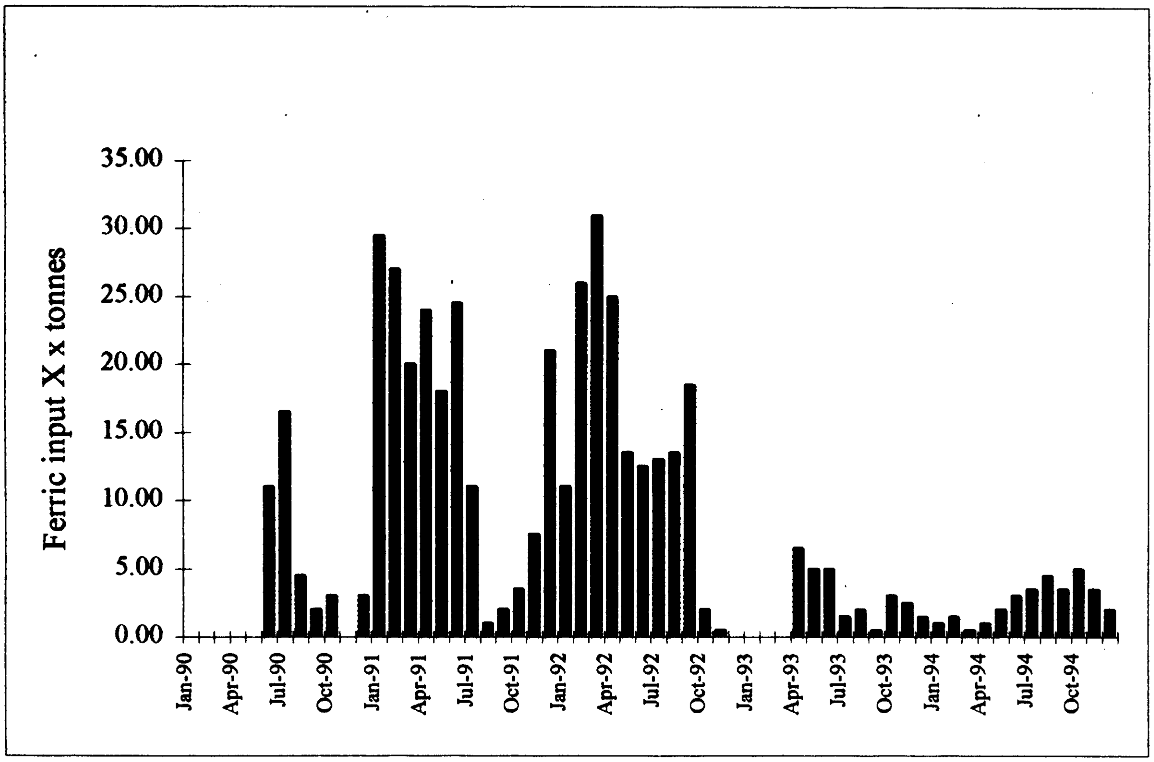


Figure 1.2 Reservoir fill level and additions of ferric sulphate to Rutland Water

1.6 Aqueous chemistry of iron

The chemistry of iron in the water column is complex. The forms of iron present depend on factors such as pH, oxygen content, and other ions present. The more stable oxidation state of iron in both acidic and basic situations is the ferrous form. However, mild oxidants such as oxygen are capable of oxidizing iron (II) to iron (III) and consequently, the more stable state in the presence of oxic conditions is the ferric form. In acidic solution, conversion of Fe^{2+} to Fe^{3+} is slow, due to kinetic factors, but in alkaline or neutral solution oxidation is rapid. In basic solutions the precipitates which form are often basic salts such as ferric chloride ($Fe(OH)_{2.7}\, Cl_{0.3}$) or ferric nitrate ($Fe(OH)_2\, NO_3$) (Mance & Campbell, 1988).

Under oxic conditions, insoluble ferric species are stabilised in colloidal form by adsorption of natural organic compounds such as humic and tannic acids, and by inorganic anions such as phosphate and silicate. Sediments in oxic waters have an oxic red/brown upper layer consisting of iron (III) hydrous ferric oxides over an anoxic black layer containing iron (II) associated with sulphide ions ($Fe^{2+}S^{-}$). Dissolved iron is usually present in the interstitial waters of the anoxic layer, which may diffuse to the oxic layer where it is oxidised to iron (III) and precipitated. Thus, in the absence of stratification there is no net release of iron to the overlying water (Davison & Tipping, 1984).

The addition of iron as ferric sulphate to a reservoir leads to rapid ionic bonding of ferric iron as ferric oxides with phosphates, which precipitate to the bottom of the reservoir as insoluble clumps. Under oxic conditions this phosphate remains tightly bound to the ferric iron, and unavailable to biota. In anoxic conditions some phosphate release from interstitial waters may occur, which may diffuse to the oxic layer, where it binds with dissolved ferric oxides and is precipitated once more. In this way the addition of iron to a reservoir reduces the phosphate available to the biota.

The availability of iron in its various forms to the biota depends on the redox potential of the water and the sediments. Colloidal and particulate iron, the dominant iron fractions in most redox conditions, are important in the cycling of other trace elements. This solid fraction, composed of polymeric oxides and hydroxides and complexes with naturally occurring organic acids and trace metals are adsorbed to the surface (Balistrieri *et al.*, 1992). Dissolved iron (as Fe (II) and Fe (III)) is taken up readily by algae and utilised for chlorophyll synthesis (Allnutt & Bonner, 1987a &b). Iron acts as an electron-binding site in photosynthesis and respiration in plants, and is vital in the production of haemoglobin, used by mammals and some invertebrates. However dissolved iron is only present in small quantities in oxic waters, unless resulting from pollution, for example from mine drainage (Mance & Campbell, 1988).

1.7 Use of iron precipitation techniques elsewhere

Iron salts have been effective at removing phosphates from the water column by precipitation and sedimentation. In White Lough Lake, Northern Ireland (Foy (1985) a single treatment with ferric aluminium sulphate immediately prior to the autumn overturn was followed by a large decrease in the lake iron and phosphorus due to precipitation. A single iron addition proved effective for two years, suggesting that continual addition is necessary to ensure sustained phosphate inactivation. Under oxidised conditions (>10% oxygen) in laboratory tests, phosphates remain bound in the sediments (A. Love, pers. comm.).

The use of ferric sulphate in reservoirs in Great Britain has been largely experimental. In Foxcote reservoir (Buckinghamshire) the species diversity of algae initially increased following the application of ferric sulphate, and there was an overall reduction in biomass. Macrophyte beds then developed and cyanobacterial cell counts were reduced (Young *et al.,* 1988). However, very little is known about the effects of ferric sulphate on the rest of the food chain.

The response time of lakes to nutrient control techniques is variable and may take some years to be achieved (Petersen *et al.*, 1976). Reduction in phytoplankton production subsequently leads to a decline in the sedimentation of labile organic matter. As a consequence the aerobic surface crust should persist such that no release of phosphorus from the substrate occurs (Young *et al.,* 1988). The use of iron salts is at the present time more economic than the extensive filtering treatment used to remove algae for public water supply (Daldorph, pers. comm.).

Rutland Water has been dosed with ferric sulphate since June 1990 for operational reasons alone. No environmental assessment of this eutrophication control method was conducted, hence no effective 'control' study of the zooplankton population had been carried out. Harper and Ferguson (1982) and Smith (1985) however, studied the zooplankton and their data are used as pre-ferric 'control' data.

1.8 Study outline

No clear information is available about the consequent effects of ferric sulphate application in reservoirs on the aquatic food chain. This study was instigated therefore, to investigate the direct and indirect effects of ferric dosing on zooplankton. Zooplankton are major grazers of algae and other small particles and so have an important role in the cycling of nutrients in a water body. Additionally, they are a significant food source for invertebrate and vertebrate grazers, so any decline or enhancement of the zooplankton populations would have an important consequence on the rest of the food chain. Direct or indirect effects of ferric sulphate on zooplankton might be expected in the following ways: impacts on the physical and chemical environment; toxic effects at the population level; reduction of the food supply; individual responses to the addition of particulate, non-food material. These potential impacts were evaluated by field and laboratory investigations which sought to answer the following questions.

1) What were the physical effects of ferric sulphate in the water column? Ferric sulphate, added to the pumped inflows, settles out of the water column at a rate influenced by wind and circulation in the waterbody. It was hypothesised that its particulate nature could affect the transparency and light transmittance as well as increasing the amount of solid material carried in the water column. The sediment thickness around the inlet zone would increase, and there might be more sediment available for resuspension in suitable wind conditions. The incidence of these physical effects were measured in the field.

2) What were the chemical effects of ferric sulphate in the water column?
The addition of ferric sulphate contributes to the iron and sulphate already present in the reservoir. It was hypothesised that particulate iron concentrations could increase in oxic waters and in the anoxic interstitial waters of the sediments dissolved iron might accrue. Additionally, the acidic nature of ferric sulphate could lead to reduced pH around the inlet. As a result of the addition of the salt, an impact on conductivity was expected. Each of these parameters was measured in the field.

3) What were the effects of ferric sulphate on phytoplankton?
Ferric sulphate was added to the reservoir to precipitate phosphate and reduce the algal biomass, in particular the cyanobacteria, by nutrient limitation, cellular aggregation and species competition. It was hypothesised that there could be a reduction in biomass and that the population might change from cyanobacteria to chlorophyte species. Field measurements were made to test this hypothesis.

4) What were the predicted toxic effects of ferric sulphate on zooplankton?
A literature study was undertaken to determine the known effects of ferric sulphate and related compounds on plankton. It was hypothesised that there could be direct toxic effects on the population of the cladoceran, *Daphnia longispina* O.F. Müller[1], and that ferric sulphate might inhibit algal growth in the dosed area of the reservoir. Field measurements were made to test this hypothesis.

5) What are the other predicted effects of ferric sulphate on the zooplankton?
Ferric sulphate was added to the reservoir to precipitate phosphate and reduce the algae biomass. It was hypothesised that this precipitated material could dilute the food supply causing physical blockages in the feeding mechanism, and an increase in the filtering area of *Daphnia longispina* in the dosed area

[1]Harper & Ferguson (1982) and Smith (1985) both described the dominant Cladoceran in Rutland Water as *Daphnia hyalina*. Throughout this study it is known as *Daphnia longispina*. The reasons for the change in name are given in appendix I(a).

of the reservoir. Additionally, the reduction in food supply might lead to a reduction in the population growth rate of *Daphnia longispina* in the dosed area. The incidence of these effects was measured in the field.

6) What experimental studies are needed to predict the effects of ferric sulphate on phytoplankton?
The literature described some of the effects of a number of iron compounds on phytoplankton, although these effects needed confirmation. It was hypothesised that ferric sulphate might inhibit growth of an alga.

7) What experimental studies are needed to predict the effects of ferric sulphate on zooplankton?
The literature described some of the effects of a number of iron compounds in a variety of situations on various fauna, although the effects on zooplankton needed confirmation. It was hypothesised that the mortality of *Daphnia* might increase, and reproductive rate decrease in ferric sulphate. Additionally, it was hypothesised that feeding rate might increase and the area of the filtering apparatus could increase in response to a reduction in food concentration and dilution of the food supply by inedible material. These hypotheses were tested in the laboratory under controlled conditions.

It is probable that effects other than ferric dosing could also have exerted an impact upon zooplankton. These include altered fish predation due to changes in recreational management. Alternatively, other environmental factors, such as water levels, circulation and mixing, might conceivably have had an influence on zooplankton, masking any effect of iron dosing. These factors were reviewed in order to evaluate their relative importance in the final discussion.

1.9 Thesis structure

Chapter Two is a review of literature describing toxicity of iron to algae, invertebrates and fish, and other direct physical effects and indirect effects that the addition of a particulate material might exert on a zooplankton population. This chapter also describes physical forces impacting on plankton populations in a water body, and the importance of zooplankton, in particular *Daphnia*, in the nutrient cycling of a reservoir. The physical and chemical effects of the addition of ferric sulphate in the reservoir are described in Chapter Three, and observed field effects on zooplankton populations described in Chapter Four. Chapter Five describes investigations into the potential effects of ferric sulphate on plankton populations. These include growth rate observations on the alga *Chlorella vulgaris*; acute and chronic toxicity tests on the Cladoceran *Daphnia longispina*; and behavioural and morphological measurements on the daphnids. The final chapter discusses the significance of the results obtained during the field and laboratory investigations and evaluates the extent to which the overall set of investigations supported the working hypotheses.

Chapter Two - The environmental impact of ferric with particular respect to *Daphnia*

2.1 Introduction

Ferric sulphate might impact *Daphnia* at population or individual level in a number of ways: toxic impacts on the zooplankton (direct chemical effects); physical interference of feeding (direct physical effects); or dilution of the food supply (indirect effects). Other environmental impacts in the reservoir might obscure any effect of ferric sulphate.

First, the direct chemical effects of iron were considered. There are few details in the literature about impacts on *Daphnia,* so the literature describing effects of iron and other metals on aquatic insects and fish were reviewed. Next, literature describing the way *Daphnia* feed and the way in which particulate materials may impact on feeding behaviour were considered. Thirdly, factors causing dilution such as the impact of iron on the growth of algae and aggregation effects were reviewed, and the ways in which *Daphnia* manage these effects were considered.

Observation of these impacts is relatively easy in laboratory studies, but in the field they may be obscured by environmental influences. The impact of wind and circulation on plankton populations and the interactions between *Daphnia* and its predators were reviewed in order to evaluate their possible importance in masking the effects of ferric sulphate in Rutland Water. Consideration of the literature enabled refinement of the hypotheses outlined in Chapter One for consideration through field and laboratory studies.

2.2 Direct chemical effects

2.2.1 Conditions under which effects may be observed

Various metal salts are constituents of mine effluents, brines from oil wells, and wastes from metal processing and chemical manufacturing, all of which may enter water courses (Mace & Campbell, 1988). To protect aquatic life from such discharges the development and use of toxicity tests using animals such as *Daphnia* (Cladocera), have become an important means of developing water quality criteria and standards.

The general health of *Daphnia* plays an important role in its response to toxic substances. Chandini (1991) exposed *Daphnia carinata* to low food concentrations and dissolved cadmium in laboratory experiments. Reproduction was inhibited by cadmium, although the effects were mitigated by the presence of food (Biesinger & Christensen, 1972; Chandini, 1991). Enserink *et al.* (1990) found that good maternal nutrition reduced the sensitivity of a brood to cadmium.

Genetic fitness is also believed to play an important role in the tolerance of cladocerans to metal toxicity (Cowgill, 1987; Baird *et al.*, 1990; Barber *et al.*, 1990; Münzinger & Monicelli, 1991). Bodar *et al.* (1990) exposed three generations of *Daphnia magna* to sublethal cadmium concentrations under artificial conditions and thereafter assessed their resistance to the metal in acute EC_{50} tests. Resistance was acquired during a single generation, but lost within 21 days if the neonates of cadmium-exposed daphnids were placed in cadmium-free test solutions.

Several workers related the degree of toxicity of metal salts in zooplankton to physicochemical properties of the metals (Kaiser, 1980; Khangarot & Ray, 1989). The latter determined that the more chemically reactive an element, the more toxic it is, although they could not predict the degree of toxicity. Mercury and copper were the most toxic, and magnesium and sodium the least toxic metals in their laboratory study.

Biesinger and Christensen (1972), believed that metal ions exert their toxic influence by covalent bonding at cell surfaces and that their electronegativity is a toxicity-determining factor. They correlated the relative chronic toxicities of metal salts with certain physicochemical properties, such as the solubility product, electronegativity and equilibrium constant. In chronic tests iron, magnesium, chromium, nickel, copper and cobalt salts did not affect survival and reproduction of *Daphnia magna.* The percentage protein increased in the presence of calcium, magnesium, strontium, iron, manganese, zinc and cobalt (ranked order). A correlation between toxicity and the solubility of metal sulphides suggested that metals may combine *in vivo* with sulphydryl groups on enzymes, which affects their solubility and catalytic activity.

2.2.2 Iron

Most of the work on the effects of iron on daphnids has been concerned with its role as a nutrient, particularly with reference to haemoglobin synthesis (Hoshi & Kobayashi, 1972) and the distribution of iron histologically (Smaridge, 1956; Perkins, 1985). Daphnids take up iron from the water column as part of their nutrition (Tazima *et al.*, 1975). Yan *et al.* (1989) showed in Canadian lakes free from metal contamination that uptake of iron was highest in neutral pH compared with acidic or alkaline. Daphnids were important recyclers of iron, excreting it as soluble, reactive particulate and particulate organic fractions.

Few toxicity studies have examined the effects of iron on *Daphnia.* Biesinger and Christensen (1972) determined an LC_{50} (48 hour) of 9.6mg Fe l^{-1} for iron (II) as ferrous chloride ($FeCl_3 . 6H_2O$). A similar study by Khangarot and Ray (1989) determined an EC_{50} (48 hour) of 7.2mg Fe l^{-1} iron (II) as ferrous sulphate ($FeSO_4 . 7H_2O$). The use of iron (III) in dissolved and particulate form on *Daphnia* has not been described in the literature, although the effect of particulate iron (II) and (III) on macroinvertebrates and fish, has been examined in iron-polluted rivers.

The majority of iron entering freshwaters does so as a product of coal-mine drainage in the form of pyrite (iron sulphide) (Mace & Campbell, 1988). On exposure to the air pyrite is oxidised:

$$2FeS_2 + 7O_2 + 2H_2O \text{ ------> } 2FeSO_4 + 2H_2O \quad \text{(Murphy, 1979)}$$

Discharge or run-off into streams or rivers produces waters rich in acidic ferrous iron (considered to be more toxic than ferric, due to its greater solubility). Further oxidation and subsequent hydrolysis as the acid mine waters are diluted can result in an increase in pH and eventually to the formation of ferric hydroxide (ochre) which is deposited on the stream bed ($Fe\ (OH_2)^+$).

Healthy invertebrate communities occurred at concentrations of 0.7-2.7 mg l^{-1} total iron (Letterman & Mitsch, 1978) in rivers polluted by mine waters, although the sensitivity of different species varies. According to Maltby *et al.* (1987) the LC_{50} for *Asellus aquaticus* (Isopoda) was 3mg Fe^{2+}. Warnick and Bell (1969) found *Ephemerella subvaria* (Ephemeroptera) was highly sensitive to ferric sulphate (LC_{50} 0.32mg Fe^{3+} l^{-1}) compared with two other insects, *Acroneuria lycorias* (Plecoptera) and *Hydropsyche bettini* (Trichoptera) which exhibited LC_{50} values of 16mg Fe^{3+} l^{-1}. Gerhardt (1992) examined the survivorship, gill ventilation, moulting and feeding of *Leptophlebia marginata* (Ephemeroptera) when dosed with iron under artificial conditions. At pH 4.5 Fe^{2+} was dominant; Fe^{3+} dominated at pH 7. Iron was precipitated above pH 5 and was apparently more toxic - probably due to precipitation of iron on the gills and thorax of the larvae. As the dose of iron was increased the insects stopped feeding and appeared constipated. Radford (1994) examined the effects of ferric sulphate precipitate on the chironomid *Chironomus riparius* in the laboratory, finding larval growth and adult emergence to be reduced above 90mg l^{-1}.

Sykora *et al.* (1972) found that the age of the precipitate of ferrous sulphate played an important role in its toxicity. In a series of tests, in a variety of pH and water hardnesses, which did not apparently influence toxicity, *Gammarus minus* (Amphipoda) was exposed to precipitating iron freshly made up or 6.5 hours old. Fresh precipitate was more toxic in both acute (7 day) and chronic (21 day) tests. In fresh precipitate an LC_{50} of 7.2mg Fe^{2+} l^{-1} was observed; whereas 6.5 hours old precipitate an LC_{50} value of 12.9mg Fe^{2+} l^{-1} was determined. The reasons for this difference were not established.

Fisheries studies have shown that variation existed between life-history in their tolerance of iron contamination. Scullion and Edwards (1980a & b) found healthy populations of adult *Salmo trutta* (brown trout) in the River Taff at 0.71mg l^{-1} total iron whilst at an iron contaminated site downstream containing 2.39mg l^{-1} total iron, fish biomass six times lower with reduced hatching and survival occurred. Alevin growth was impeded at 3.02mg l^{-1} total iron (2.09mg l^{-1} dissolved) and hatching was reduced at 5.17mg l^{-1} total iron (2.95mg l^{-1} dissolved) mostly due to smothering by the iron precipitates in laboratory studies (Geertz-Hansen & Mortensen, 1983). Iron has been associated with changes in the mucus cell structure of bluntnose minnow (*Pimephales notatus*) and creek chub (*Semolitus atromaculatus*) (Keller *et al.*, 1984).

Laboratory tests found that Fe II was more toxic than Fe III. Decker and Menendez (1974) exposed 14 month old brook trout (*Salvelinus fontinalis*) to dissolved iron in the form of iron II sulphate. At pH 7.0 the 96-hour LC_{50} was 1.75mg Fe^{2+} l^{-1} decreasing to 0.41mg Fe^{2+} l^{-1} at pH 5.5. In comparison, juvenile brown trout (*Salmo trutta*) and juvenile rainbow trout (*Salmo gairdneri*) in dissolved iron as iron III sulphate, showed 96-hour LC_{50} values of 8.5 and 2.9mg Fe^{3+} l^{-1} respectively (Abraham & Collins, 1981). Exposure of 90 day old brook trout to suspended ferric hydroxide (iron III) led to significant growth reduction at 12mg Fe^{3+} l^{-1}. Dalzell (1996) exposed brown trout (*Salmo trutta)* to both AnalaR and commercial grade ferric sulphate, and found that commercial grade ferric sulphate, a by-product of the titanium dioxide industry, was 5 times more toxic than AnalaR grade - LC_{50}s 0.05mg Fe l^{-1} (dissolved) and 0.24mg Fe l^{-1} (dissolved) respectively.

Daphnids store iron (both in its ferrous and ferric form) in their tissues (Smaridge, 1956; Tazima *et al.*, 1975; Perkins, 1985). This may be linked to its role in haemoglobin synthesis, production of which increases in low oxygen conditions (Hoshi & Kobayashi, 1972). Wong *et al.* (1982) documented iron granules in the gut tissues of chironomid larvae. Rainbow trout (*Salmo gairdneri*) was found to concentrate significant amounts of iron in its tissues when fed activated sewage sludge as 30% of a nutritionally balanced diet.

2.2.3 Comparisons between heavy metals

Winner and Farrell (1976) investigated sensitivity to copper salts of *Daphnia magna, D. pulex, D. parvula* and *D. ambigua* in laboratory studies. All four species exhibited reduced survival at copper concentrations greater than 40μg l^{-1}. Decreased instantaneous rate of population change (r) of *D. magna* occurred above 60μg l^{-1}, whilst r for the other three species was reduced above 40μg l^{-1}. Brood size was reduced above 40μg l^{-1} for *D. ambigua* and greater than 60μg l^{-1} for *D. pulex* and *D. parvula*. *D. magna* did not exhibit reduced brood size, although reproduction was inhibited above 80μg l^{-1}.

Warnick and Bell (1969) examined the sensitivity of three insect species: *Acroneuria lycorias* (Plecoptera); *Ephemerella subvaria* (Ephemeroptera); and *Hydropsyche bettini* (Trichoptera) to salts of copper, zinc, cadmium, lead, iron, nickel, cobalt, chromium and mercury in the laboratory. They found that these insects were not as sensitive to metals as were fish and that the sensitivity varied between species, with *Ephemerella* being the most sensitive, especially to copper and iron. Arthur and Leonard (1970) determined a safe level for copper on *Gammarus pseudolimnaeus* of 0.0046mg l^{-1} above which reproduction was impaired.

The effects of metals on fish has been of some concern due to the sensitivity of fisheries and the high costs of restoration (Mace & Campbell, 1988). As a result, safe levels for some metals have been determined, above which reproductive impairment would be expected. These are shown in table 2.1 in comparison with *D. magna.*

In summary, the toxicity of metals including iron is dependent on a number of factors. The sensitivity of invertebrates and fish to iron and other metals varies and differs within the life history of a species. Food availability and maternal nutrition affected resistance to metal toxicity in *Daphnia* and the form of iron influences its impact on *Daphnia* - iron II was more toxic than iron III. The degree of toxicity of metal salts to zooplankton may be correlated with physicochemical factors such as electronegativity and solubility product. The toxicity of ferrous iron has been determined in two studies on zooplankton (Biesinger & Christensen, 1972; Khangarot & Ray, 1989), although the toxicity of ferric iron has not been established. This review of the literature was useful in indicating the possible effects of iron sulphate on the plankton.

2.3 Direct physical effects

The particulate nature of ferric sulphate means it is suspended in the water column with food. Hence, it was important to consider the ways in which daphnids select food particles and the mechanisms of feeding.

Table 2.1 Safe metal levels for *Daphnia magna* and some fish species

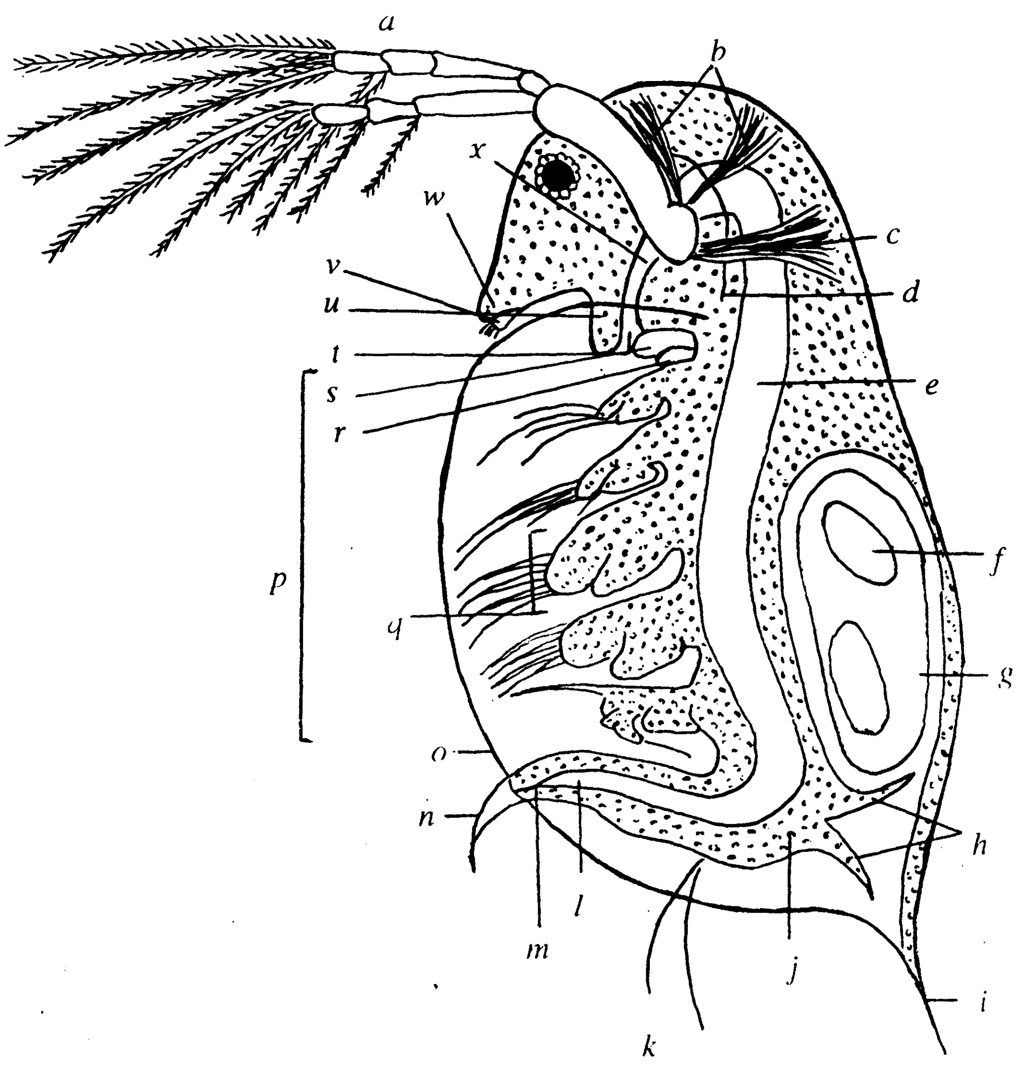
Metal	Form	Safe Level mg l^{-1}	Species	Reference
Chromium	$CrCl_3$	0.33	*Daphnia magna*	A
	$Na_2Cr_2O_7$	0.2-0.4	*Salvelinus fontinalis*	B
Copper	$CuCl_2$	0.022	*D. magna*	A
	$CuSO_4$	0.010	*Pimiphales notatus*	C
	$CuSO_4$	0.014	*P. notatus*	D
	$CuSO_4$	0.0095	*S. fontinalis*	B
Zinc	$ZnCl_2$	0.070	*D. magna*	A
	$ZnSO_4$	<0.180	*P. notatus*	E
Cadmium	$CdCl_2$	0.001	*D. magna*	A
	$CdSO_4$	0.037	*P. notatus*	F
Nickel	$NiCl_2$	0.030	*D. magna*	A
	$NiSO_4$	0.4	*P. notatus*	C

(*Salvelinus fontinalis* = Brook trout; *Pimiphales notatus* = Bluntnose minnow) A: Biesinger & Christensen (1972); B: McKim & Benoit (1971); C: Mount & Stephan (1968); D: Mount (1968); E: Brungs (1969); F: Pickering & Gast (1972).

2.3.1 Morphology of feeding apparatus

Cladocerans have five pairs of limbs, two of which (thoracic III and IV) have fine meshes (often below 1 μm^3) which act as filters (fig 2.1). These limbs have a three-dimensional structure of chitinous setae and setules, in the form of a filtering comb, which together with the carapace form a suction and pressure pump. Two such pumps are located one behind the other (Brendelberger, 1985). Scanning electron microscopy has determined the detailed structure of daphnid filtering limbs (Crittenden, 1981; Geller & Müller, 1981). Long stiff setae approximately 10μm apart support two rows of fine setules (figure 2.2). The distance between the setules (intersetular distance) is considered to play an important role in the size of the particles ingested (Urabe & Watanabe, 1991a & b). High food concentrations benefit animals with a small filtering comb; whereas when food is scarce individuals with a large comb area are at an advantage. The ability to change the size of the filtering mesh is advantageous in environments where the size of food particles changes over the year (Bern, 1990; Stuchlik, 1991).

The phenomenon of increase in the size of the filtering area of thoracic limbs amongst different *Daphnia* populations in response to declining seston levels has been extensively



a 2nd antenna; *b* antennal adductor muscles; *c* antennal levator muscles; *d* fornix; *e* midgut; *f* eggs; *g* brood pouch (ovary not shown); *h* abdominal processes; *i* apical spine; *j* post abdomen; *k* abdominal setae; *l* hindgut; *m* anus; *n* post-abdominal claw; *o* carapace; *p* thoracic appendages 1-5; *q* 3rd thoracic appendage; *r* maxillule; *s* mandible; *t* mouth; *u* labrum; *v* antennule; *w* rostrum; *x* foregut

Figure 2.1 Schematic drawing of partial anatomy of a daphnid. Redrawn from Griesbach (1987)

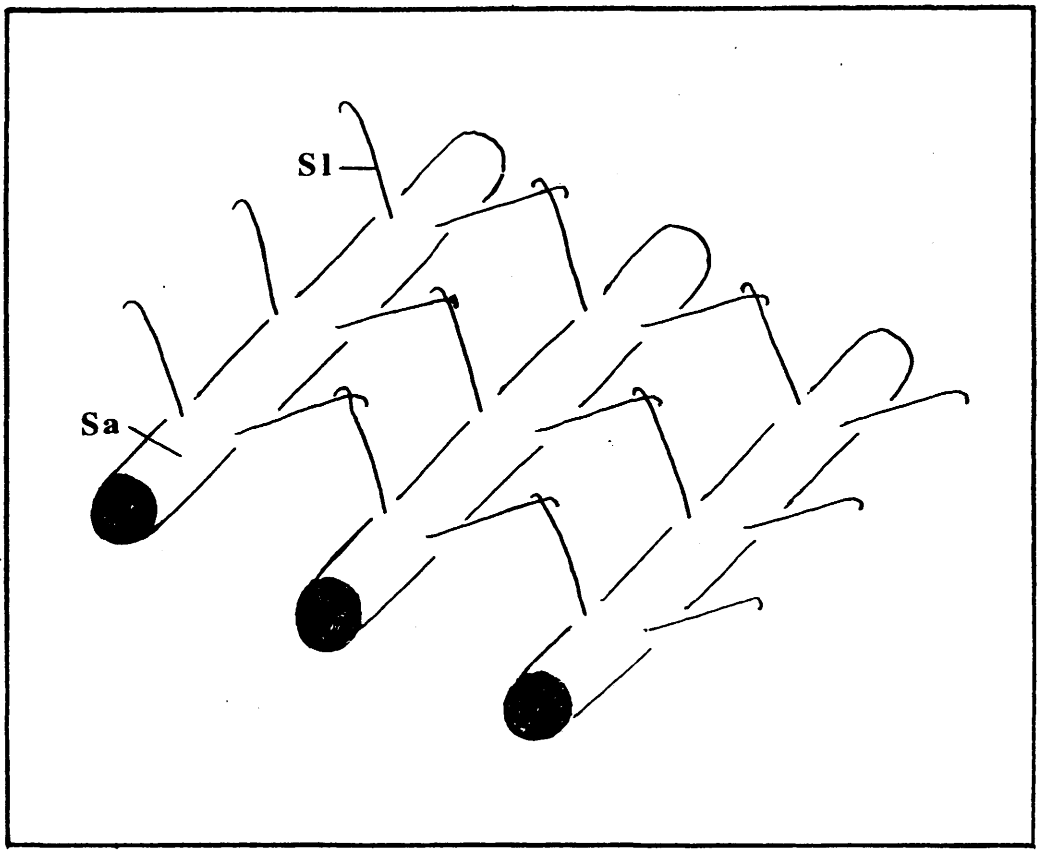


Figure 2.2 Schematic representation of cross section of daphnid filter screen showing parallel setae (Sa) and fine setules (Sl) connected by hook like tips. Redrawn from Lampert (1987) (not to scale)

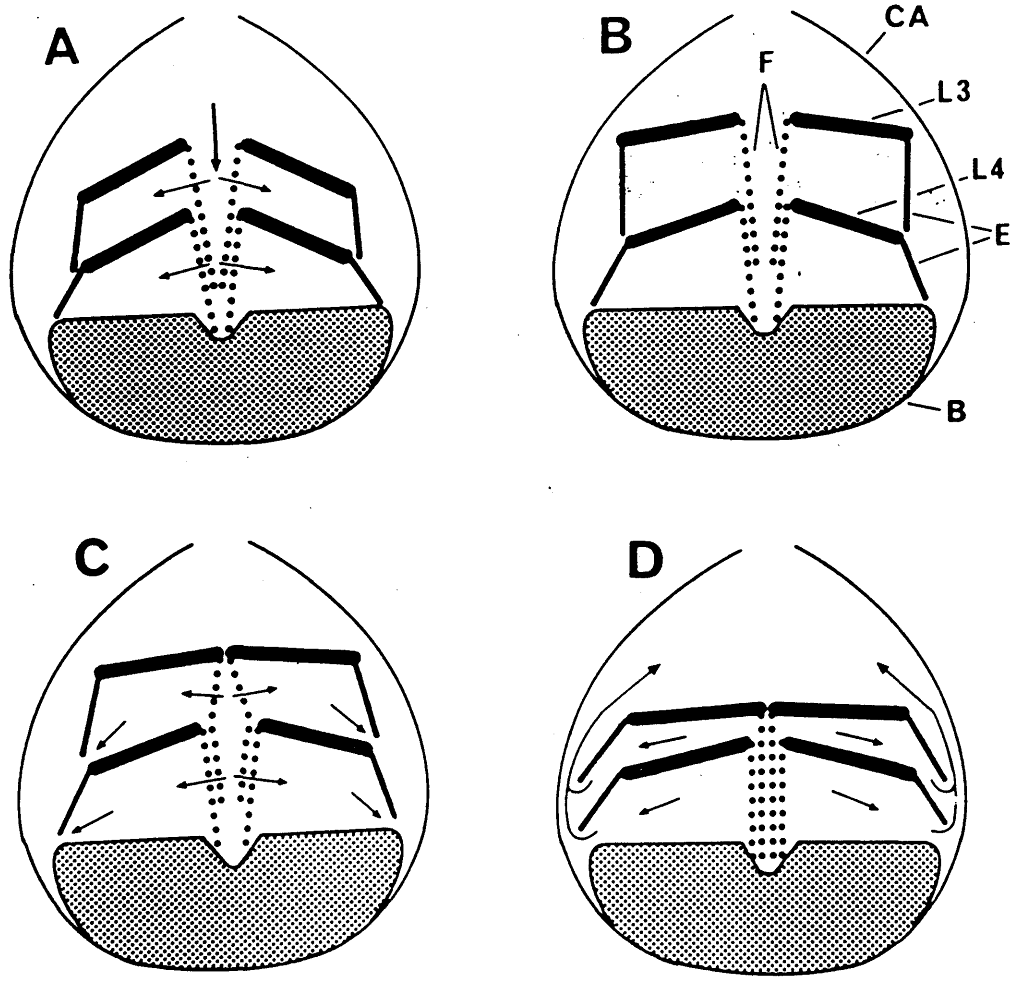
studied since 1940. Coker and Hayes (1940) made quantitative measurements of setules covering the filtering setae of thoracic limbs and established that populations and species in a lake had very similar filtering areas and Smirnov (1971) used the functional morphology of thoracic limbs to differentiate species. Environmental factors such as reduced food concentrations led to an increase in the area of the filtering screen in relation to the standard length of the daphnid and increased density of setules in *Daphnia pulicaria* (Korinek & Machacek, 1979). Lampert (1974), Fott *et al.* (1974), Hrbacek *et al.* (1979), Lampert and Brendelberger (1996) suggested that adaptive changes of the filtering screens was a logical response among Cladocera in fluctuating concentrations of seston. Korinek *et al.* (1985) found that differences in the size of the filtering combs of *Daphnia pulicaria* were not only habitat specific, but subject to seasonal changes within a population. Comparisons of the filtering combs on the 3rd and 4th thoracic limbs in several species of *Daphnia* and *Ceriodaphnia* from many habitats indicated that the 3rd pair of limbs were most likely to show an increase in size in response to declining phytoplankton concentrations (Korinek *et al.*, 1985). Pop (1991) found this adaptation occurred in individuals during moulting, rather than in successive clones coexisting in one population.

2.3.2 Filtering action

Storch (1924) described the feeding action of daphnids (Figure 2.3):

> *'When the third and fourth appendages move forward and laterally, the space between them widens and creates a vacuum which enables water to be sucked from the medial chamber through the screen into the volume between the legs. During the backwards stroke a small volume of water is trapped in the filter chamber and pressed through the screens whilst the filtered water originally contained in the inter-limb space escapes between the limb and the inner carapace wall.'*

Consequently, a continuous stream of water is forced through the filter screens from the inner to the outer part of the chamber. The water enters the filtering chamber at the anterior portion of the carapace margins and leaves posteriorly, near the post abdominal



Four phases of a filtering cycle (Storch, 1924). Arrows indicate the flow of water. A/B: Legs move upwards. Water is sucked into filtering chamber and into widening inter-limb spaces. C/D: Downwards stroke. Water is pressed through filter screens and escapes from narrowing inter-limb spaces. L3 3rd limb; L4 4th limb; F filter screens; E exopodite 'valves'; CA carapace; B body

Figure 2.3 Schematic oblique section through the filtering apparatus of a daphnid (Lampert, 1987)

claw (Nauman, 1921; Strickler, 1984). DeMott (1985), however, stated that the filtering appendages functioned as solid paddles with little or no flow of water through the setae and setules. Direct interception and retention of particles declined as particle size decreased below the mesh size of the filter.

Once particles enter the feeding chamber, they are channelled to the food groove, situated ventrally. The food is then processed by the mandibles and swallowed, if of a suitable size. The food groove is cleared by rejection movements of the post-abdominal claw if it contains too many particles, or unsuitable particles.

2.3.3 Factors affecting filtering and ingestion rates

(I) Concentration of food

The rate at which daphnids filter has been shown *in situ* and in the laboratory to be influenced by a variety of factors. Rigler (1961) found that below 10^5 yeast cells ml^{-1} the feeding rate was limited by the amount of water the animal could filter.Food concentrations in the field fluctuate very widely so it is assumed that there are periods when the animals starve and others when they have sufficient food. For filter-feeders, the amount of food ingested is dependent on the food concentration in their environment, hence there is a critical concentration of food below which the animal starves, egg production falls, and the population declines. This is known as the 'threshold concentration', when the animal is just able to equalise its metabolic losses so that it does not grow, but does not lose weight either (Lampert & Schober, 1980). To an individual, the threshold concentration is reached when assimilation balances respiration.

At the threshold concentration for the population, reproduction compensates mortality, which is set by physiological constraints and may be species-specific. Those species with lower thresholds are better competitors for limited resources (DeMott, 1982). Efficiency of assimilation is related to food concentration. Geller (1985) found that *Daphnia hyalina*'s minimum food requirement was 0.4mg (measured as dry weight (DW) algae) and the maximum was 0.76mg DW; for *Daphnia longispina* the minimum was 0.6 mg DW and the maximum 1.45mg DW.

At high concentrations the gut retention time becomes shorter, so there is insufficient time for complete digestion and absorption (Porter *et al.*, 1982). The level above which there is no limiting effect of food supply is known as the 'incipient limiting level'(ILL). Above this level, food intake is constant, no matter how much food is available (McMahon, 1965).

(ii) Food quality

The quality of food has an important effect on assimilation efficiency, although insufficient research has been carried to determine the quality of different food species and what is the ideal alga for *Daphnia*. The majority of ingested algae found in *Daphnia* guts by Infante (1973) and Lampert (1987) were protococcal algae, small greens, diatoms and flagellates. Algae with gelatinous coats, *Sphaerocystis schroeteri, Elakotothrix gelatinosa* (Chlorophyta) and the cyanobacterium *Chrococcus limneticus* were still intact in the gut of *Daphnia pulex* 5 days after ingestion (Porter, 1973). During clear water phases bacteria featured highly in *Daphnia* diets (Simek *et al*, 1990). Analysis of gut contents by Ferguson *et al.* (1982) found that *Daphnia* ate colonies of *Microcystis* that were less than 10^5 μm^3 volume when cyanobacteria dominated.

The nutritional value of algae varies, for example, an alga may be of high quality to a copepod but poor to a cladoceran (Lundstedt & Brett, 1991). Porter and Orcutt (1980) found that most cyanobacteria are digested and assimilated as easily as green algae of high food quality, although zooplankton species and strains differ in their abilities to utilise, detoxify or discriminate against cyanobacteria. Ingestion, assimilation, survivorship and reproduction of *Daphnia pulex* fed on cyanobacteria were lower than those fed on green algae (Arnold, 1971). Small-bodied cladocerans and rotifers were less affected by large colonies of *Microcystis* than larger daphnids because of the mechanical exclusion of colonies by their smaller filtering apparatus (Gliwicz, 1977; Gliwicz & Lampert, 1990). Small species were only affected if the cyanobacterium fell within the preferred size fraction (3-20μm) (Porter & Orcutt, 1980).

Benndorf and Henning (1989) found that *Microcystis aeruginosa* was non-toxic at the beginning of the growing season, but developed an endotoxin, microcystin, as grazing pressure increased. Microcystin inhibits the filtering rate, although since it is an endotoxin it has to be ingested for the zooplankton to experience its toxicity. Despite this, a rapid reduction in filtering rate by daphnids to its presence has been observed (Jungmann *et al.*, 1991). *Anabaena flos-aquae* contains a cocaine-like toxin whose effect on zooplankton is unknown (Porter & Orcutt, 1980). The toxicity of cyanobacteria to zooplankton has not been firmly established, although their toxicity to mammals is fairly well recognised (Codd and Beattie, 1991; Hunter, 1991; Keevil, 1991; NRA, 1990; Reynolds, 1991).

(iii) Nutrient limitation

Sommer (1992) showed that low concentrations of a phosphorus-limited culture of the green alga *Scenedesmus acutus* (C:P 1:<0.0011) caused slow growth of *Daphnia* with reduced rates of biomass gain, increased age at first reproduction, reduced clutch size, increased mortality and reduced reproductive rate. At higher concentrations of the *Scenedesmus* culture and higher C:P *Daphnia* developed dense populations which reduced the algal biomass ten-fold.

(iv) Mechanical interference

Ingestion rate may control assimilation, respiration and growth rate as well as fecundity (Benndorf & Horn, 1985). An increase in the number of times food was rejected would reduce ingestion rate and potentially lower metabolism and growth. Cladocerans reject colonies and filaments which clog the filtering appendages, such as particles above $20\mu m^3$ (McMahon & Rigler, 1965; Gliwicz, 1977) or particles clumped together (perhaps including iron (Kirk, 1991; Urabe, 1991)). This is achieved using the post-abdominal claw with the help of the first pair of thoracic limbs. This method reduces the overall efficiency of food intake, since feeding is interrupted and nutritious food already in the food groove is often rejected with unacceptable particles. It is also energetically costly (Dawidowicz, 1990).

(v) Hunger

Hungry daphnids show no clear incipient limiting level (McMahon & Rigler, 1965). The typical functional response - decreased feeding rate as the ILL was reached in increasing concentrations of food - has been found only in animals pre-fed at the experimental conditions. Feeding rates of starved animals increased with food levels above the normal ILL for the species, although 30 minutes of pre-feeding has been sufficient to eliminate the starvation effect. Additionally, Muck and Lampert (1984) and Thompson *et al.*, (1982) measured a depression in filtering rate in *D. hyalina* exposed to low food levels for three weeks and *D. longispina* starved for more than one day, which resulted in weight loss of the animals.

(vi) Temperature

McMahon (1965) found that the filtering rate of *Daphnia magna* increased up to an optimum at 24°C and decreased slowly above this value until 33°C was reached, at which point a sharp drop in filtering rate was observed. The smaller, *Daphnia rosea* showed an optimum filtering rate at 14°C after being cultured at 12°C, and an optimum of 20°C when cultured at 20°C suggesting that the temperature at which the optimal filtering rate occurred depended on the temperature to which the animal was acclimatised (Burns & Rigler, 1967).

(vii) Other factors

Greater filtering rates have been observed in *D. pulex* and *D. galeata* in the dark compared with the day, suggesting that there is a diel component in daphnid feeding behaviour (Haney, 1987). Crowding reduced the filtering rates of *D. hyalina* at densities of more than one daphnid per 20ml. However, the mechanism by which this depression occurs is not known.

2.4 Indirect effects of ferric salts upon food supply

Ferric sulphate is added to the water column to inactivate the available phosphorus compounds. One of the possible consequences is that growth of phytoplankton and cyanobacteria is inhibited, transparency of the water column is increased and the growth of marginal aquatic plants is promoted. The impact of iron additions on the algal populations have important consequences on the zooplankton population. For example, a reduction in algal biomass will reduce the food available to zooplankton.

The effects of iron on phytoplankton growth and its promotion or inhibition of primary production, have been little studied. Iron is an essential nutrient to algae, and may in some instances be a limiting factor in growth (Morel *et al.*, 1991). In oceanic systems, where iron is not generally abundant, new production of cyanobacterial biomass is iron-limited, but new production of eukaryotic biomass is not (Brand, 1991). Addition of 0.89nM iron caused an increase in productivity, chlorophyll *a* and cell densities in the natural subarctic Pacific plankton assemblage (Coale, 1991). Freshwater algae have similarly been stimulated in the presence of iron. The nitrogen and carbon fixation rate and chlorophyll *a* levels in eutrophic Clear Lake, USA, were stimulated by 500% in the presence of 15-30μg l^{-1} dissolved iron (Wurtsburgh & Horne, 1983). Below this level the effects of low nitrogen and reduced cyanobacteria growth were aggravated, leading to increased marginal macrophyte growth.

Laboratory studies demonstrated that iron is taken up by algae such as *Chlorella* (Chlorophyta) by reduction involving adenosine triphosphatase or a phosphate intermediate (Allnutt & Bonner, 1987a & b). Initial addition of iron to *Chlorella vulgaris* by Becker and Keller (1973) led to an increase in laboratory populations, until lethal concentrations (nominal concentration 520mg Fe l^{-1} as iron sulphate) were reached. Mallick and Rai (1992) determined that an addition of 20mg l^{-1} iron inhibited nitrate reductase activity of *Anabaena doliolum* and *Chlorella vulgaris* by 98%, suggesting that growth inhibition occurs by chemical inactivation of enzyme reactions.

Ferrous sulphate or ferrous aluminium sulphate (alum) have been used for decades in Europe in water treatment works as a coagulant to remove particles, including algae (Mackenthun & Keup, 1970; Lynch, 1981; Vollenweider & Kerekes, 1982). Coagulation of algal particles leads to a faster sinking rate, so that less adherent algal species or those that include buoyancy mechanisms will come to dominate.

Jackson and Lochmann (1992) investigated the effects of coagulation on algae in the laboratory and found that cell division declined when algae were growing at a fairly constant rate, reducing the maximum potential biomass. This led to more rapid sinking from the surface mixed layer over shorter periods at rates greater than those associated with the settling of single cells.

The natural flocculation of algae and diatoms into aggregates varies with species (Kiorboe & Hansen, 1993). Field populations of the diatom *Skeletonema costatum* excreted a solute substance that depressed flocculation, reducing cell loss from the euphotic zone during the growth phase, whilst the diatom *Chaetoceros affinis* was not adherent itself, but produced exopolymeric particles which caused the cells to stick together (Kiorboe & Hansen, 1993). The benefits of flocculation are unclear, although for species that over-winter in the sediment, the advantage of sinking from the euphotic zone at an appropriate time are obvious.

When soluble ferric is added to the water column it binds with phosphates and forms a floc. The amount of suspended matter in the water column therefore increases. Photosynthetic rates will probably be inhibited by the increase in the amount of suspended material and resultant decrease in underwater light in the water column, since the flocculated iron will be under the same influence of wind and circulation as other suspended particles.

2.5 Other environmental impacts on *Daphnia* which might obscure an effect of ferric salts

2.5.1 Predation

Predation has a major impact on the zooplankton biomass and species composition of a lake. Predation affects all sizes of *Daphnia*: - planktonic invertebrate predators such as *Leptodora* feed on zooplankton up to 1mm length, and planktivorous fish feed on those over 1mm.

Carpenter *et al.* (1985) found that where piscivore density was high, planktivorous fish declined while invertebrate planktivores increased. The plankton community shifted towards larger zooplankton and lower phytoplankton biomass (measured as chlorophyll *a*). Where piscivore density was low, planktivorous fish increased at the expense of invertebrate planktivores, resulting in small zooplankton dominance with high levels of chlorophyll *a*. In a study by Salki *et al.* (1985) differences in the number of planktivorous fish in enclosures led to variations in abundance of the predatory *Leptodora kindtii* (Cladocera) which affected abundances of the smaller cladoceran *Bosmina longirostris*.

Grazing by zooplankton maintains high transparency favouring green algae. In eutrophic lakes a dense fish population led to reductions in benthic fauna and planktonic cladocerans and a high concentration of chlorophyll, blooms of cyanobacteria, high pH and low transparency (Threlkeld, 1988). Haney (1987) investigated a eutrophic lake in which the large cladoceran *Daphnia pulicaria* was present, in association with *Aphanizomenon*. When planktivorous fish were introduced there was a shift in algal population to *Microcystis*. This cyanobacterium is unsuitable as food for actively growing zooplankton due to its large colony size and low nutritional status.

Fish predation of *Daphnia* has been shown to be more important in summer, compared with winter when environmental conditions such as temperature were acting to control the daphnid biomass (Gophen & Pollingher, 1985). When fish predation was high, *Bosmina* increased to large numbers and *Daphnia* became rare. Conversely, McQueen and Post (1984) showed that *Daphnia* had competitive advantage over *Bosmina* when there were few fish in Canadian lakes.

The sensitivity of daphnids to predation varies between species. Birth rates and mortality rates of the larger *Daphnia hyalina* were more drastically reduced than those of *Daphnia cucullata* in the presence of fish (Vijverberg & Richter, 1982). Milbrink & Bengtsson (1991) found that in a mixed population of *Daphnia magna* and *Daphnia longispina*, *D. magna* became extinct at high predation rates. When *D. magna* was the only species present it soon became extinct as the predation pressure increased. When *D. longispina* was the only species present extinction did not occur under high predation rates. Additionally, food levels are important. Orcutt (1985) found *Daphnia ambigua* to be competitively dominant over *Diaphanosoma brachyurum* when food was abundant in high predation conditions, but when food levels were limited the reverse situation occurred. Where fish predation becomes less important, for example following high fish mortality, there may be a change in daphnid species. Duncan (1975a & b) found that the daphnid population in Queen Elizabeth II reservoir during 1972 changed from the small *Daphnia hyalina* to larger *D. pulex* and *D. magna* following the removal of the perch-roach population by a virus. There was also a decline in algal biomass, which Duncan attributed to enhanced zooplankton grazing.

Fish predation is a strong regulator of size classes of *Daphnia* in lakes, especially those daphnids over 1mm long. In Lake Tjeukemeer, Vijverberg and van Densen (1984) found a low mean daphnid size during periods when 0+ fish (smelt, perch, roach, bream) were present in high numbers. Bream over 15cm length switched from particulate feeding to filtering so that the size selection depended on the mesh size of the branchiospinal system of the fish. In Lake Tjeukemeer, bream and eel populations changed their feeding habits in response to the abundances of *Daphnia hyalina* and larval chironomids (Lammens *et al.*, 1985). When the daphnid population was dominated by small individuals due to predation pressure by other fish, bream switched from a planktivorous to benthivorous diet. As a consequence, the condition of the mature bream deteriorated with poor gonad development. In response to the change to benthic food sources by the bream, eels switched from eating chironomid pupae and molluscs to a diet of fish fry. The condition of eels less than 35mm declined. When recruitment of planktivorous fish was poor the size of the daphnids was large, and the diets of the bream and eel reverted to daphnids and chironomids respectively.

Galbraith (1967) found that rainbow trout and yellow perch sometimes consumed daphnids over 1.3mm size as the only zooplankton food source. When rainbow trout were first introduced to Michigan Lake *Daphnia pulex* was eliminated and replaced by two smaller species within the first four years. The average size of daphnids declined over this time from 1.4mm to 0.8mm. The number of daphnids larger than 1.3mm declined from 58.8% to 4.7%, although the actual numbers of daphnids did not decline. In European lakes in which planktivorous fish were numerous, Gliwicz and Rykowska (1992) found that age at first reproduction as well as body size and clutch size of *Daphnia* declined, so that young were being born earlier thus keeping numbers constant despite predation pressure.

In the Bautzen reservoir in Germany, Benndorf *et al.* (1988) found that enhancement of piscivores with pike-perch (*Stizostedion lucioperca*) and catch restrictions for pike-perch and pike (*Esox lucius*) controlled planktivorous fish to a moderate density. A steady increase in the mean individual body size of herbivorous crustaceans occurred, together with strong fluctuations in the presence and abundance of *Chaoborus* and *Leptodora*.

Sed'a and Duncan (1994) found that in the London reservoirs, when cyprinid fish were scarce due to a lack of cyprinid spawning substratum, high numbers of large bodied *Daphnia* were maintained which grazed on phytoplankton and contributed to the reduction of algal crops. Copepod numbers were low due to competition between *Daphnia* and copepod nauplii.

In temperate lakes, piscivores and vertebrate and invertebrate predators reproduce annually, whereas crustacean herbivores and rotifers regenerate in a few days. Phytoplankton reproduce over hours to days, and inorganic nutrients may be recycled over minutes to hours. Enhanced piscivory may decrease planktivore density increasing grazer pressure and decreasing chlorophyll *a*. Stocking reservoirs with piscivores has promise as a tool for rehabilitating eutrophic lakes, although there may be a time lag in response of several years.

In summary, predation by planktivorous fish is one of the major influences in a waterbody on *Daphnia* populations. Fish impact on species dominance, birth and death rates and body size, which are all factors which might also be affected by the addition of ferric sulphate. Distinguishing between the effects of fish predation and the addition of ferric may be difficult to achieve. However, fish predation is likely to affect the whole of the study reservoir, and possible to measure using historical data. Any further impact of ferric sulphate was expected in the dosed parts of the reservoir and measurable as a recent change in the population data.

2.5.2 Physical influences on *Daphnia*

The distribution and biomasses of *Daphnia* populations are also influenced by environmental factors such as wind and circulation. The addition of contaminants to the environment may be compounded by such physical factors.

Reservoirs are static entities - any water displaced from one part of the reservoir as a result of steady wind from a fixed direction, will result in a build up of water at the downwind end. This difference in water level over the surface of the water body is termed denivellation (Hutchinson, 1957). This leads to the development of a slope on the water surface which causes a gradient current to start flowing, returning the displaced water to the upwind end 'conveyor belt' fashion (Hutchinson, 1957; Smith, 1975). Since the process of momentum is not dissipated, a denivellation is produced at the former windward end and a new flow starts from the former windward end to the former leeward end. This generates oscillations in the water body, motions termed seiches, which die away exponentially (Hutchinson, 1957). The velocity of oscillation is zero when the water surface is at maximum slope, and maximal when the surface is flat. As gradient currents, these seiches are independent of depth except near the bottom where the stress on the basin will gradually slow the movement. The amplitude of the seiche depends on the source of energy generating it and is therefore variable. If the lake is stratified, the various layers of different density can oscillate relative to one another. Seiches may also be generated by difference in atmospheric pressure (Hutchinson, 1957).

George and Edwards (1976) showed that wind caused green algae or diatom dominated populations to be homogeneously distributed horizontally and vertically in Eglwys Nynnydd, South Wales. Buoyant cyanobacteria and positively phototactic crustacea both tended to accumulate downwind. Local concentrations of cyanobacteria appeared when the winds were below 4m s^{-1}, although zooplankton patches were able to form during high winds. This horizontal population distribution reflected the tendency of animals to maintain themselves at a specific depth in areas of upwelling and downwelling (George, 1972). A crucial factor governing gross horizontal heterogeneity was whether the species or lifestage could and did swim strongly enough to maintain its position in the vertical plane (Colebrook, 1960a & b; George, 1972). George and Heaney (1978) found that the systematic patterns of phytoplankton distribution in Esthwaite Water in the Lake District were most pronounced when an individual species occurred in aggregations in upwelling and downwelling regions.

In conclusion, circulatory effects in a water body may (in some circumstances) have a greater influence on the location of zooplankton populations than active swimming of the plankton and their predators. By examination of patterns in zooplankton numbers in relation to wind direction, a feel for this influence should be possible.

2.6 Discussion

The literature review confirmed initial hypotheses that ferric sulphate would have an impact on *Daphnia* in a number of ways. Studies reporting toxic effects were sparse and either did not use ferric sulphate in such conditions experienced in a reservoir or reported only nominal concentrations of iron. From the studies of Biesinger and Christensen (1972) and Khangarot and Ray (1989), it was hypothesised that in field populations *Daphnia* population growth rate would be reduced in iron concentrations <10mg Fe l^{-1}. Safe levels for iron exposure by daphnids could be determined through investigation of the following null hypotheses in the laboratory:

> The death rate of *Daphnia longispina* populations would not be higher in ferric sulphate compared with a control;
>
> Clutch size and survival rate of *Daphnia longispina* neonates would not be lower in ferric sulphate compared with a control.

Ferric sulphate may affect the food supply (algae), diminishing it or causing aggregation of cells above the size which can be filtered by *Daphnia*. Although one study in the literature identified the toxicity of ferric sulphate to an alga *Chlorella vulgaris*, only a nominal concentration was given and no other effects of ferric sulphate were described. From the study by Becker and Keller (1973) it was hypothesised that algal populations would be reduced at high concentrations of iron (>100mg Fe l^{-1}) in the reservoir.

Laboratory studies could attempt to confirm Becker and Keller's study investigating the null hypotheses:

> Ferric sulphate would not inhibit growth in cultures of *Chlorella vulgaris* compared with a control;
>
> Ferric sulphate would not cause aggregation in *Chlorella vulgaris* cultures compared with a control.

Reduction in the quantity and quality of the food supply (either by toxic effects on the algae or by addition of non-food particles) affects *Daphnia* filtering rate (Rigler, 1961; Lampert & Schober, 1980; Philipova & Postnov, 1988; Kirk, 1991; Urabe, 1991) and affects the filtering area of daphnid feeding limbs (Lampert, 1974; Fott *et al.*, 1974; Hrbacek *et al.,* 1979; Korinek & Machacek, 1979; Korinek *et al.*, 1985; Lampert & Brendelberger, 1996). Although it was not possible to investigate the occurrence of these phenomena in the field, laboratory investigations could investigate the following hypotheses:

> The feeding rate of *Daphnia longispina* would not be higher in the presence of ferric sulphate compared with a control;
>
> The rejection rate of particles from *Daphnia longispina* food groove would not be higher in particles of ferric sulphate compared with a control;
>
> The mean area of the filtering apparatus of *Daphnia longispina* individuals would not be higher in ferric sulphate compared with a control.

Some of the environmental factors, such as fish predation and wind and circulation were considered to be outside the scope of this project, but their impact on daphnids is considered in the discussion in Chapter Six.

Chapter Three - The environmental impact of ferric dosing in Rutland Water

3.1 Introduction

This chapter analyses selected physical and chemical field data collected from Rutland Water by the NRA and its predecessors. Anglian Water Services Ltd began dosing Rutland Water with ferric sulphate in June 1990. The dosing regime is described in section 1.5.2. Initially, strategic parts of the reservoir (the inlet and the outlet) were dosed from a barge. The inlet pipe was later modified to enable direct dosing of the in flowing river water. The NRA came into being as a regulatory body in September 1989, at a time when cyanobacterial blooms in Rutland Water were at their highest concentration. Widespread monitoring began in 1990, to measure the impact of ferric sulphate in the reservoir, although some data collected during the 1980's was available for a number of sites. The monitoring programme continues under the successor body, the Environment Agency.

The aim of the analyses covered in this chapter was to investigate the physical and chemical effects of ferric sulphate additions on the water column, sediments and on the phytoplankton community which the practice aimed to reduce. Consideration of the effect of iron dosing on water chemistry facilitated assessment of the impacts on the daphnid population. This was achieved by examination of the physical and chemical data from sites around the reservoir and sediment data from several transects to test the hypotheses outlined below.

3.2 Hypotheses tested

3.2.1 Water level and ferric inputs

One major influence on water chemistry and plankton populations was water level. Changes in the inflow - outflow regime, and the period over which water is retained in reservoir (retention time) might be reflected in the fluctuations in the water chemistry.

The null hypothesis investigated was as follows:

> Physical and chemical measurements in the south arm were not affected by the addition of ferric sulphate to the reservoir (which itself only occurred when water was pumped into the reservoir) compared with other sites in the reservoir.

3.2.2 Environmental parameters

One possible impact of particulate iron additions was an increase in the amount of solid material in the water column. This would be measurable as a decrease in transparency and light transmission in parts of the reservoir where ferric was added, over and above seasonal variations. Any chemical reaction occurring as a result of the chemical addition of ferric sulphate might be measured as a change in temperature, over and above seasonal variations. The following null hypotheses were investigated:

> Light transmittance was not lower at the inlet compared with other sites in the reservoir;
>
> Light measurements in the reservoir for the period 1990-1994(post-dosing) were not lower than those for the period before 1990 (pre-dosing);
>
> Temperature was not higher at the inlet compared with other sites;
>
> Temperature in the reservoir for the period 1990-1994(post-dosing) were not lower than those for the period before 1990 (pre-dosing).

3.2.3 Water chemistry

The addition of ferric sulphate was expected to remove phosphorus from the water column, observed as a decline in total phosphorus. As a result of the interaction between nitrogen and phosphorus in the water column as plant nutrients, the removal of phosphorus from the water column might cause a decrease in algae biomass with the result that nitrogen increase in the water column as it is not taken up by plants. Iron and sulphate concentrations might increase as a result of their addition to the reservoir. Any chemical reaction occurring due to the addition of acidic ferric might lead to a measurable decrease in pH and alkalinity, and an increase in conductivity. The null hypotheses investigated were as follows:

Iron and sulphate concentrations were not higher at the inlet compared with other sites in the reservoir;

Iron concentrations were not significantly higher at greater depths than shallower depths;

pH and alkalinity were not lower at the inlet compared with other sites;

pH measurements in the reservoir for the period 1990-1994(post-dosing) were not lower than those for the period before 1990 (pre-dosing);

Conductivity was not higher at the inlet compared with other sites;

Conductivity measurements in the reservoir for the period 1990-1994(post-dosing) were not higher than those for the period before 1990 (pre-dosing);

Phosphorus concentrations were not lower at the inlet than at other sites in the reservoir;

Phosphorus concentrations in the reservoir for the period 1990-1994(post-dosing) were not lower than those for the period before 1990 (pre-dosing);
TON (Total oxidised nitrogen) concentrations were not higher at the inlet than at other sites in the reservoir;

TON concentrations in the reservoir for the period 1990-1994(post-dosing) were not higher than those for the period before 1990 (pre-dosing).

3.2.4 Sediment

The ferric floc might form an unconsolidated iron-rich layer over the natural sediments around the inlet. Phosphorus concentrations in the sediment would be expected to increase following precipitation from the water column. The addition of ferric sulphate to the reservoir as precipitated material might lead to an increase in sediment at the inlet site compared with elsewhere in the reservoir. The null hypotheses investigated were as follows:

Iron concentrations in the sediments were not higher around the inlet than in other parts of the reservoir;

Phosphorus concentrations were not higher in the sediments around the inlet than in other parts of the reservoir;

Sedimentation rates were not higher at the inlet where ferric sulphate was added than in other parts of the reservoir.

3.2.5 Algal biomass and species composition

The aim of the addition of ferric sulphate to the reservoir was a reduction in phytoplankton biomass and an increase in species diversity within dosed parts of the reservoir. Chlorophyll was considered a suitable measure of biomass, and species records have been kept since the reservoir began to fill in 1975. The following null hypotheses were investigated:

Phytoplankton biomass was not lower in the south arm compared with other sites in the reservoir;

Phytoplankton biomasses were not lower between 1990-1994 (post-dosing) compared the period before 1990 (pre-dosing);

Cyanobacteria were not less dominant in the summer phytoplankton of the south arm compared with other parts of the reservoir;

Cyanobacteria did not become less dominant in summer phytoplankton after 1990 (post-dosing) compared with the period before 1990 (pre-dosing).

3.3 Sampling methodology

3.3.1 Data availability and sample points

The data collected by the NRA and its predecessors was considered for the period 1981 to 1994. Weekly data were held for selected determinands from sites in the north arm (buoy N1 and Secondary Tower) and the Limnological Tower in the main basin for most of this period. For these sites and buoy S12 in the south arm, weekly data has been collected since 1990 to monitor the effects of ferric additions and from the inlet since 1992. The location of these sample points is shown in figure 3.1. During 1993 the sediments were measured bimonthly in several transects to determine the distribution of the ferric floc, that formed a layer above the natural sediments (figure 3.2). Also during 1993, a seven site transect in the south arm was sampled for chlorophyll and iron (figure 3.3).

3.3.2 Collection of Samples

(i) Hydrological measurements and ferric inputs

Anglian Water Services Ltd. provided data on percentage fill from which reservoir capacity was calculated, and also inflow and out flowing water volumes. They also supplied information on inputs of ferric sulphate.

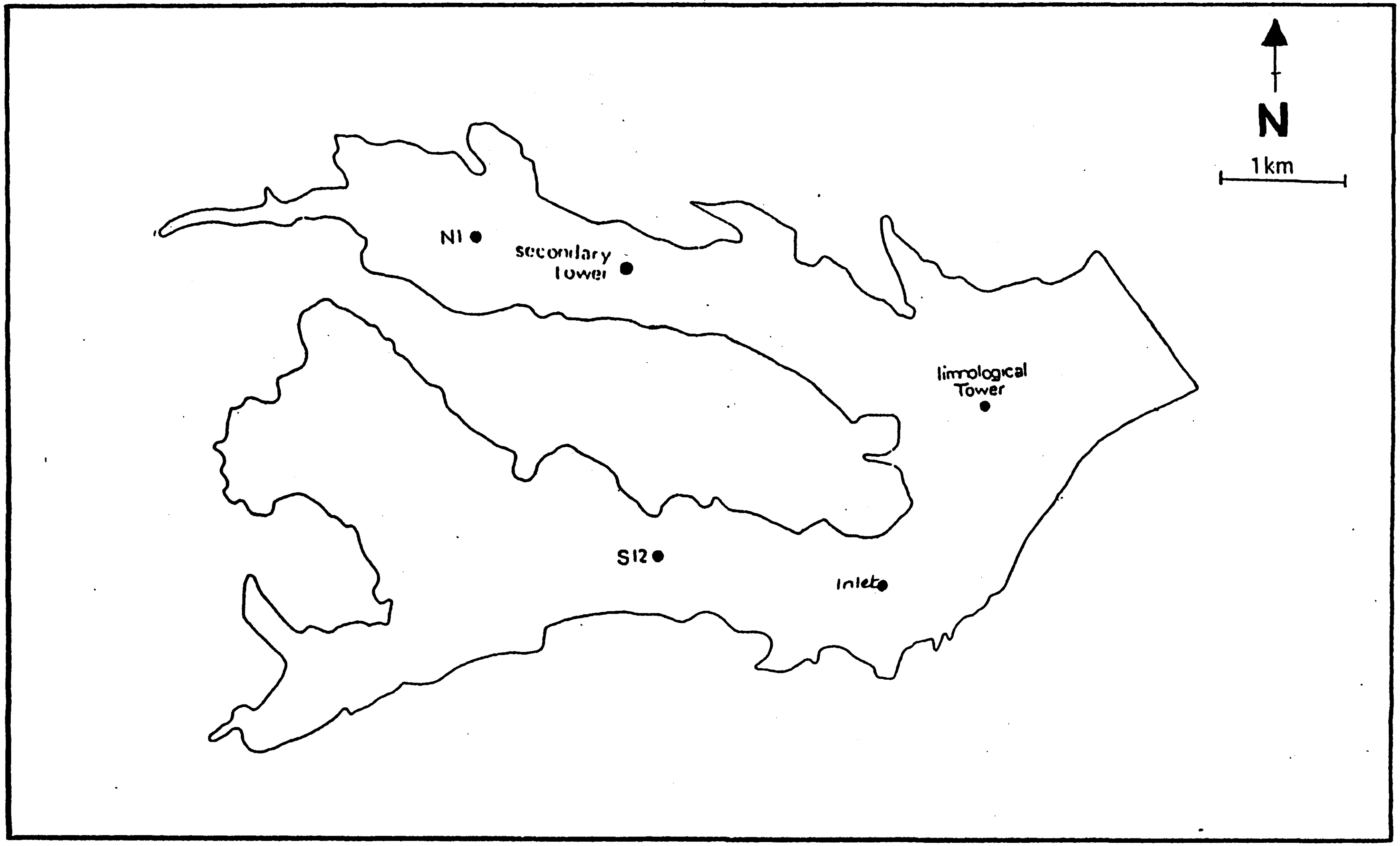


Figure 3.1 Location of NRA sampling points

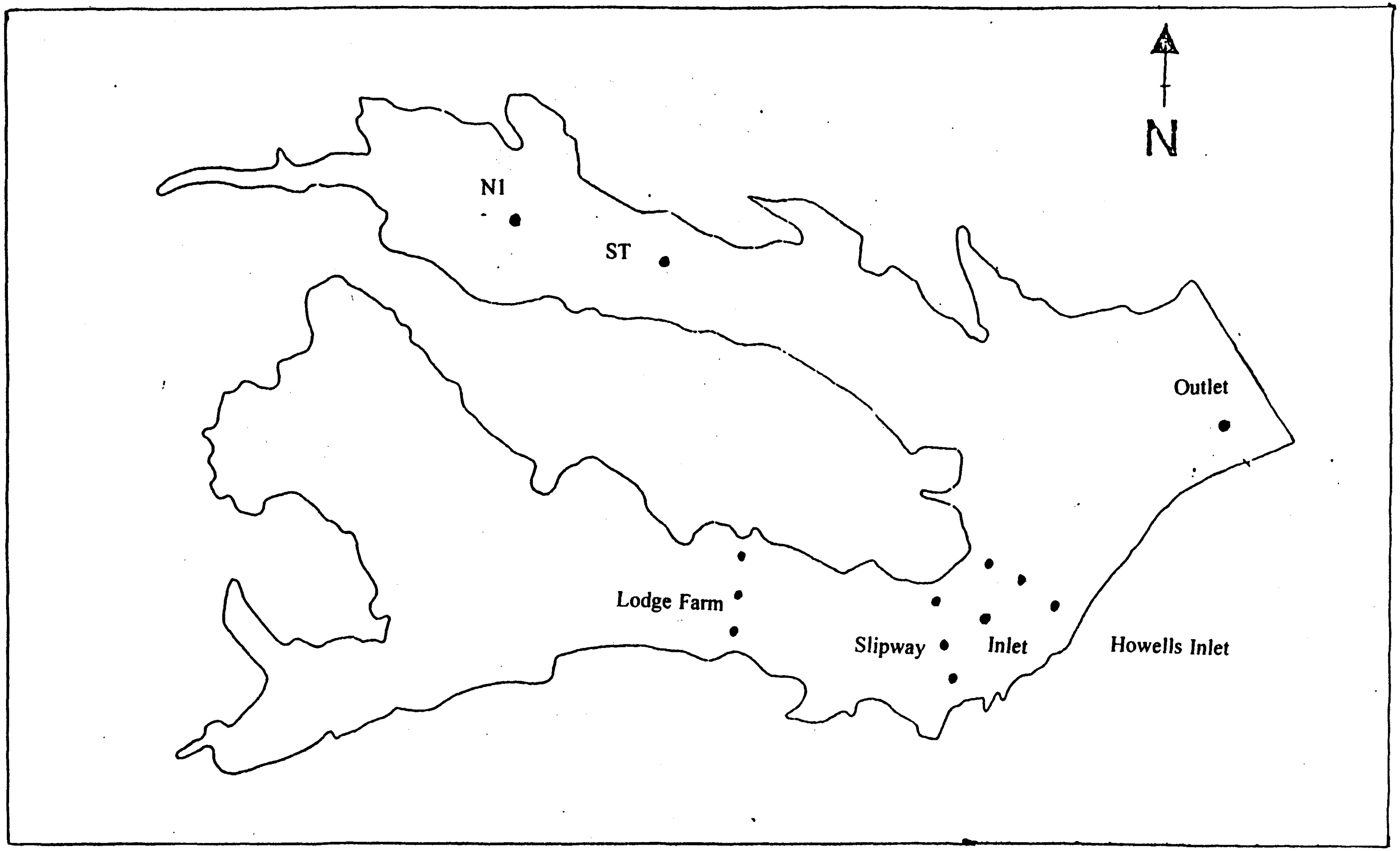
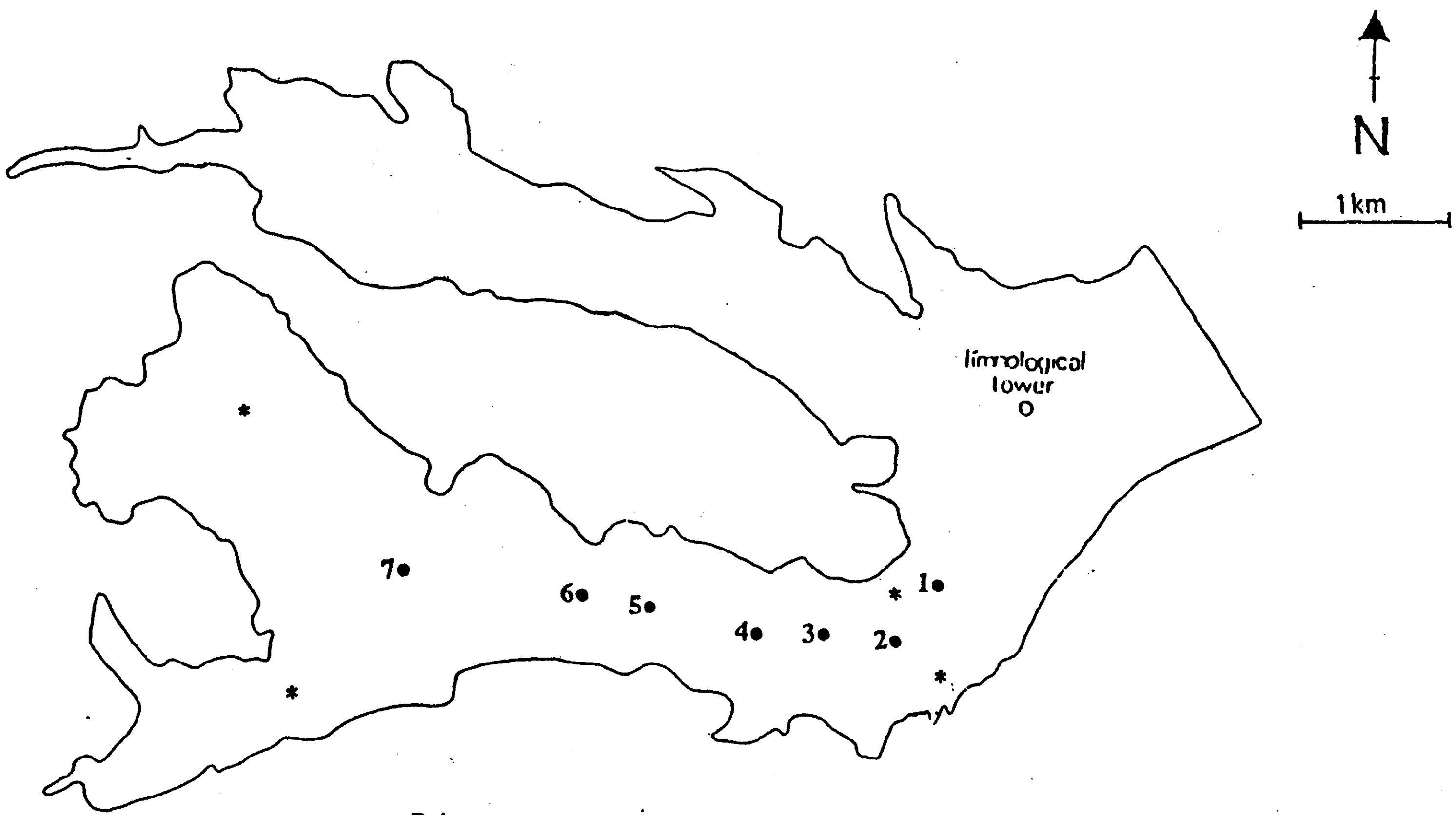


Figure 3.2 Location of sediment sampling points



Points represented by an '*' were used initially in 1992. These points were, however, in shallow water (<5m deep) where grazing pressure particularly by fish fry was high. It was, therefore, decided that the data from these sites was not comparable with other points. The data collected from these sites has not been included in this thesis.

Figure 3.3 South arm transect sites

(ii) Physical measurements

Secchi depth was measured weekly using a Secchi disk (HMSO, 1985), which was 20cm in diameter, with six segments alternately coloured black and white. The disk was lowered into the water from the side of a boat which was unaffected by shade, and the depth at which the disk was no longer visible noted. pH, light, conductivity, dissolved oxygen and temperature were measured using an automatic analyser fitted with probes (Windermere Profiler 2, Institute of Freshwater Ecology), which was lowered through the water column taking measurements at 0.5m intervals, which were recorded into a portable computer.

(iii) Water chemistry

Sample collection methods have evolved since sampling began in the reservoir. Since 1990 samples were collected weekly for analysis of the water chemistry using a 5m long rigid, opaque, plastic tube. This was lowered into the water until the top of the tube was just submerged. A bung was placed on the end of the tube, which was carefully drawn out of the water and the contents poured into a 10 litre bucket. This procedure provided an integrated sample between 0 and 5 metres. The contents of the bucket were then mixed thoroughly and poured into labeled containers - opaque 1 litre Nalgene polythene bottles for chlorophyll *a*, and transparent bottles for other chemical attributes - TON (mg l^{-1} N), Total P (mg l^{-1} P), Alkalinity ($CaCO_3$ mg l^{-1}, Total Fe (mg l^{-1} Fe) Sulphate (mg l^{-1} SO_4). At each of the seven sites in the south arm, a 10 litre water sample was collected from 2, 4, 6, 8, and 10m depth, emptied into a bucket and mixed. The contents were then poured into labeled containers as above for iron and chlorophyll *a* analysis.

(iv) Sediment

Sediment was collected monthly using an Ekman grab (Ekman, 1947). The grab was discharged using a brass messenger on the rope once the grab reached the reservoir floor. The grab was brought up to the surface carefully and emptied into a tray. A 5ml sample of sediment was collected into a plastic tube, for analysis of iron (g kg^{-1}), total phosphorus (mg kg^{-1}), and other measurements. Sedimentation rates were estimated using 4 replicate tubes at the inlet and the Limnological Tower, which were left for a known period of days before being drawn up to the surface and the contents emptied into labeled plastic tubes.

3.3.3 Preservation and analysis of samples

All water samples were transported to the laboratory in a cool box. Chlorophyll samples were analysed within four hours of return. If it was not possible to complete the analysis on the same day, they were filtered and frozen. Other water samples were transported the same day to the NRA's regional laboratory for analysis. The sediment samples were dried in an oven at 105 °C, and 5g of each sample were sent to the regional laboratory. The analytical methods used to analyse some of the water and sediment samples are described in appendix I(a) and I(b), although a summary of the methods used is given in Table 3.1.

3.4 Data analysis

3.4.1 Water chemistry and physical measurements

The aim of the examination of the NRA data was to establish the baseline water chemistry of Rutland Water and the effect of ferric dosing on it. Temporal variations in physico-chemical parameters were examined graphically for seasonal trends. Two way analysis of variance (ANOVA) was conducted on the data for August and September for the years 1990 to 1994, to investigate the null hypotheses that physico-chemical parameters did not differ significantly from year to year or from site to site. Such analyses carried out on the wholedataset was considered misleading due to the effects of seasonal variation (daylight hours, air and water temperature, rainfall). Figures 3.4, 3.5, and 3.6 were used to find periods of time since 1990 when hydrological circumstances in the reservoir were similar, apart from ferric dosing. August and September were chosen as two months when these conditions were met. The reservoir was usually >80% full between 1990 to 1992, and in 1993 and 1994 >90% full. Inputs in 1992 were higher than in other years, which is reflected in higher additions of ferric sulphate at this time. Two way ANOVA was carried out on the 0-5m water samples and on the results for the upper 10m only from the automatic analyser data. The results of these analyses are tabulated in the appendix II(l).

Table 3.1 Summary of analytical methodologies

Determinand	Method (ref)	Summary
Alkalinity	Flow injection analysis (HMSO, 1981a & b)	Weakly buffered methyl orange is mixed with the sample and the colour change is measured. Method 11 (NRA, 1991)
TON	Flow injection analysis (HMSO, 1981a & c)	Redution of nitrate to nitrite in copperized cadmium column which reacts with sulphaniliamide NEDD reagent to produce a magenta dye, the concentration of which is measured colorimetrically. Method 9 (NRA, 1991)
Sulphate	Flow injection analysis (HMSO, 1981a)	Sulphate reacts with barium chloride in acid solution to form a suspension of barium sulphate & turbidity is measured at 420nm. Method 20 (NRA, 1991)
Total P (in water)	Manual digestion & air segmented continuous flow (HMSO, 1980)	Hydrolysis of phosphorus compounds to orthophosphate using persulphate oxidation and sulphuric acid. Orthophosphate is then measured by air segmented continuous flow. Phopshorus reacts with ammonium molybdate under acid conditions to form molybdo-phosphoric acid which is reduced using ascorbic acid to phosphomolybdenum blue and is measured colorimetrically. Method N35 (NRA, 1991)
Total P (in sediment)	Microwave digestion followed by flow injection analysis (HMSO, 1981a)	Hydrolysis of phosphorus compounds by acid microwave digestion. Orthophosphate measured by continuous flow analysis. Reaction with acid molybdate reagents to form reduced phosphomolybdenum blue complex, the concentration of which is measured colorimetrically. Method N61 (NRA, 1991)
Total Fe (in water)	Atomic absorption spectophotometry (HMSO, 1979)	Iron is measured against a standard using atomic absorption spectrophotometry. Method 216 (NRA, 1991)
Total Fe (in sediment)	Microwave digestion followed by atomic absorption spectrophotometry (HMSO, 1979)	Hydrolysis of iron compounds by acid microwave digestion.Iron is measured against a standard using atomic absorption spectrophotometry. Method 200 (NRA, 1991)

3.4.2 Sediments

All results for the sediment transects were compared using two way ANOVA to investigate the null hypotheses that the results at each site did not vary significantly over time, or between sites.

3.5 Results

3.5.1 Water level and ferric inputs

Figures 3.4 and 3.5 show the hydrological inputs and reservoir capacity since the reservoir began to fill. The inputs and outputs fluctuated month by month probably with seasonal fluctuations in the river inputs. An additional strategy carried out by AWS Ltd to aid the reduction of phosphorus in the reservoir, was a reduction in the volume of water pumped from the rivers (P. Daldorph, pers. comm.). The reservoir capacity fluctuated too but was generally above 80% full. Between the end of 1989 and autumn 1992 the capacity declined to about 65% as a result of the drought. Table 3.2 shows the retention time of the reservoir in years (data supplied by J. Krokowski, pers. comm.) This was calcutaed from the inflowing and outflowing volumes. Retention time was highest when the reservoir was filling, and lowest between 1987 and 1991 and it has risen since then. Figure 3.6 represents the monthly inputs of ferric sulphate since June 1990. Dosing was greatest between January and May 1991 and December 1991 to September 1992. Dosing continued during 1993 and 1994, but at a lower level.

Table 3.2 Retention times in Rutland Water 1977 - 1993

Year	Retention time (yr)	Year	Retention time (yr)
1977	35.59	1986	2.10
1978	21.63	1987	1.98
1979	3.01	1988	3.22
1980	2.51	1989	1.75
1981	2.76	1990	1.43
1982	2.65	1991	1.51
1983	2.47	1992	2.14
1984	2.41	1993	2.08
1985	6.75		

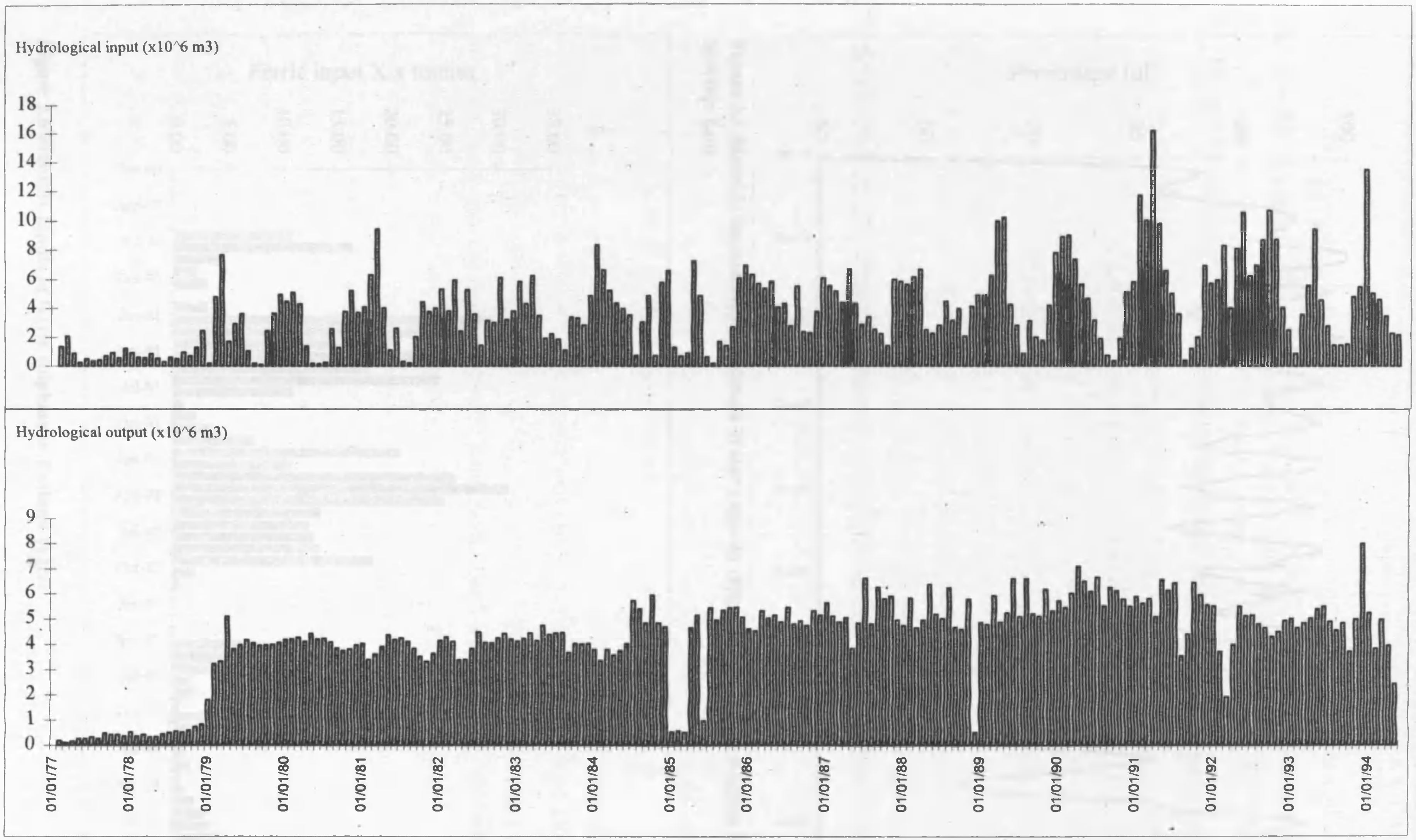


Figure 3.4 Monthly fluctuations in the total hydrological inputs to and outputs from Rutland Water

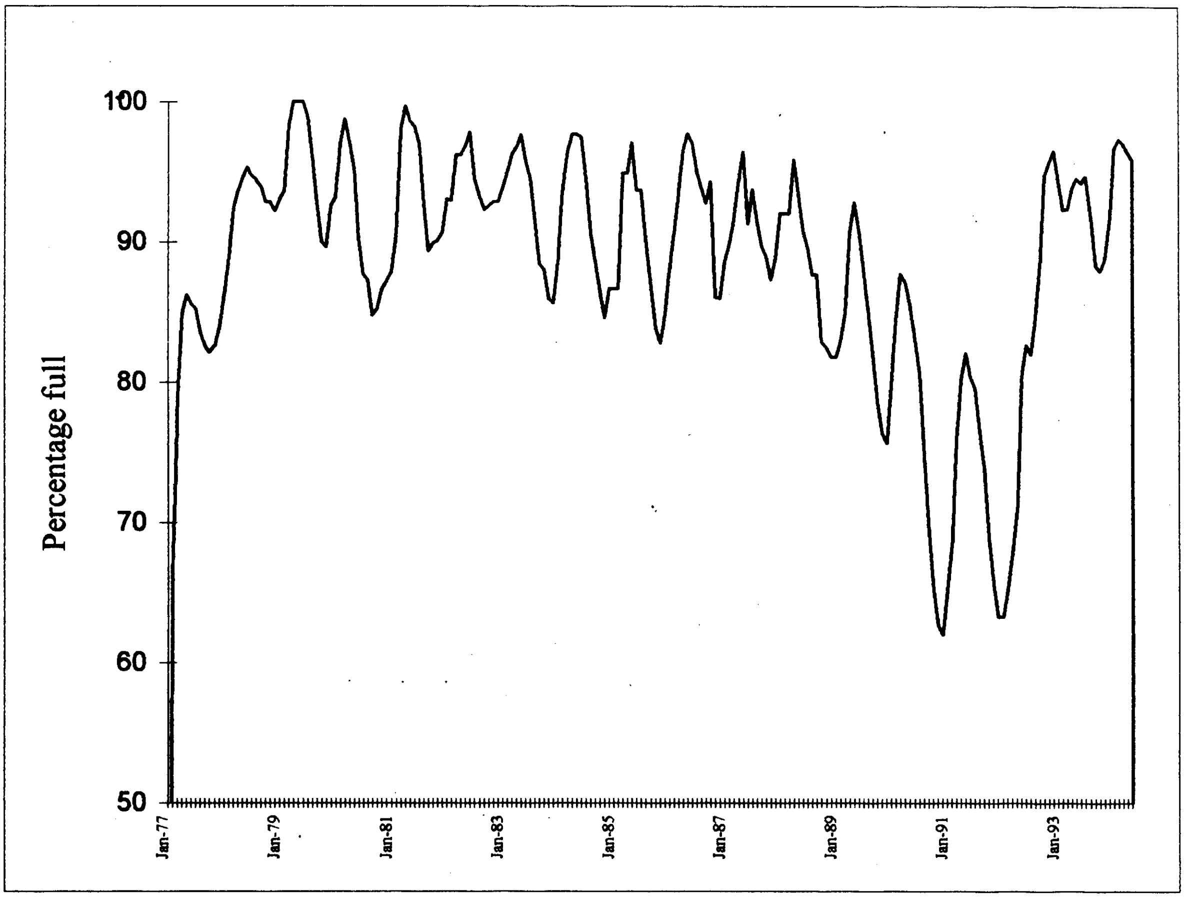


Figure 3.5 Monthly fluctuations in Rutland Water capacity (Figures supplied by Anglian Water Services Ltd)

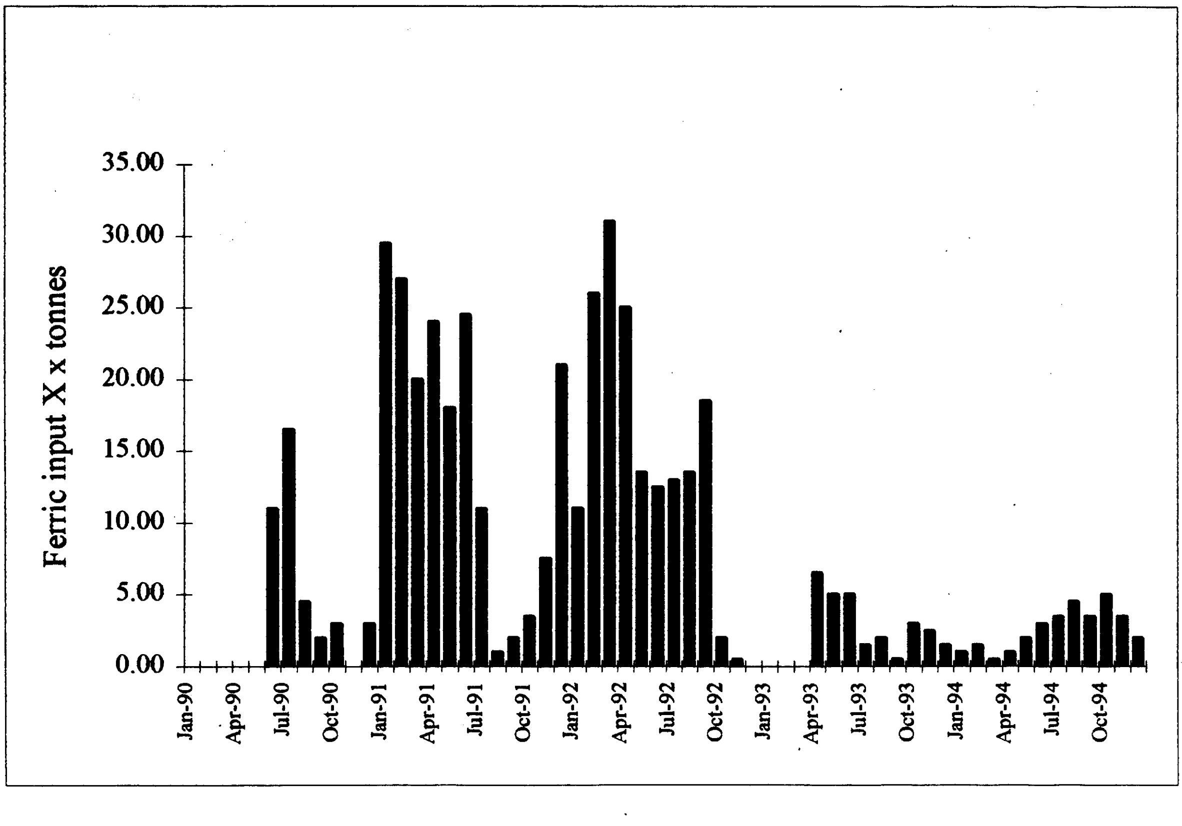


Figure 3.6 Monthly inputs of ferric sulphate to Rutland Water

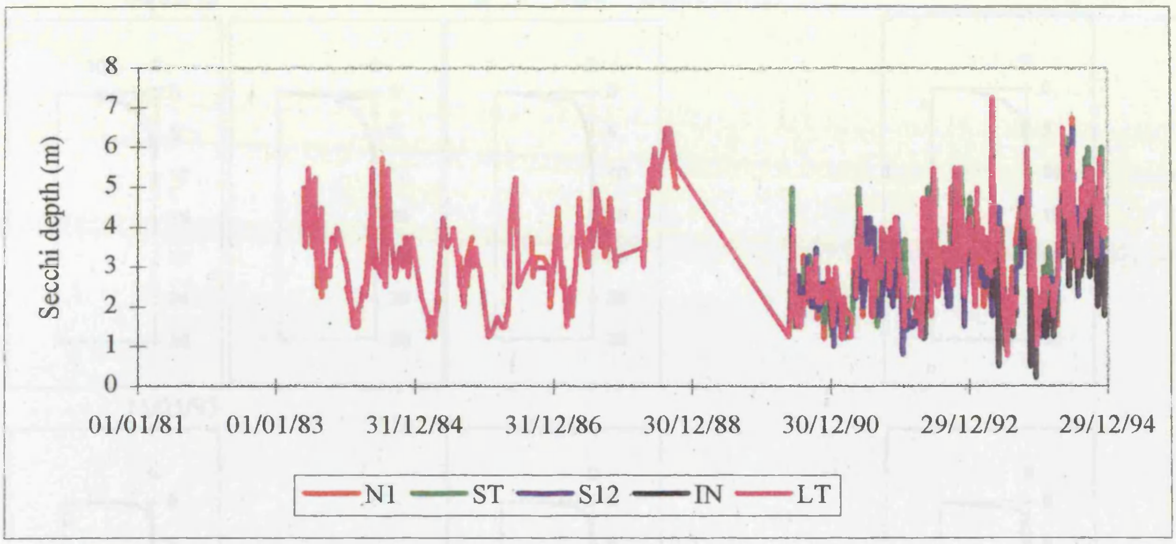
3.5.2 Environmental parameters

Figure 3.7a shows the secchi depth recordings since 1983. Secchi depth varied over the year and from year to year, and were highest in 1988 and 1994. Between 1983 and 1990 the lowest secchi depth was about 1.25m (raw data in appendix II(b)). From 1990 onwards secchi depths of less than 1m were recorded annually. Secchi depths at buoy S12 and the inlet (IN) both of which are in the south arm, are frequently lower than at other sites, although not significantly so ($p>0.05$). There was no correlation between secchi depth and tonnes of iron input into the reservoir ($r=0.003$), or between water temperature and secchi depth ($r=0.065$), using Kendalls rank correlation coefficient. Covariance analysis established that there was no relationship between secchi depth and the retention time of the reservoir 1984-1988 ($r=-0.144$) or 1990-1994 ($r=0.276$); or chlorophyll concentrations 1984-1988 ($r=-0.189$) or 1990-1994 ($r=-0.46$). Light measurements with the automatic analyser also showed a wide variation at the top of the water column over the years (figure 3.7b). Raw data are given in appendix II(b).

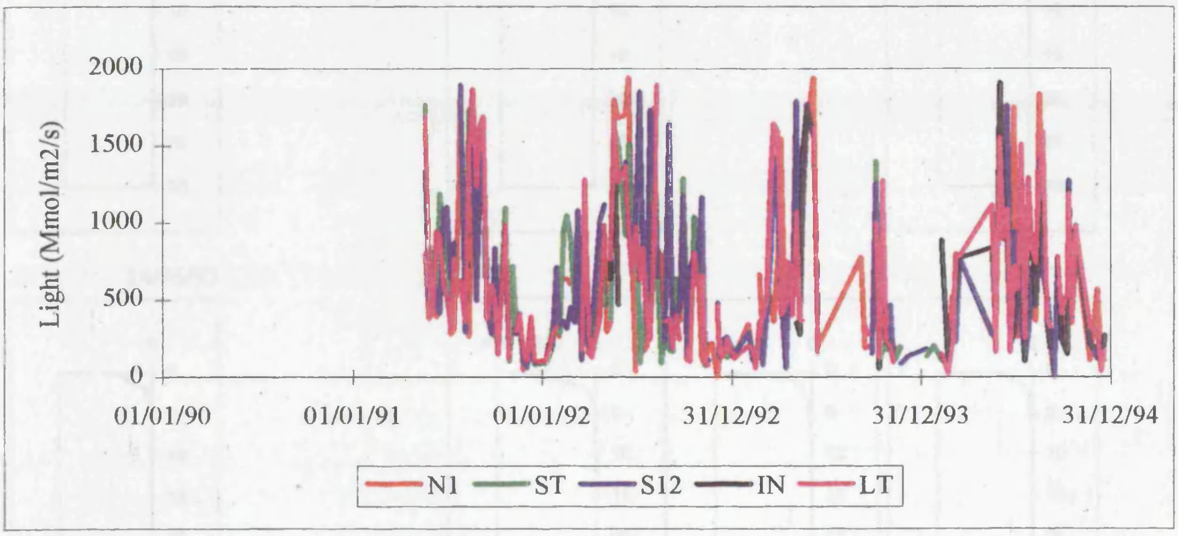
Figure 3.8 shows the seasonal variation in light penetrating the whole water column, which was quickly lost with depth. In January light penetrated to 10m depth, and around 5m during the rest of the year. Raw data are in appendix II(g).

Water temperature fluctuated with the season each year, with little variation from site to site since records began in 1981 (Figure 3.7c). Surface temperature increased smoothly in spring to a maximum in June or July. Some fluctuations were observed in summer with a decline from September onwards. The long-term data showed no change in this pattern since dosing began in 1990. Analysis of variance conducted on August and September data showed that temperatures at N1 and S12 were significantly lower in 1993 ($p<0.05$) than in other years. The temperature throughout the whole water column showed wide variation (figure 3.9). Temperature was stable at LT and N1 buoys throughout the whole water column in January, but increased by up to 1°C with depth at ST and S12 buoys. Throughout the summer temperature declined with depth by less than 2°C, but stabilised by September. Raw data are given in appendix II(b).

a) Secchi depth



b) Light



c) Water temperature

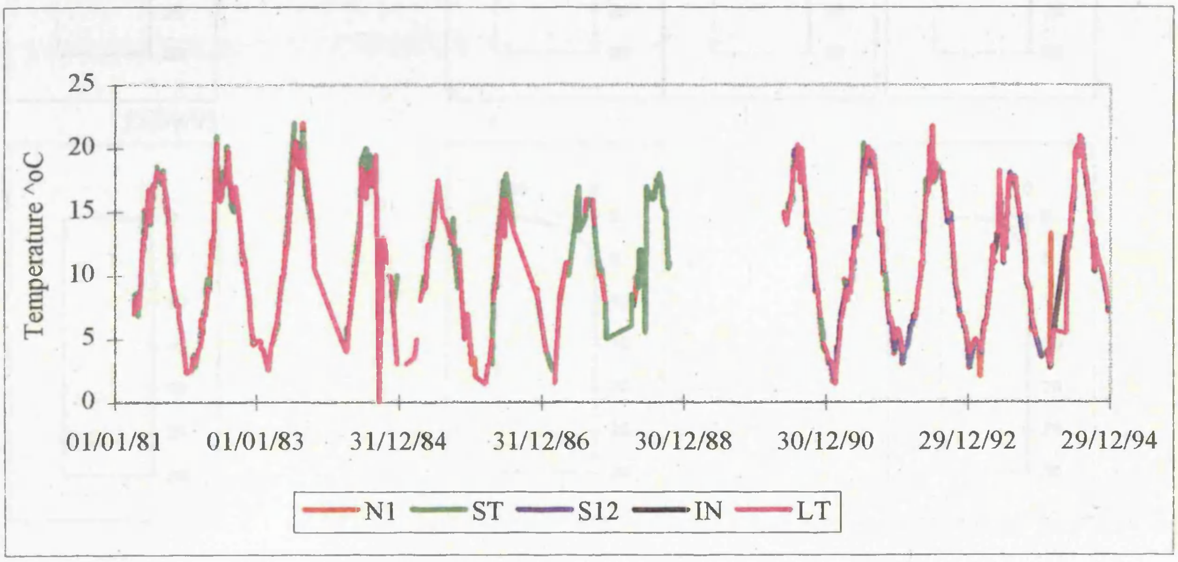


Figure 3.7 Environmental parameters in Rutland Water

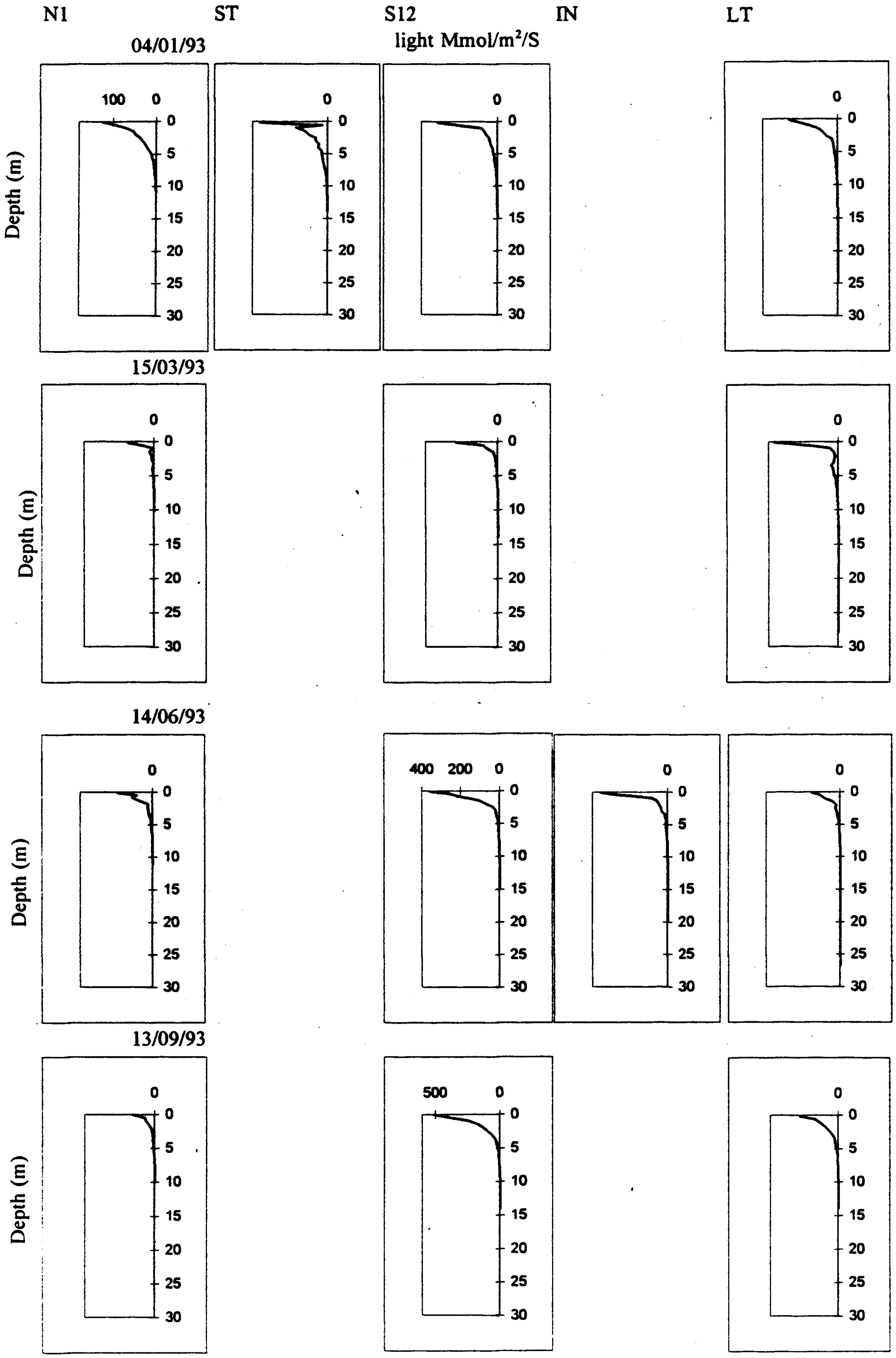


Figure 3.8 Depth profile of light (Mmol/m2/s) in water column in Rutland Water

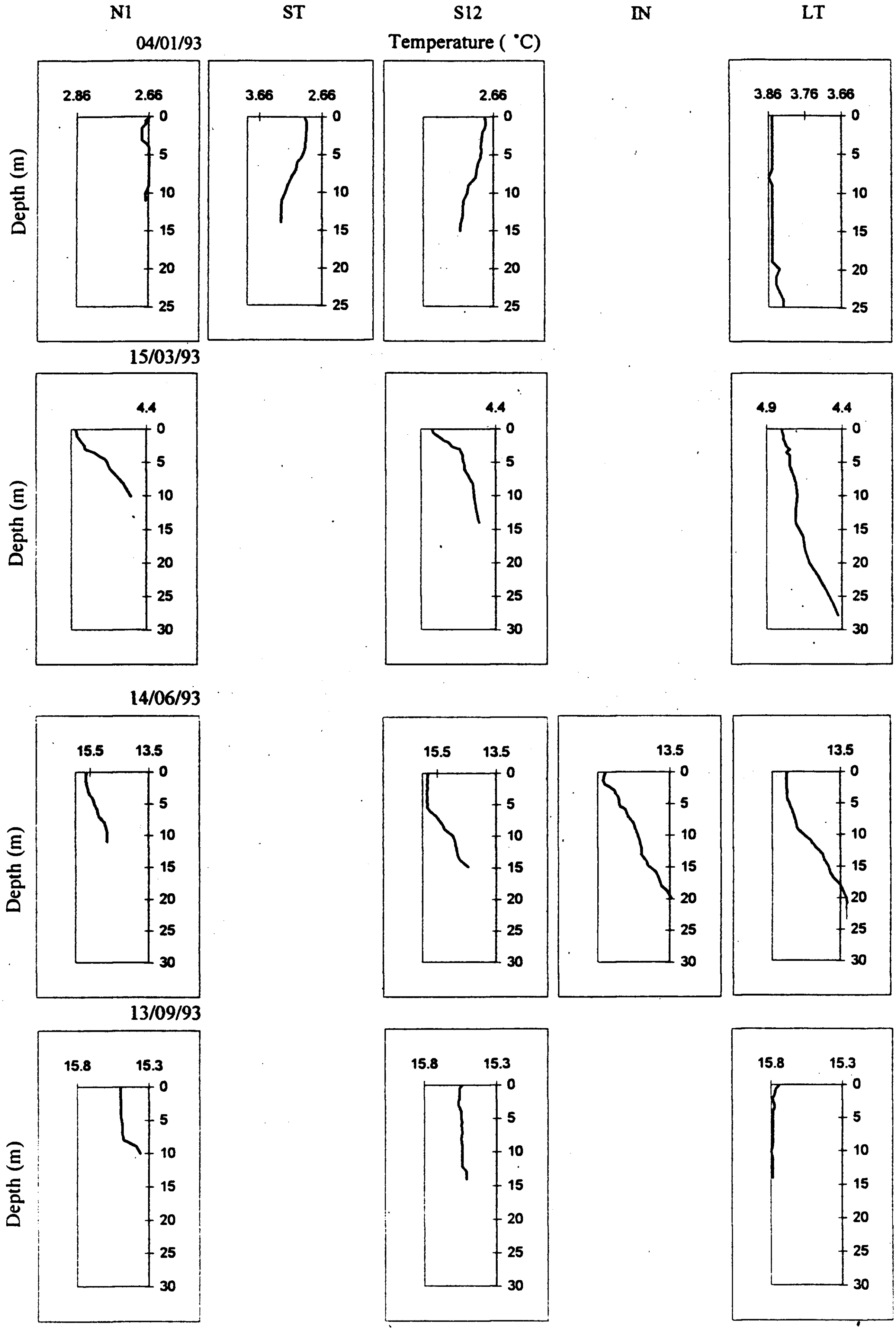


Figure 3.9 Depth profile of Temperature (Degrees Centigrade) in water column in Rutland Wate

3.5.3 Water chemistry

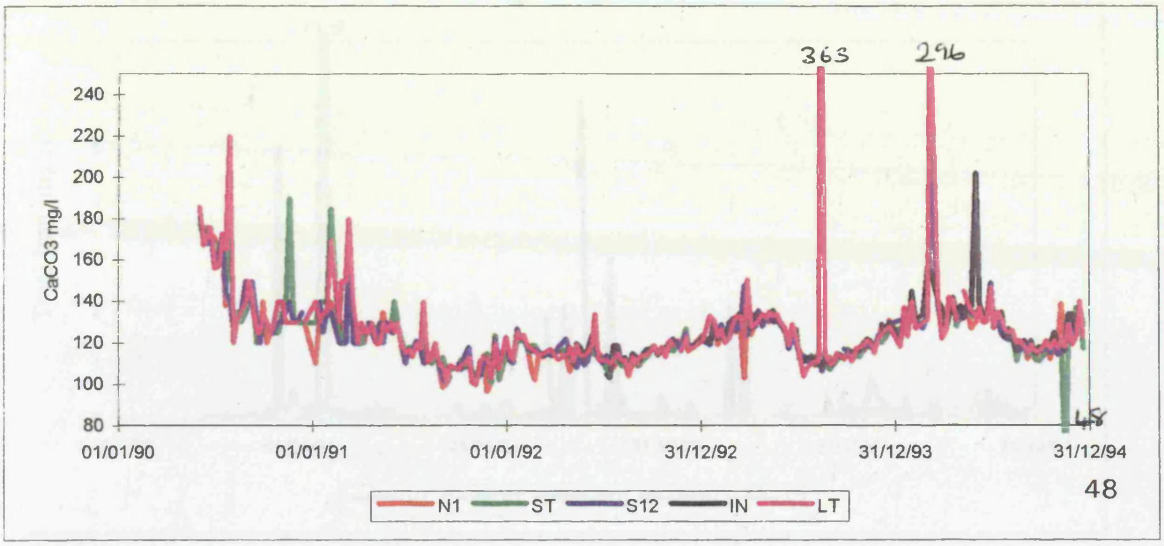
The total iron concentration in the water column (0-5m) were generally less than 0.5mg l^{-1} at most sites (fig 3.10a). The majority of this was particulate iron. Dissolved iron (<0.45μm) was typically below the limit of detection 0.05mg l^{-1} (S. Brierley, pers. comm.) Maximum figures of 5.06 mg l^{-1} at S12 (19/11/90); 17.5mg l^{-1} at ST (20/2/91); 1.74mg l^{-1} at N1 (22/6/92); and 1.7mg l^{-1} at site S12 (23/1/93) are unusual. ANOVA showed significantly more iron occured around the inlet than at other sites ($p<0.05$). Figure 3.11 shows the total iron concentration at depths 2, 4, 6, 8 and 10m at two sites in the south arm in 1993. Total iron was significantly higher at depths 8 and 10m ($p<0.05$; $F=4.22$; $n=30$) at site 2 (inlet) than site 6 (appendix II(e)). Figure 3.12 shows the iron concentrations in a south arm transect of 7 sites (data in appendix II(c)). The concentration was generally higher at sites 1 and 2 in the eastern end of the reservoir, although ANOVA showed them not to be significantly so ($p>0.05$; $F=0.66$; $n=44$).

Figure 3.10b shows that sulphate was typically between 150 - 200mg l^{-1} between 1992-1994, fluctuating at each site throughout the year. ANOVA showed there were no significant differences between the sites ($p>0.1$).

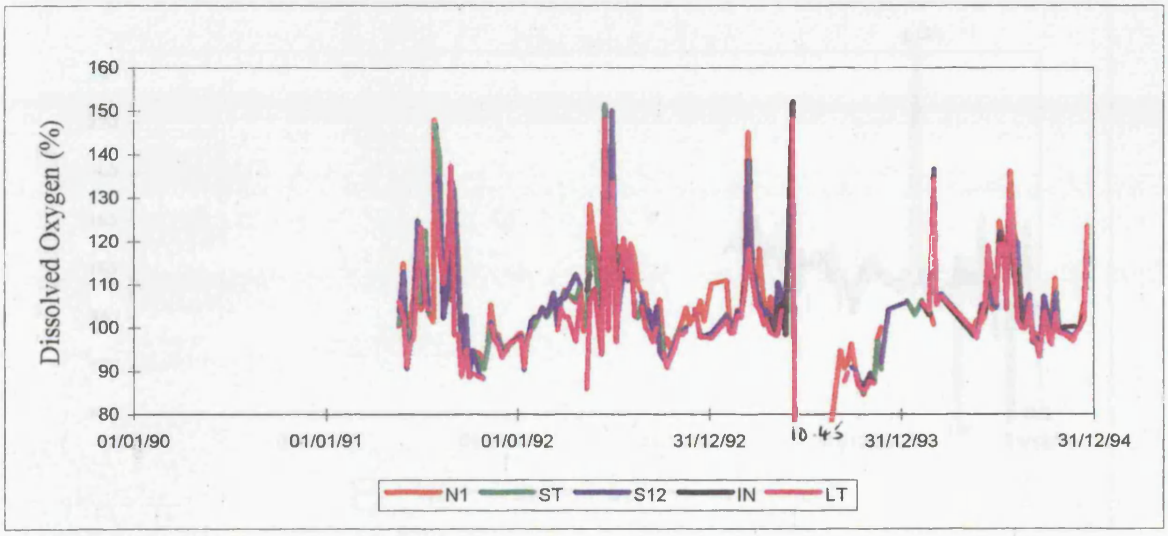
pH in the top 5m of the water column, fluctuated between 8.5 in the summer to 7.8 in the autumn (figure 3.10c), although measurements as low as 6.75 have been recorded since 1990 (appendix II(a)). All sites showed the same fluctuation. ANOVA showed that in 1990/91 pH was significantly lower at N1 than at other sites ($p<0.05$) and at the inlet in 1992 ($p<0.05$), and significantly lower at LT in 1994 ($p<0.001$). Figure 3.13 shows that pH profiles in the water column vary between 0.5-1 pH unit over that depth (appendix II(g)). The profiles were different for each site, although ANOVA showed these differences were not significant ($p>0.05$).

Figure 3.10d shows the temporal variation in alkalinity measured as $CaCO_3$mg l^{-1} at each site in the reservoir. Throughout 1990, there was an overall decline in alkalinity at each of the four sites then sampled (LT, ST, N1, S12). Alkalinity increased over the autumn and winter and declined in the spring and summer. This seasonal trend occurred at each

d) Alkalinity



e) Dissolved oxygen



f) Conductivity

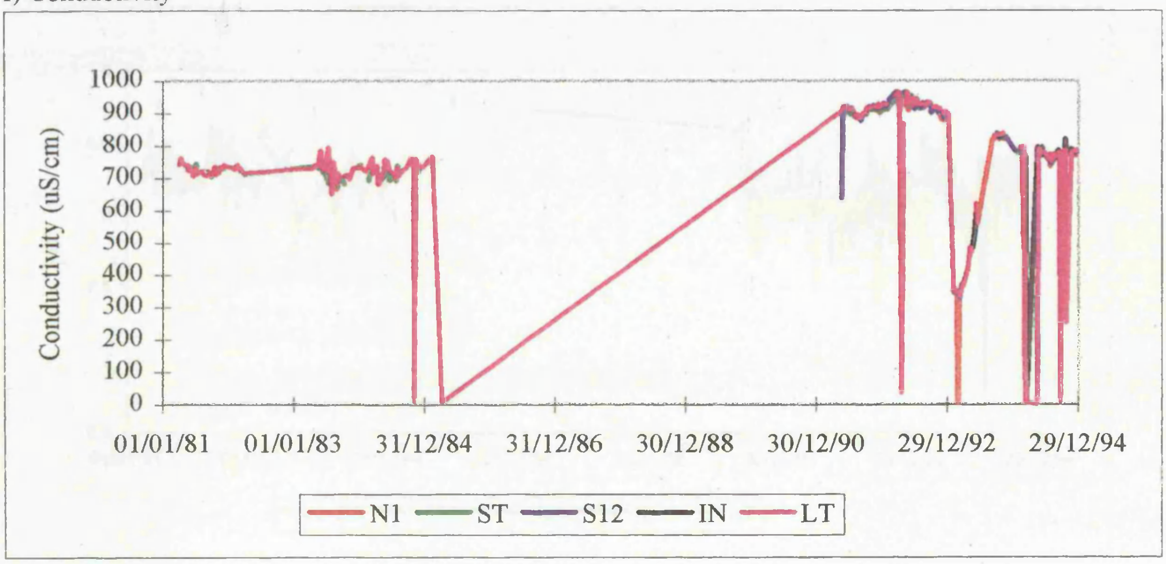
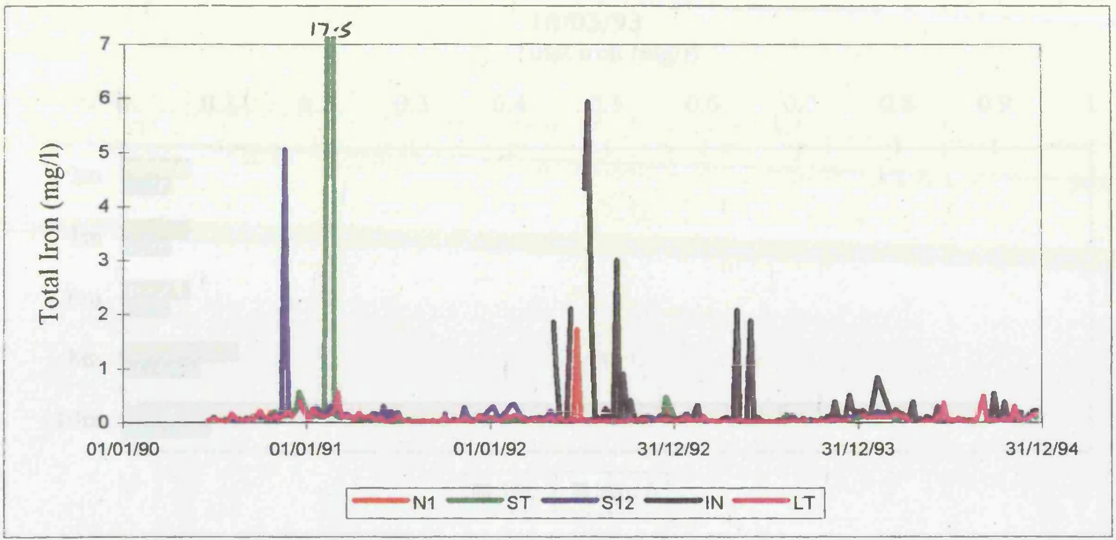
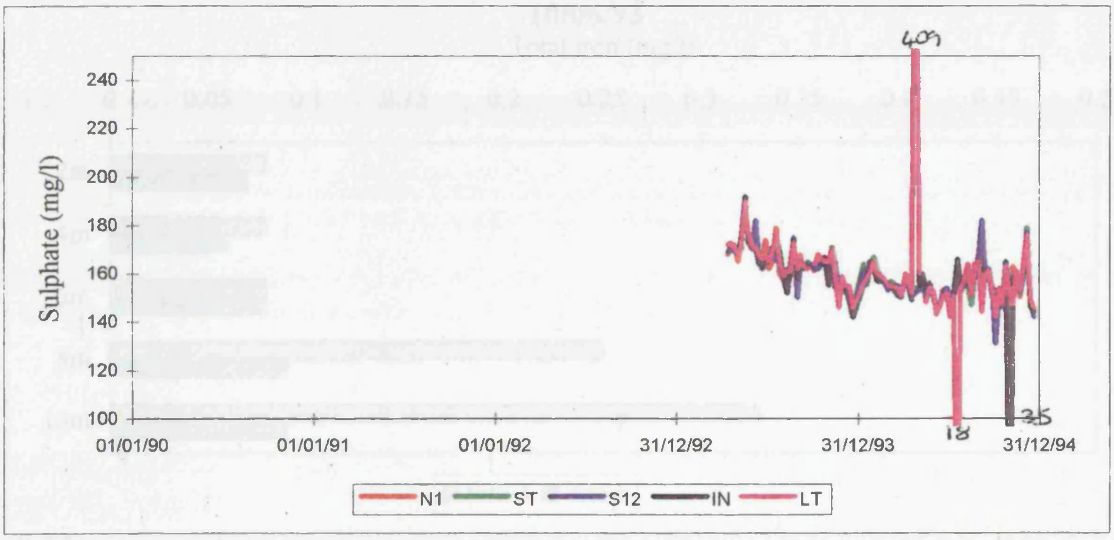


Figure 3.10 Water chemistry in Rutland Water

a) Total iron



b) Sulphate



c) pH

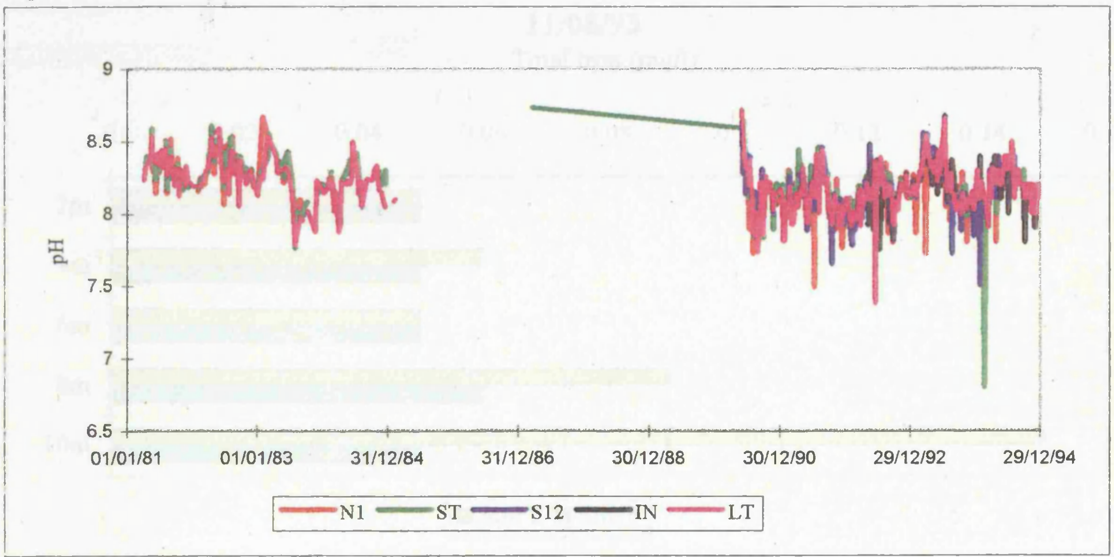


Figure 3.10 Water chemistry in Rutland Water

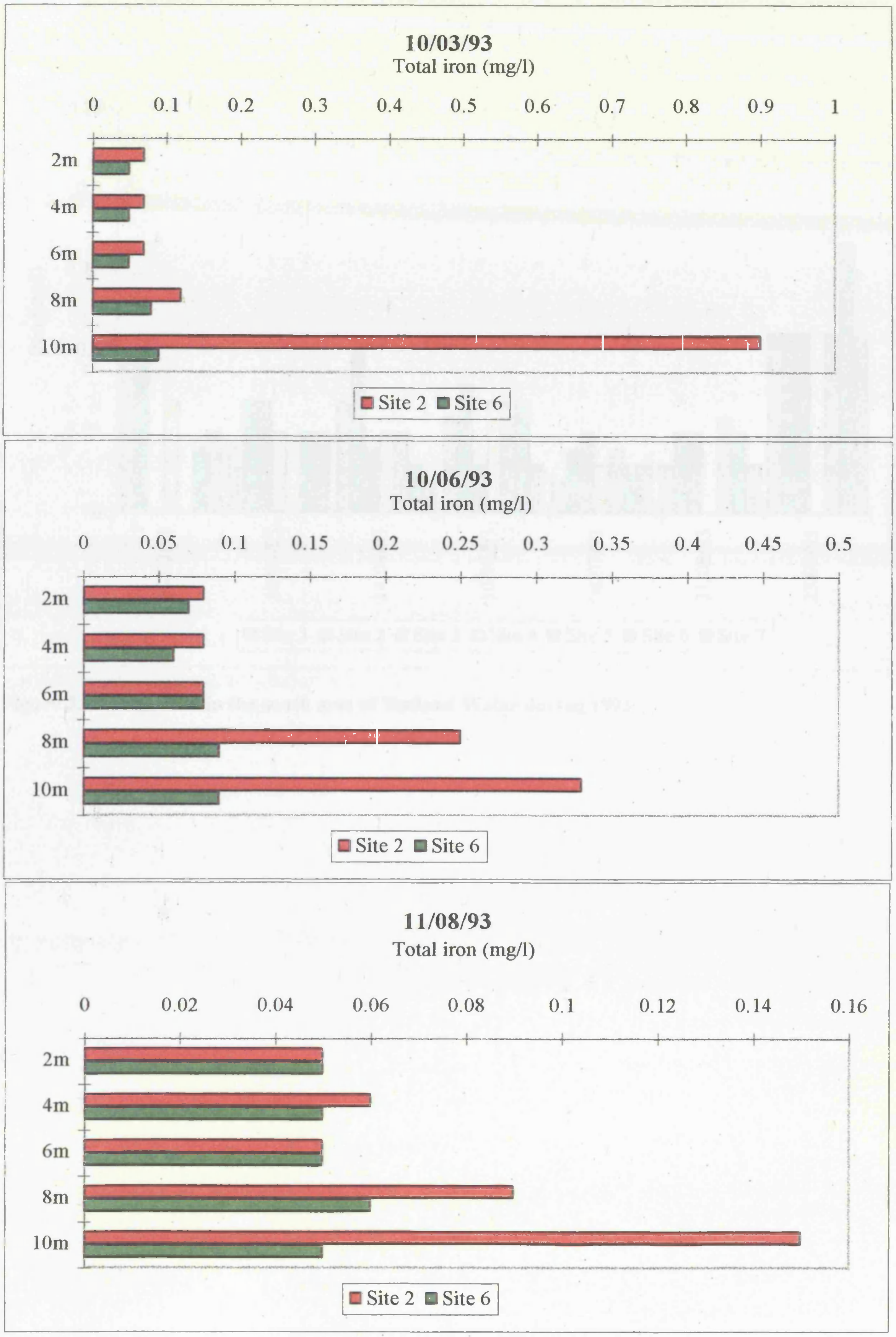


Figure 3.11 Depth variation in total iron at 7 sites in the south arm of Rutland Water

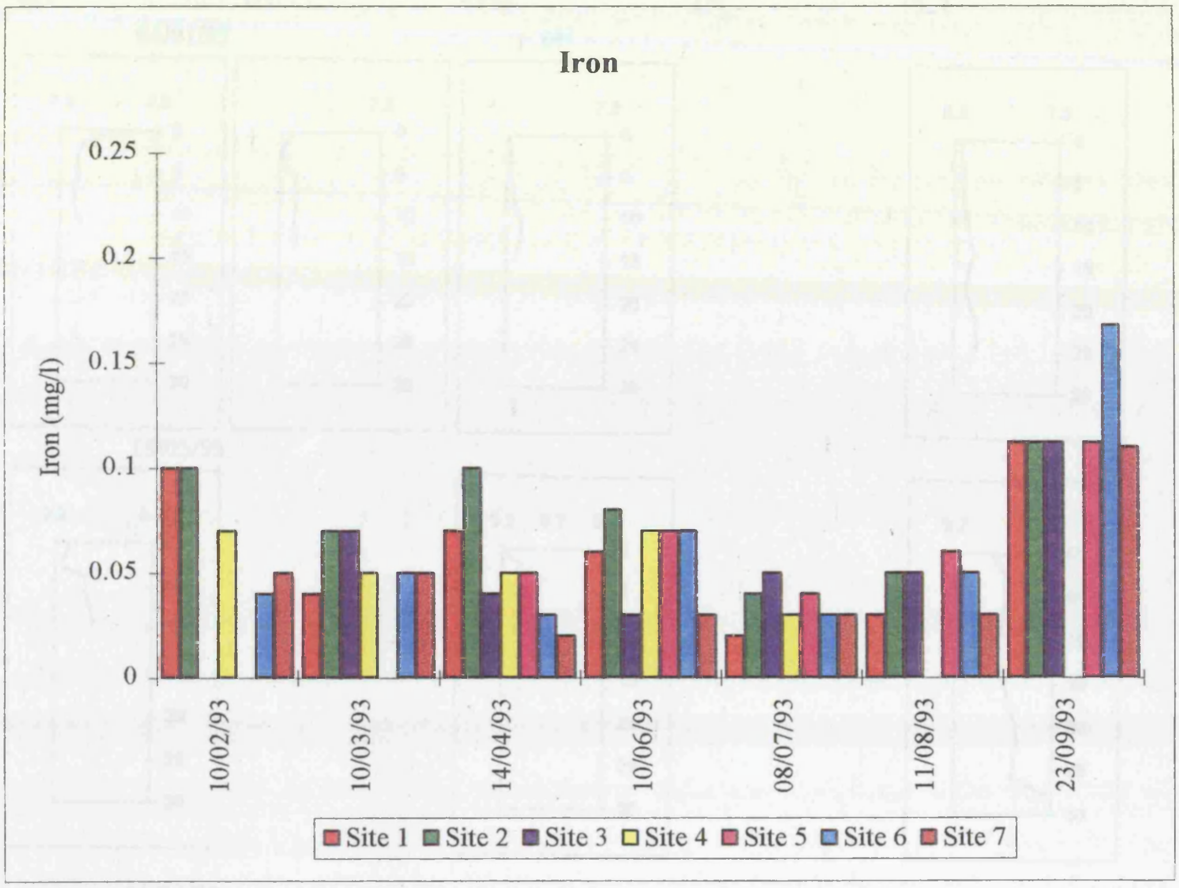


Figure 3.12 Total iron in the south arm of Rutland Water during 1993

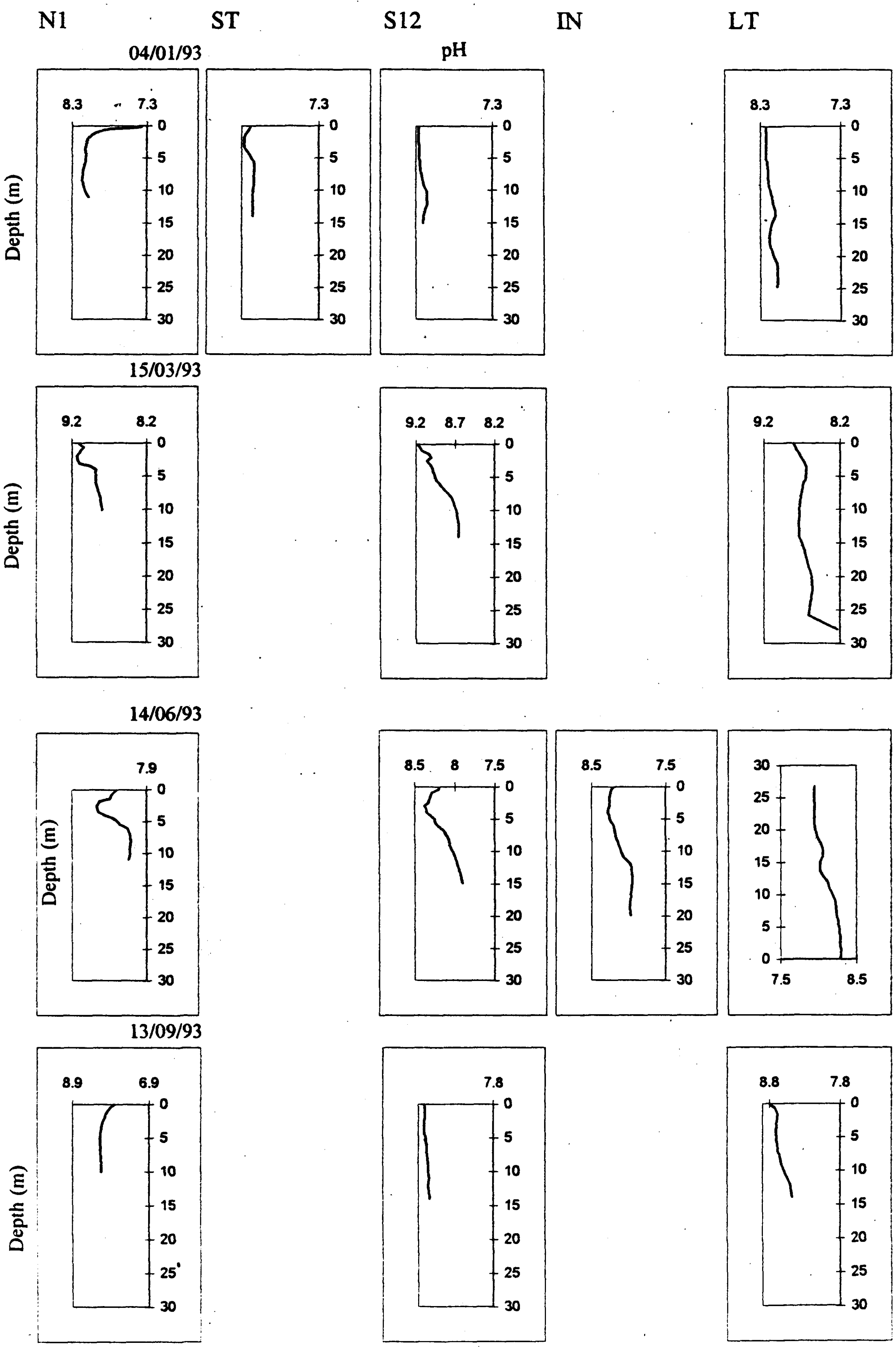


Figure 3.13 Depth profile of pH in water column in Rutland Water

site, and ANOVA established that there were no significant differences between the sites (appendix III).

Dissolved oxygen was generally between 90 - 100% at the surface at all sites in the reservoir (figure 3.10e), and is significantly lower within the top 10m at the inlet in August and September 1993 and 1994 ($p<0.05$) (raw data in appendix II(a)). Figure 3.14 shows the profile of dissolved oxygen throughout the water column in 1993 (appendix II(g)). The scale on 14/6/93 is thought to reflect an error in the probe, although the pattern of the profile itself is considered to be correct. The lowest dissolved oxygen percentage occurred in September, although it was still above 85%.

Surface conductivity is shown in figure 3.10f. Between 1981 and 1984 measurements between 700 and 800 μS/cm were recorded, increasing to 900 μS/cm between 1991 and 1992, probably reflecting the addition of volumes of ferric sulphate at this time. This has declined since 1991 to 800. There was a dramatic decline at all sites at the beginning of 1993 from which there was a slow return over 9 months to near former levels. Conductivity was significantly lower at LT in August and September 1994 ($p<0.001$) possibly as a result of some very low measurements at this site. Figure 3.15 shows the conductivity profile at the 5 sites at times throughout 1993. Conductivity varied with depth at each site throughout the year.

Total phosphorus measurements began in 1986 (figure 3.16a) (appendix II(a)). Peaks above 0.2mg l^{-1} were observed twice in 1988 at N1. Peaks above that were often seen between 1990 and 1994, although the general trend was a decline since records began. Total phosphorus was highest in spring and lowest in winter. ANOVA showed there was significantly more phosphorus in the water column at the inlet than at other sites ($p<0.05$), and the concentrations were significantly higher in 1992 and 1993 than in 1994 ($p<0.05$).

Figure 3.16b shows that the total oxidised nitrogen (TON) measured until 1990 in the reservoir was lower (between 1 - 3 mg l^{-1}) than in subsequent years ($p<0.05$). Since 1990, TON in autumn and winter was about 3mg l^{-1} and increased to a maximum of 7mg^{-1} by spring (appendix IIa). Concentrations declined over the spring and summer. In 1992, TON

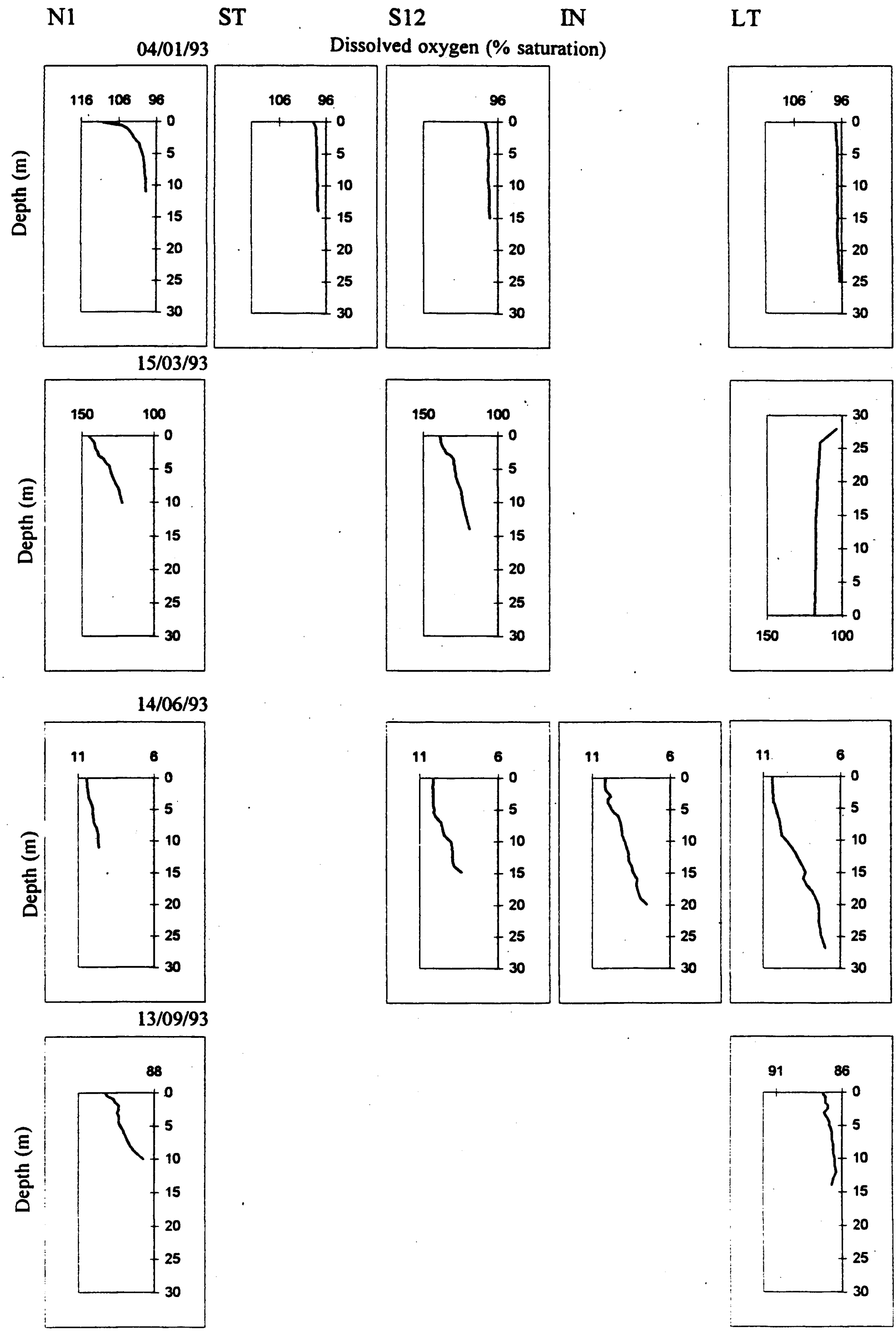


Figure 3.14 Depth profile of dissolved oxygen (% saturation) in water column in Rutland Water

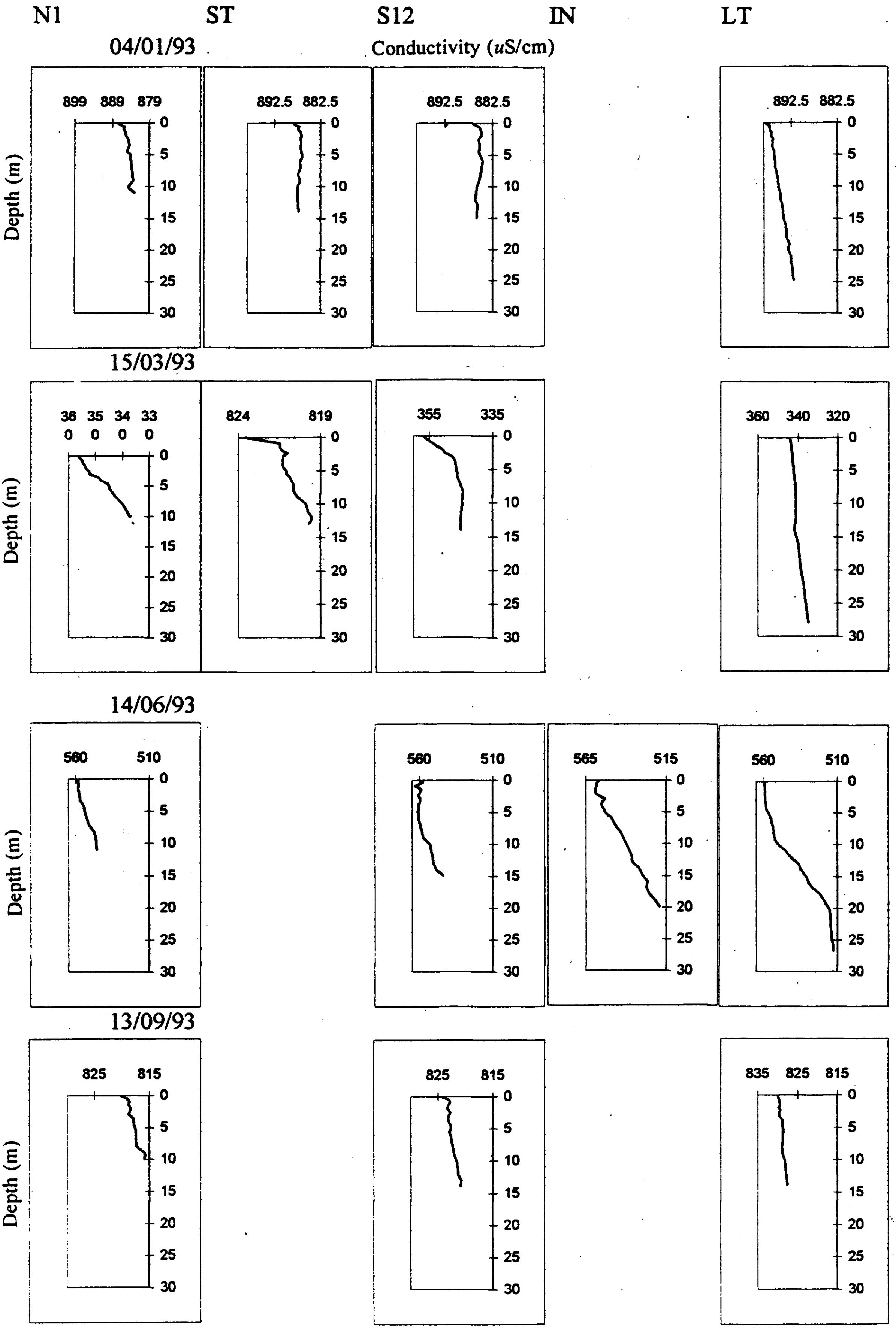
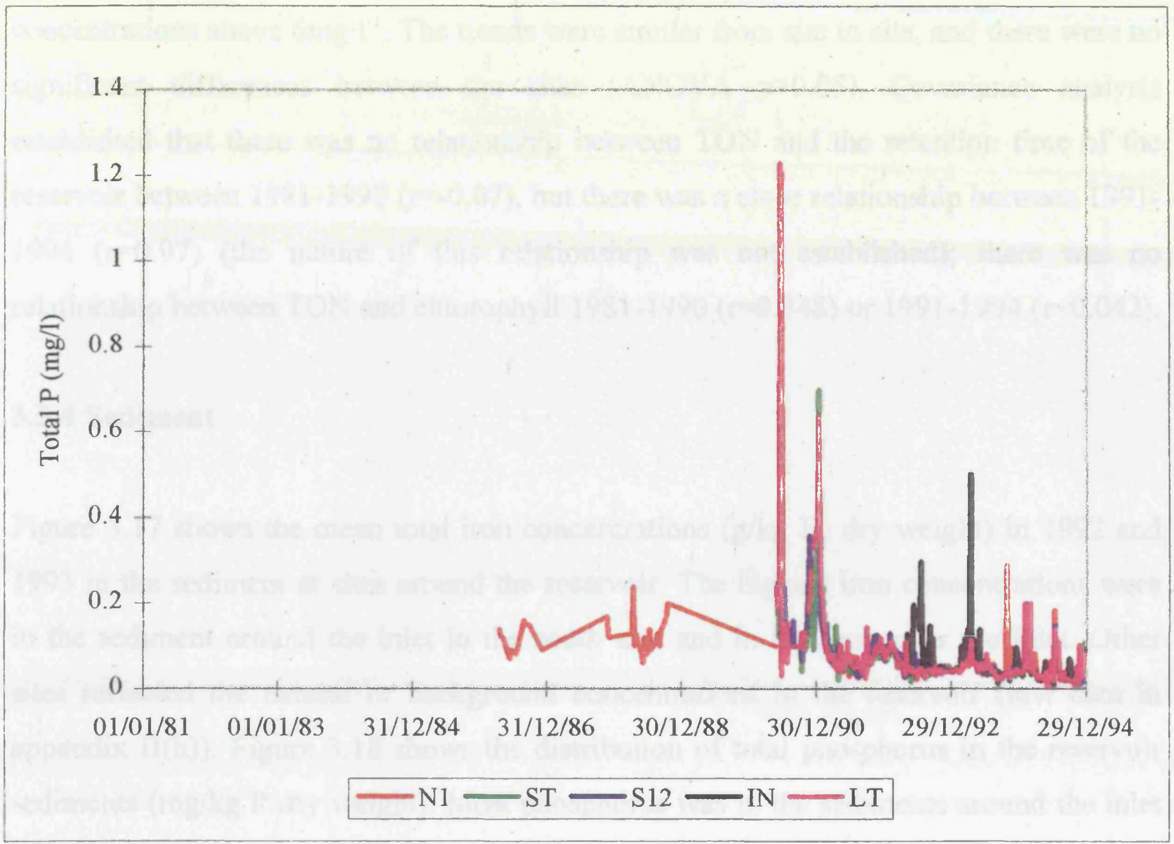


Figure 3.15 Depth profile of conductivity (uS/cm) in water column in Rutland Water

a) Total phosphorus



b) Total oxidised nitrogen

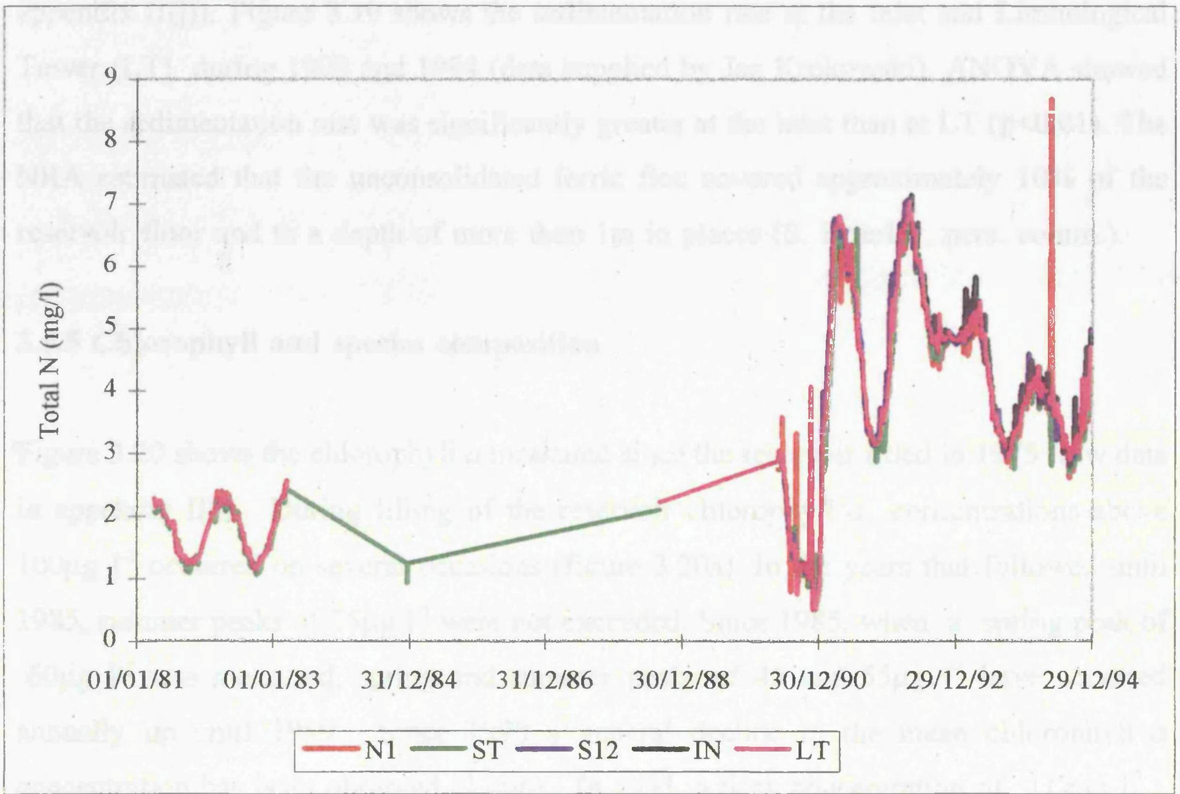


Figure 3.16 Plant nutrients in Rutland Water

declined to about 4.5mg l^{-1} in autumn and in the following years did not reach concentrations above 6mg l^{-1}. The trends were similar from site to site, and there were no significant differences between the sites (ANOVA $p>0.05$). Covariance analysis established that there was no relationship between TON and the retention time of the reservoir between 1981-1990 ($r=-0.07$), but there was a close relationship between 1991-1994 ($r=0.97$) (the nature of this relationship was not established); there was no relationship between TON and chlorophyll 1981-1990 ($r=0.348$) or 1991-1994 ($r=0.042$).

3.5.4 Sediment

Figure 3.17 shows the mean total iron concentrations (g/kg Fe dry weight) in 1992 and 1993 in the sediment at sites around the reservoir. The highest iron concentrations were in the sediment around the inlet in the south arm and in transects near the inlet. Other sites reflected the natural or background concentrations in the reservoir (raw data in appendix II(h)). Figure 3.18 shows the distribution of total phosphorus in the reservoir sediments (mg/kg P dry weight). Most phosphorus was in the sediments around the inlet where it had entered the reservoir bound to particulate iron and settled out (raw data appendix II(j)). Figure 3.19 shows the sedimentation rate at the inlet and Limnological Tower (LT) during 1993 and 1994 (data supplied by Jan Krokowski). ANOVA showed that the sedimentation rate was significantly greater at the inlet than at LT ($p<0.01$). The NRA estimated that the unconsolidated ferric floc covered approximately 10% of the reservoir floor and to a depth of more than 1m in places (S. Brierley, pers. comm.).

3.5.5 Chlorophyll and species composition

Figure 3.20 shows the chlorophyll *a* measured since the reservoir filled in 1975 (raw data in appendix IIk). During filling of the reservoir chlorophyll *a* concentrations above 100µg l^{-1} occurred on several occasions (figure 3.20a). In the years that followed until 1985, summer peaks of 25µg l^{-1} were not exceeded. Since 1985, when a spring peak of 60µg l^{-1} was measured, spring and summer peaks of 45 and 55µg l^{-1} have occurred annually up until 1989. Since 1990 a general decline in the mean chlorophyll *a* concentration has been observed (3.20b). In 1993, a peak concentration of 112µg l^{-1}

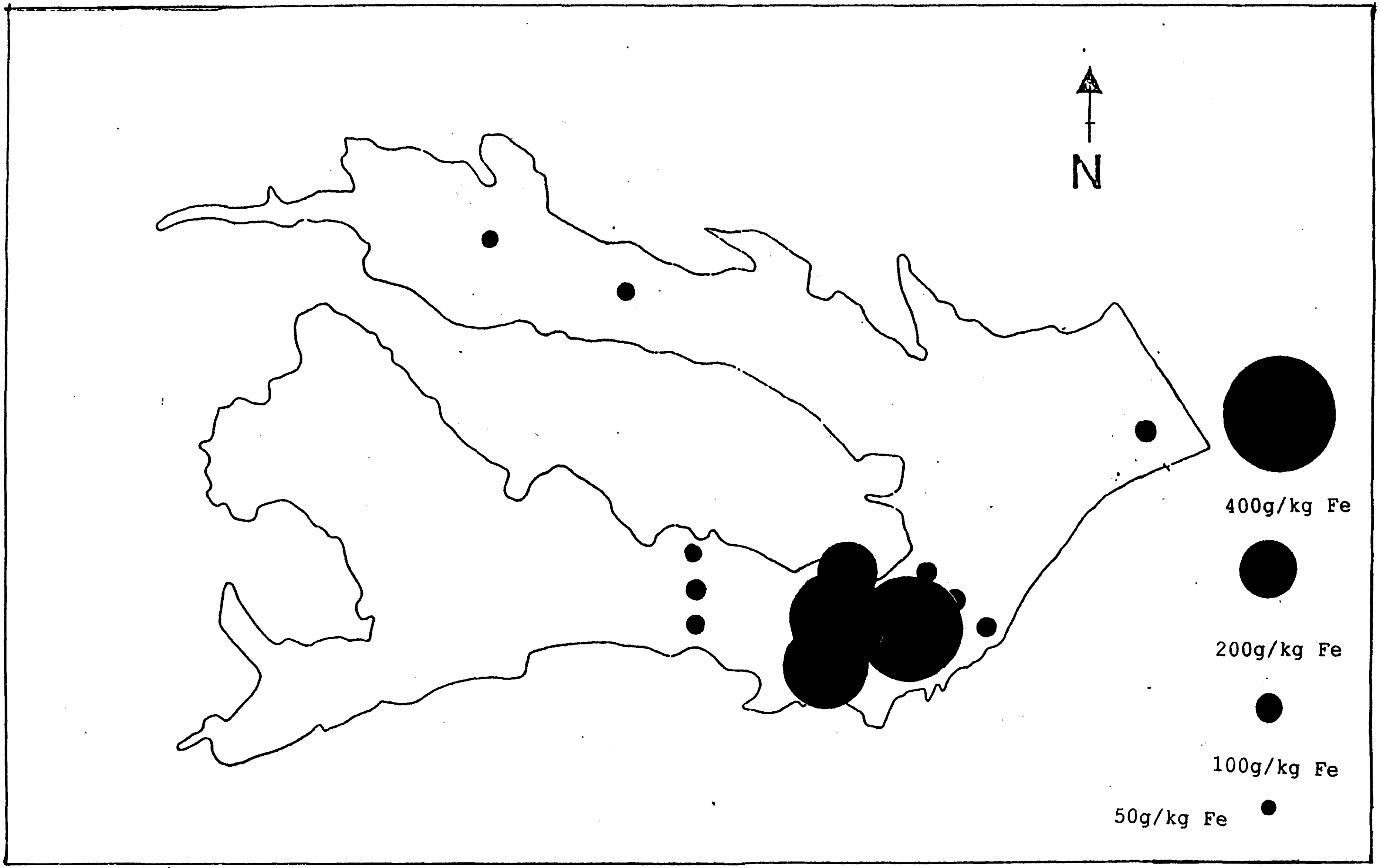


Figure 3.17 Total iron in sediments in Rutland Water

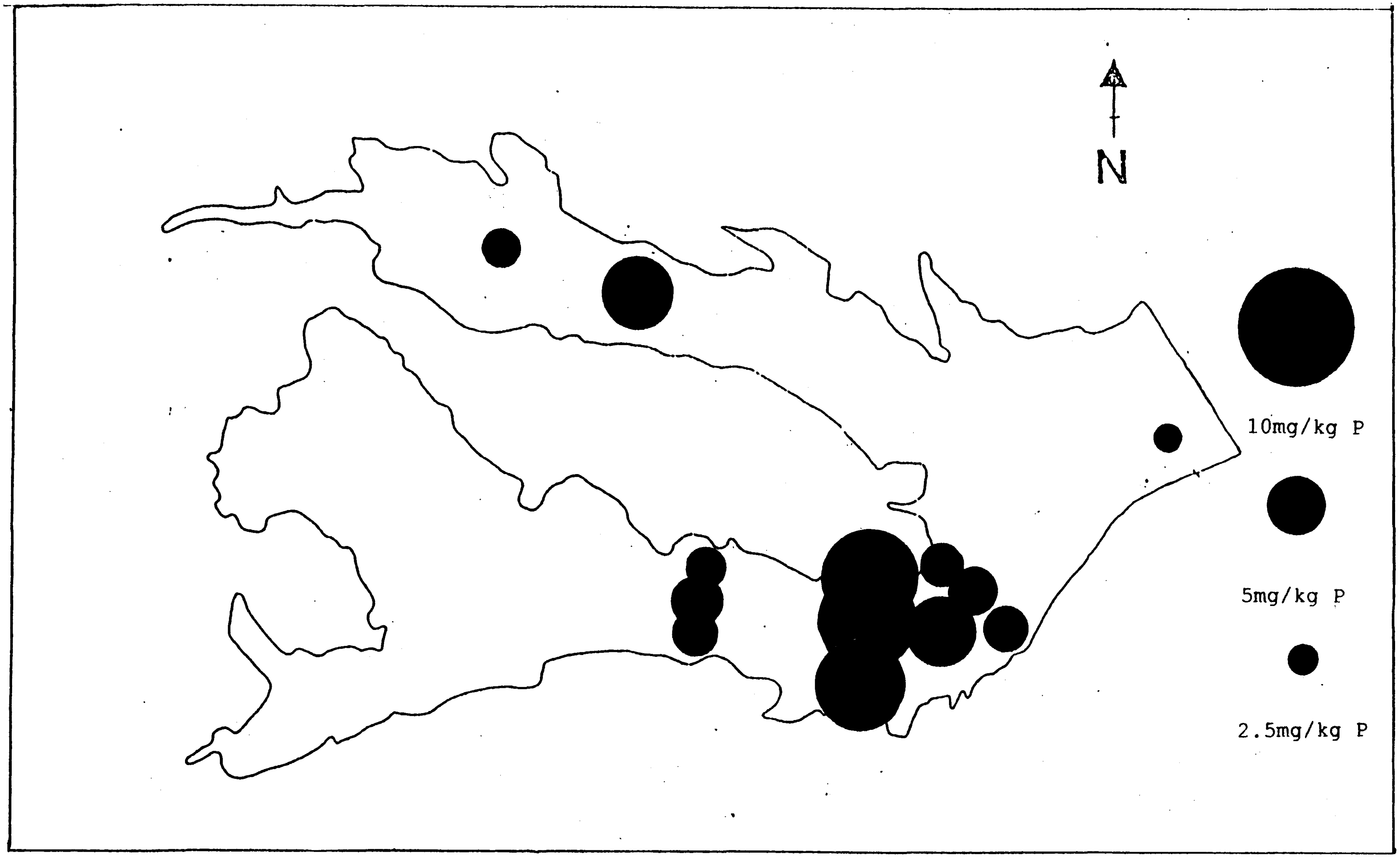


Figure 3.18 Total phosphorus in sediments in Rutland Water

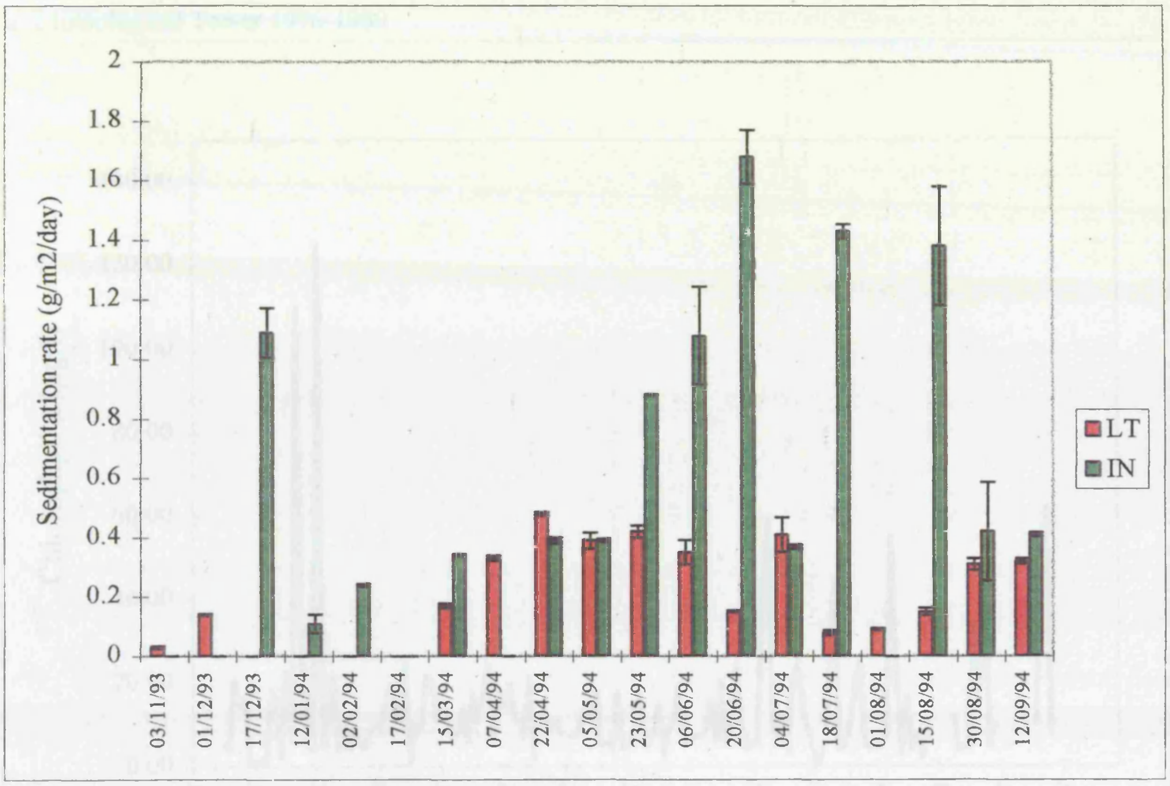
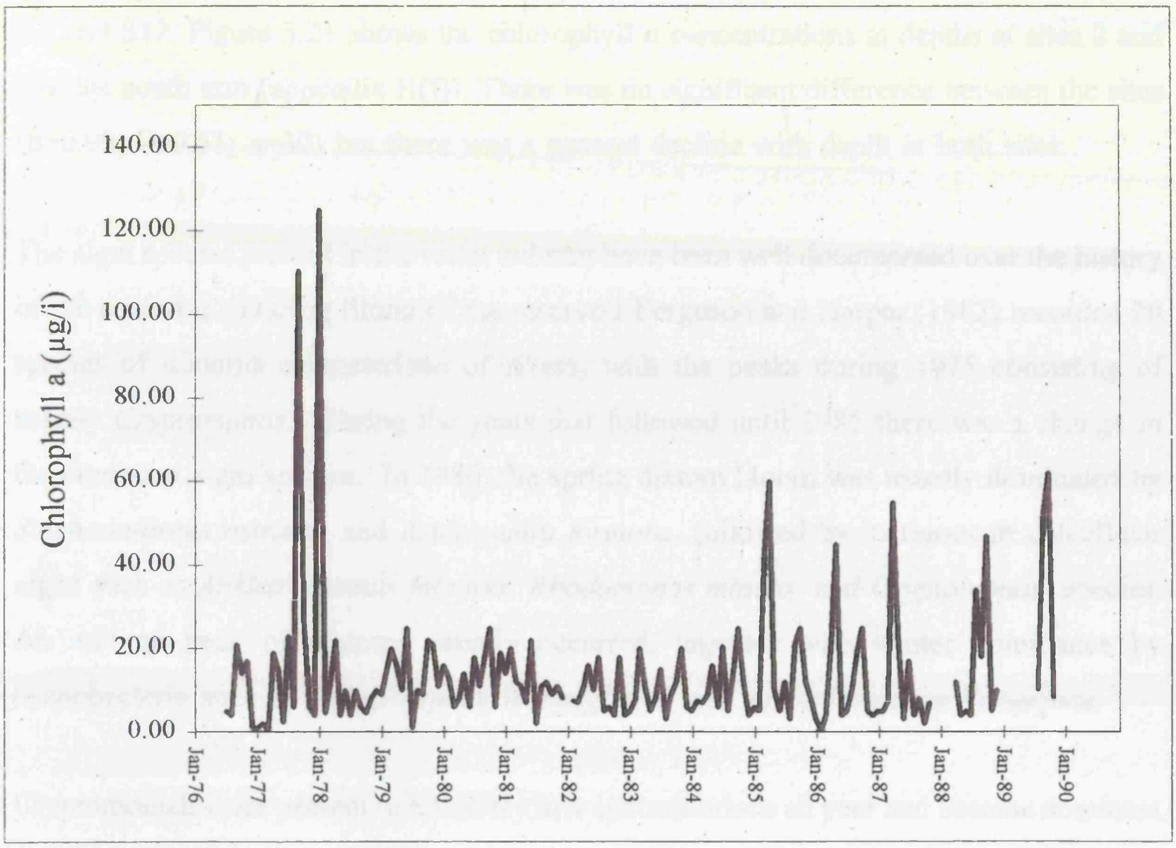


Figure 3.19 Sedimentation rate at Limnological Tower (LT) and Inlet (IN) of Rutland Water

a) Limnological Tower 1976-1989



b) All sites 1990-1994

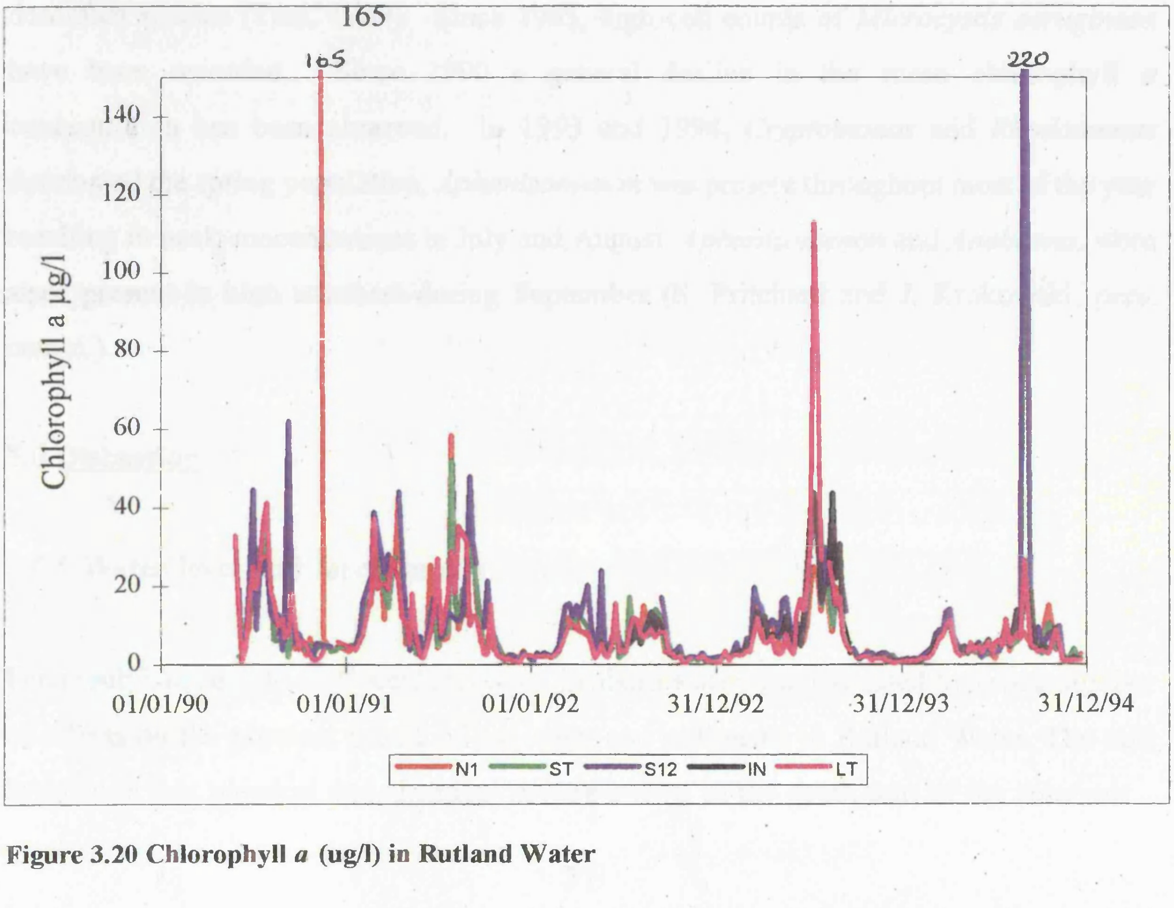


Figure 3.20 Chlorophyll *a* (ug/l) in Rutland Water

chlorophyll *a* was recorded in July and in 1994 peaks above 150μg l^{-1} were recorded at ST and S12. Figure 3.21 shows the chlorophyll *a* concentrations at depths at sites 2 and 6 in the south arm (appendix II(f)). There was no significant difference between the sites ($p>0.05$; $F=0.61$; $n=30$) but there was a general decline with depth at both sites.

The algal species present in the water column have been well documented over the history of the reservoir. During filling of the reservoir Ferguson and Harper (1982) recorded 20 species of diatoms characteristic of rivers, with the peaks during 1975 consisting of mainly *Cryptomonas*. During the years that followed until 1985 there was a change in the dominant algal species. In 1980, the spring diatom bloom was usually dominated by *Stephanodiscus astraea* and *Asterionella formosa* followed by increases in unicellular algae such as *Ankistrodesmus falcatus, Rhodomonas minuta* and *Cryptomonas* species. An autumn peak of diatoms usually occurred, together with winter dominance by cyanobacteria such as *Gomphosphaeria naegliana* and *Aphanizomenon flos-aquae.*

Cryptomonads were present in relatively low concentrations all year and became dominant for short periods. Between 1980 and 1985 *Ceratium* and *Microcystis* became more dominant species (Teal, 1989). Since 1985, high cell counts of *Microcystis aeruginosa* have been recorded. Since 1990 a general decline in the mean chlorophyll *a* concentration has been observed. In 1993 and 1994, *Cryptomonas* and *Rhodomonas* dominated the spring population, *Aphanizomenon* was present throughout most of the year resulting in peak concentrations in July and August. *Aphanizomenon* and *Anabaena.* were also present in high numbers during September (S. Pritchard and J. Krokowski, pers. comm.).

3.6 Discussion

3.6.1 Water level and ferric inputs

Ferric sulphate, due to its flocculent nature in alkali water, was expected to have a number of effects on the physical nature of the water and sediments in Rutland Water. The null hypothesis that physical and chemical measurements in the south arm of the reservoir

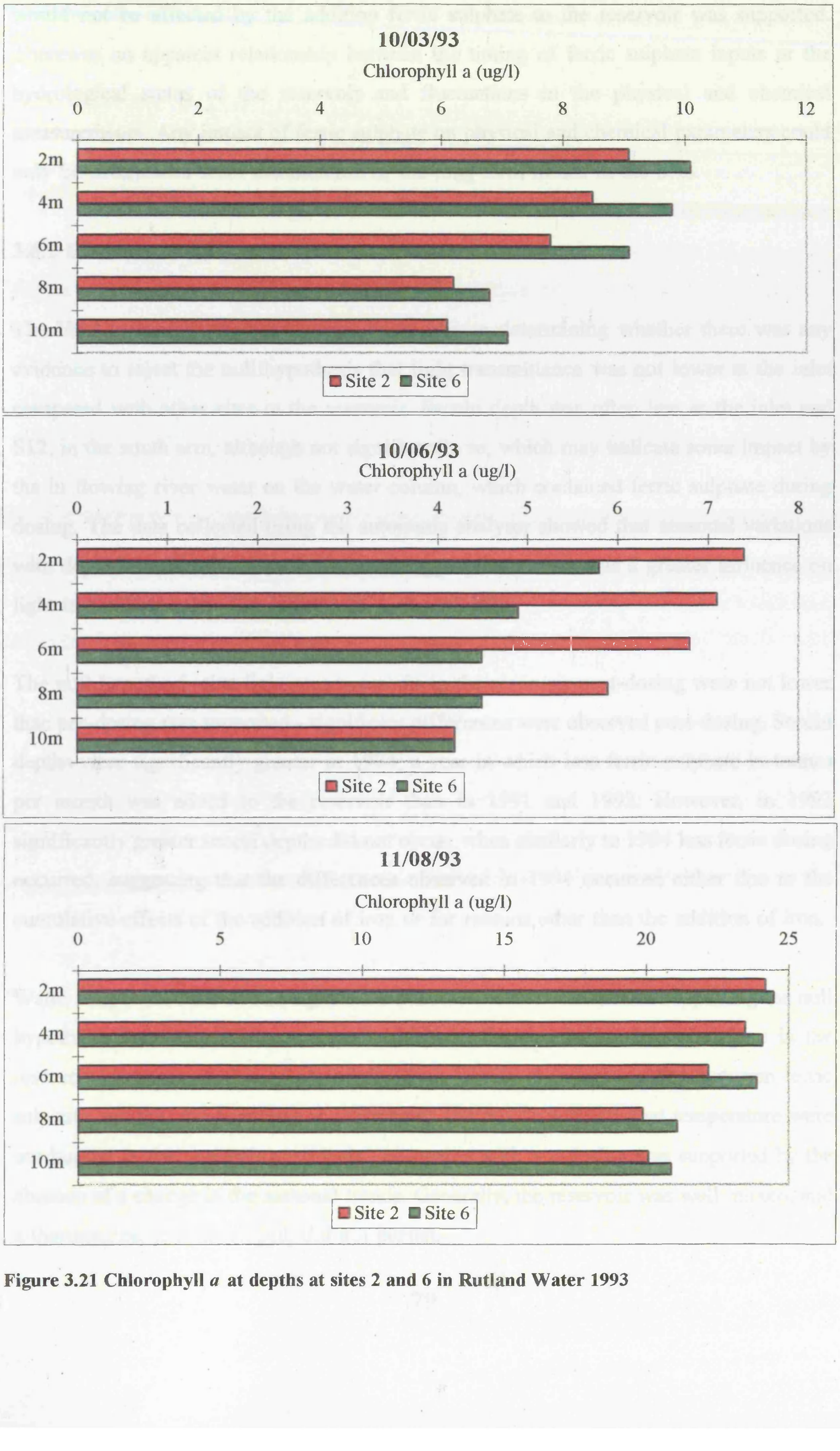


Figure 3.21 Chlorophyll *a* at depths at sites 2 and 6 in Rutland Water 1993

would not be affected by the addition ferric sulphate to the reservoir was supported. Therewas no apparent relationship between the timing of ferric sulphate inputs or the hydrological status of the reservoir and fluctuations in the physical and chemical measurements. Any impact of ferric sulphate on physical and chemical parameters could only be determined from examination of the long-term trends in the data.

3.6.2 Environmental parameters

The NRA collected data which went some way to determining whether there was any evidence to reject the null hypothesis that light transmittance was not lower at the inlet compared with other sites in the reservoir. Secchi depth was often less at the inlet and S12, in the south arm, although not significantly so, which may indicate some impact by the in flowing river water on the water column, which contained ferric sulphate during dosing. The data collected using the automatic analyser showed that seasonal variations with depth were similar at each site, and suggest that season was a greater influence on light transmission than the addition of ferric sulphate.

The null hypothesis that light measurements in the reservoir post-dosing were not lower than pre-dosing was supported - significant differences were observed post-dosing. Secchi depths were significantly greater in 1994, a year in which less ferric sulphate in tonnes per month was added to the reservoir than in 1991 and 1992. However, in 1993 significantly greater secchi depths did not occur, when similarly to 1994 less ferric dosing occurred, suggesting that the differences observed in 1994 occurred either due to the cumulative effects of the addition of iron or for reasons other than the addition of iron.

Water temperature showed no significant difference between sites that supporting the null hypothesis that temperatures were not higher in the dosed arm than elsewhere in the reservoir. A temperature increase might result from a chemical reaction between ferric sulphate and the water column or sediments. The null hypothesis that temperature were not hugher in the reservoir post-dosing compared with pre-dosing was supported by the absence of a change in the seasonal trends. Generally, the reservoir was well mixed, and a thermocline, if it developed, did not persist.

3.6.3 Water chemistry

The null hypothesis that iron and sulphate concentrations were not higher in the south arm of the reservoir as a result of dosing was supported. Concentrations of dissolved iron less than 0.05 mg l^{-1} and total iron between 0.2-0.5mg l^{-1} found in Rutland Water are typical in eutrophic lakes (Wurtsburgh & Horne, 1983). The occasional peaks above these concentrations reflect the circulation of the dosed ferric within the water column. The dosing regime described in 1.5.2, means that the addition of iron to the water column was variable over months, weeks and days which led to variation in the iron concentration in the water column. An orange plume observed when dosing occurred was quickly dissipated and its persistence depended on wind and circulation in the reservoir. Sulphate fluctuated over the year, but there was no evidence of increased concentrations as a result of ferric sulphate dosing.

The null hypothesis that iron concentrations were not significantly higher at greater depths than shallower depths was rejected by the finding that significantly more iron was found at 8 and 10m depths at the inlet.

The null hypothesis that phosphorus concentrations were not lower in the water column in the south arm was supported. Phosphorus concentrations at the inlet were higher than at other sites as its compounds bound to iron and settled out of the water column. Phosphorus measurements, suggest that ferric dosing has had the desired effect of reducing the phosphate concentrations throughout the reservoir over time, reducing the amount available for phytoplankton growth. As a result the null hypothesis was rejected. However, this will continue for only as long as the ferric floc layer over the sediment persists (Foy, 1985). Part of the reason for the decline in phosphorus was was reduced pumping of river water into the reservoir during the drought, and due to attempts to reduce P-loading by AWS Ltd (P. Daldorph; J. Krokowski, pers. comm.). Coincident with the decrease in phosphorus, total oxidised nitrogen (TON) has decreased in the reservoir since dosing began so the null hypothesis that concentrations would rise was rejected. The decline in TON may explain the continued growth of algae, especially cyanobacteria and may be accounted for by the change in species dominance from

Microcystis to *Aphanizomenon.*

The null hypothesis that pH and alkalinity were not lower at the inlet as a result of the addition of acidic ferric sulphate was supported. pH measurements were not lower post-dosing compared with pre-dosing so this null hypothesis was supported. pH measured at different sites in the reservoir was significantly different at different sites in different years. This inconsistency in results suggests that ferric sulphate dosing has not had an impact on the pH in the reservoir, although the NRA recorded pHs of 2-3 at the inlet, associated with the in flowing dosant (S Brierley, pers. comm.). At these pHs ferric is readily soluble (Mance & Campbell, 1988), however, since the reservoir has a slightly alkaline pH of 8 throughout most of the year, ferric is precipitated as ($Fe_2O_3.nH_2O$) within a few days. The data suggest that any effect of the dosing was localised and shortlived. Alkalinity was also unaffected.

Dissolved oxygen (%) was significantly lower at the inlet than at other sites in 1993 and 1994, but given that less ferric sulphate was added in these years than in 1991 and 1992, this result could not result from ferric dosing. The null hypothesis that the addition of ferric sulphate salt would not raise conductivity around the inlet was supported. The null hypothesis that conductivity post-dosing would not be higher than pre-dosing was also supported, although there were some changes over time. Conductivity was higher in 1991 and 1992, when the greater volumes of ferric sulphate were added to the reservoir, than 1993 and 1994, which may represent an impact by ferric sulphate. In 1993 and 1994, when less ferric was added, there were sudden reductions in conductivity around February, which are difficult to explain in relation to ferric dosing, and probably result from other features in the water at that time. Sudden decreases in conductivity were also observed in 1984, supporting the idea that these fluctuations were not caused by ferric sulphate additions.

The bottom waters of Rutland are generally oxidised. Under these conditions, insoluble ferric species are stabilised in colloidal form by the adsorption of natural compounds such as humic and tannic acids, and bu inorganic anions such as phosphates and silicates. Dissolved iron occurs principally as Fe(III) as hydrous ferric oxides ($Fe_2O_3.nH_2O$). If the water becomes anoxic, iron is reduced to Fe(II) and exists as aquated species (Martin, 1991). Anoxic conditions are often present in the interstitial waters of the sediment. From these waters dissolved iron species may diffuse into the oxic layer where it is oxidised to iron (III) and is precipitated. As a result, in the absence of stratification, there is no net release of iron to overlying water (Davison and Tipping, 1984).

3.6.4 Sediment

The null hypothesis that the iron concentrations in the sediments were not higher around the inlet that in other parts of the reservoir was rejected. The iron concentration in the sediments around the inlet, and into the south arm, increased by up to 600% as dry weight, over 10% of the reservoir floor (NRA, 1992).

The null hypothesis that phosphorus concentrations were not higher in the sediments around the inlet was rejected. Phosphorus concentrations were higher in sediments around the inlet compared with elsewhere as phosphorus compounds were removed from the inflowing river waters on entry to the reservoir. The majority of this phopshorus was bound up with insoluble iron compounds. Under oxic conditions this phosphorus remains tightly bound to the ferric iron and does not become available to the biota. In anoxic conditions there is some diffusion of phosphorus to the overlying oxic water, where it binds with dissolved ferric oxides and is precipitated once more. In the absence of stratification there is unlikely to be a net release of iron to the overlying water (Davison & Tipping, 1984).

The null hypothesis that sedimentation rates were not higher at the inlet where ferric sulphate was added than in other parts of the reservoir was rejected by the comparison of sedimentation rates at the inlet with rates at the Limnological Tower. Some of this sediment would have been suspended solids from the river water, although this was not quantified by the NRA.

Particulate iron settles out of the water column as ferric hydroxide ($Fe(OH)_2$) floc. This flocculation and precipitation of phosphorus occurred within the pipeline from

Empingham pumping station and the reservoir inlet, and the particulate material was carried into the reservoir. The unconsolidated nature of the ferric floc makes it vulnerable to redistribution by wind and circulation. Most of it collected around the inlet and up into the south arm and formed a significant layer over the reservoir natural sediments. NRA investigations showed that the floc smothers the sediment, reducing benthic faunal diversity, although less than 10% of the reservoir floor has been affected in this way (NRA, 1992; Radford, 1994).

The interaction between the sediments and the water column was probably altered in this zone as well. There is net retention of nutrients, such as phosphorus in the sediments of lakes (Hayes *et al.*, 1952; Rigler, 1978). However, not all of the nutrients taken up remain there - some fraction may be recycled into the water column at a later time. The presence of iron in the sediments keeps phosphorus within the sediments. This is the principle behind ferric dosing. Its permanent removal from the water column depends on the maintenance of the ferric floc layer. This layer is susceptible to distribution by wind, due to its unconsolidated nature, and will eventually be incorporated into the natural reservoir sediment by biological activity of burrowing animals such as chironomids, some species of which are able to tolerate relatively high concentrations of particulate iron (Radford, 1994).

3.6.5 Chlorophyll and species composition

The aim of the addition of ferric sulphate to the reservoir was a reduction in phytoplankton biomass and an increase in species diversity within the reservoir. The null hypothesis that phytoplankton biomass was not lower in the south arm compared with the rest of the reservoir was supported, although there was a general decline throughout the reservoir when the historical data were examined, failing to support the null hypothesis of no change post-dosing. There was evidence to support the null hypothesis that cyanobacteria would not became less dominant in the summer, and that cyanobacteria would not become less dominant post-dosing.

Since dosing began in Rutland Water, there has been a decline in chlorophyll *a* concentration, which may be a response to reduced concentrations of phosphorus in the reservoir. Summer peaks of *Aphanizomenon* or *Microcystis* have occurred annually, and these cyanobacteria are present in the reservoir all year round. There is some evidence in the literature of an increase in cyanobacteria following inoculation with iron (Brand 1991). However, the iron concentrations in Rutland Water are not much higher than average for eutrophic lakes (Wurtsburgh & Horne, 1983).

In Foxcote reservoir the diversity of algae species increased following ferric dosing (Young *et al.*,1988), an impact not yet observed in Rutland Water to date. Surveys of macrophyte populations are being undertaken by the Environment Agency, although the rise and fall of the waterline has had a big impact on their growth cover. There has not yet been a perceivable reduction in cyanobacterial counts, although species dominance has shifted. Climatic factors such as water level, water temperature and solar radiation may have a greater influence on plant growth than ferric.

3.6.6 Likely effects of ferric sulphate on zooplankton

The effects of ferric sulphate that might be observed on the zooplankton population fall into two categories - direct and indirect. One direct effect might be toxicity from the added iron itself from the water or from the sediments. The data do not show much increase in the iron concentrations within the water column, although concentrations have been as high as 17.5 mg Fe l^{-1}. Iron concentrations in the reservoir have generally been below 0.5mg l^{-1}. Letterman and Mitsch (1978) found healthy (stream) invertebrates at 2.7mg l^{-1} total iron in stream populations, and LC_{50} values for *Daphnia* of 9.6mg Fe l^{-1} and 7.2mg Fe l^{-1} as ferrous iron were determined by Biesinger and Christensen (1972) and Khangarot and Ray (1989) respectively, although ferric iron may have different toxicity, and sublethal effects have not been established.

Most of the iron added to Rutland Water has ended up in the sediments, and although 10% of the reservoir floor by area is affected, the depth of unconsolidated sediment, which is greater than 1m in places (S. Brierley, pers. comm), is a considerable store of iron for release into the water column through wind and circulation, and through bioturbation.

The indirect effects of ferric dosing on zooplankton are those affecting things such as the food supply. There is little evidence in the data of any impact of ferric on parameters such as oxygen concentration, temperature or light (although, light is often lower in the south arm), which might affect the growth of phytoplankton. Parameters in the reservoir that have been affected, are the nitrogen and phosphorus concentrations, which are primary plant nutrients. Phosphorus concentrations have declined, and so has the mean concentration of chlorophyll *a*. There has been a reduction in the amount of food available to zooplankton, which might result in fewer zooplankton and a lower birth rate in the reservoir.

The addition of particulate ferric sulphate may have two impacts on zooplankton. Firstly, ferric will be subject to the influences of wind and circulation as phytoplankton are, and suspended in the water column ferric is taken in by filter-feeding zooplankton as food. Carried in the water column with algae, bacteria and other particles, ferric may effectively dilute the food available to zooplankton. Secondly, this particulate material may be clumped together in particle sizes large enough to interfere with the feeding behaviour of the zooplankton. Both of these 'effects' of ferric sulphate may lead zooplankton to make suitable compensating morphological and behavioural adaptations as they would do in environments where food concentrations are low.

Chapter Four - The impact of ferric dosing on zooplankton populations in Rutland Water

4.1 Introduction

Zooplankton such as *Daphnia*, are central to the pelagic food web in a water body such as Rutland Water. They are major grazers of algae and are also a food source for invertebrate predators and planktivorous fish. The objectives of field studies carried out during 1992 and 1993, were to establish whether the addition of ferric sulphate to the south arm of the Rutland Water had had an impact on the population of *Daphnia longispina*. Ferric sulphate was expected to have effects on *Daphnia longispina* directly through toxic effects and physical interference of feeding, and indirectly through its toxic impact or dilution of the food supply. Population statistics derived from densities and body measurements were compared spatially (vertically and horizontally) throughout the reservoir, and temporally with data collected by Smith in 1985. These data were used to investigate the hypotheses detailed below.

4.2 Hypotheses tested

4.2.1 Densities

Direct toxicity of ferric sulphate would cause an increase in mortalities, observed in field populations as reduced densities in the dosed area of the reservoir. The null hypotheses were as follows:

> Daphnid densities were not significantly lower at greater depths than shallower depths;
>
> Daphnid densities were not significantly reduced at sites close to the dosed inlet compared with other sites in the south arm;

Daphnid densities were not significantly reduced at site 6[1] in 1992-1993 (post-dosing) compared with at the Limnological Tower (LT) during 1985 (pre-dosing).

4.2.2 Population dynamics

Both direct and indirect toxicity of ferric sulphate would result in a decline in fecundity, egg ratio, birth rate, and instantaneous growth rates and an increase in the death rate of field populations of *Daphnia* in the dosed area of the reservoir. The null hypotheses were as follows:

Egg ratios in populations from the dosed area of the reservoir were not significantly lower at greater depths than shallower depths;

Fecundity, egg ratio, birth rate and instantaneous growth rate were not significantly lower, and death rate was not higher at sites around the inlet compared with other sites in the south arm;

Fecundity, egg ratio, birth rate and instantaneous growth rate were not significantly lower, and death rate was not higher at site 6 in 1992-1993 (post-dosing) compared with at LT during 1985 (pre-dosing).

4.2.3 Body size

Reductions in body size of the daphnid population and in the size of the daphnid population and in the size of egg-bearing females would be expected if the growth rate of daphnids was reduced as a direct or indirect result of ferric sulphate additions. Maturity at a smaller size ensures continued population growth rate. The null hypotheses investigated were as follows:

[1]Site 6 is known to the NRA as buoy S12 (figure 3.1)

Body size of daphnids was not significantly less at sites around the dosed inlet compared with other sites in the south arm;

Body size of daphnids was not significantly less at site 6 in 1992-1993 and LT 1990-1991 (post-dosing) compared with LT during 1985 and 1979-1980 (pre-dosing);

The size of egg-bearing females was not significantly less at site 6 in 1992-1993 and LT 1990-1991 (post-dosing) compared with LT in 1985 (pre-dosing).

4.2.4 Feeding morphology

Daphnia are able to adapt the morphology of their feeding apparatus to changes in food concentrations, to maintain their intake of food particles and to maintain their growth rate. Any reduction in the food supply of *Daphnia* would be expected to cause an increase in the size of the filtering area of daphnid thoracic limbs. The null hypotheses investigated were as follows:

The filtering area of daphnids was not significantly greater at sites around the dosed inlet compared with other sites in the reservoir;

The filtering area of daphnids collected during November (low food concentration) was not significantly less compared with daphnids collected during July (high food concentration).

4.3 <u>Sampling Methodology</u>

4.3.1 Sample sites

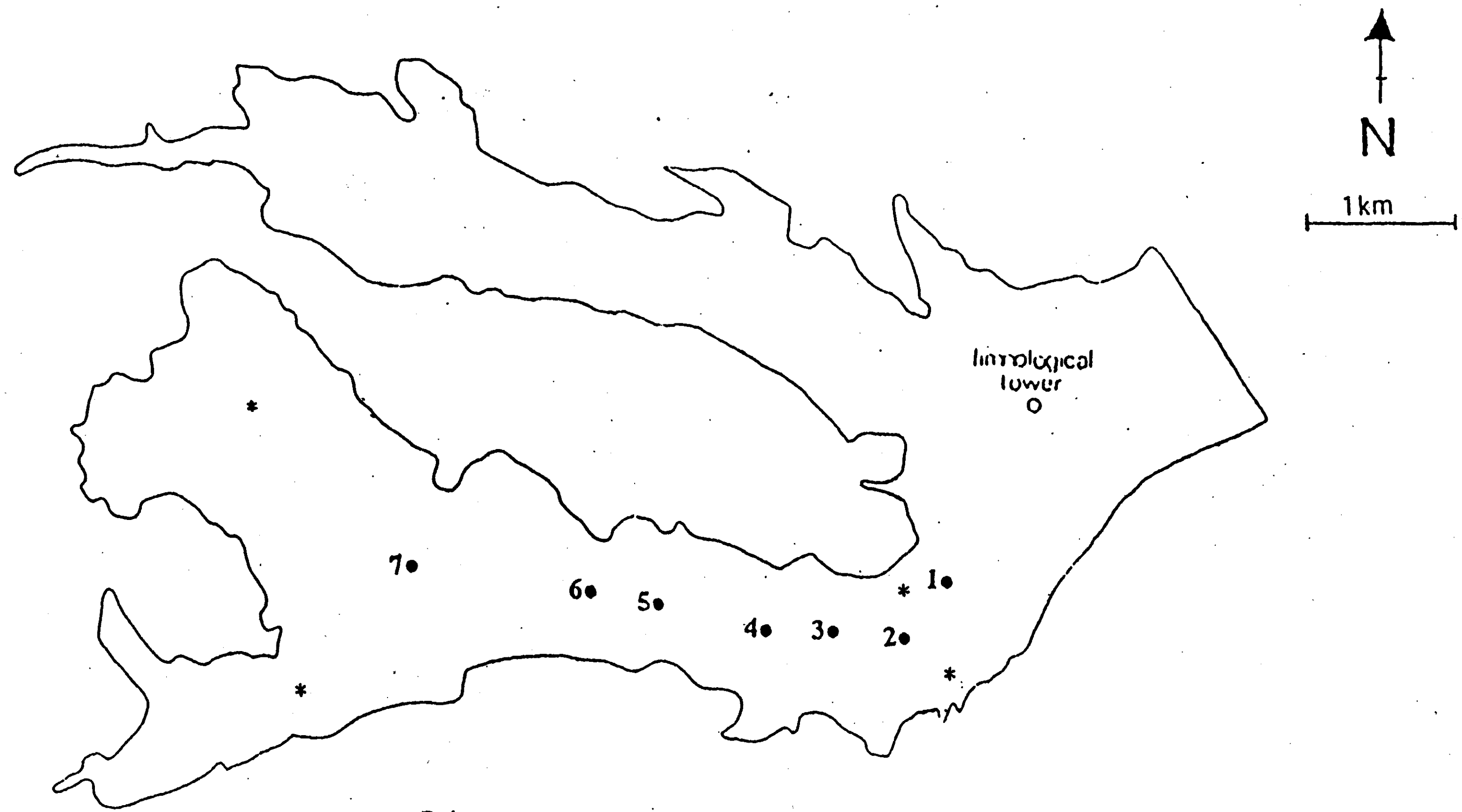
The NRA collect samples weekly from four or five sites around the reservoir, which were analysed as part of a concurrent study, so efforts were concentrated on a transect in the south arm. Any effects of ferric on the daphnid population would be expected to be manifested most strongly in this arm. The location of sample sites was decided after a preliminary spatial survey to examine the variation in the distribution of *Daphnia* in the south arm of the reservoir (May 1992). Further surveys were carried out over the whole reservoir in July and November 1993 to establish whether there were any differences between the numbers of daphnids, and concentrations of total iron and chlorophyll *a* in different areas of the reservoir. These investigations are reported in appendix I(d).

The number of samples required to give accurate estimates of the spatial distribution of daphnids, was large (between 34-121) so it was decided in 1992 to collect 33 samples from 11 fixed sites on a longitudinal transect in the south arm. This was modified to 35 samples from 7 sites in 1993. This showed general trends in the population measurements, although it was accepted that confidence limits could not be placed on the data.

The sampling sites used throughout this study are displayed in figure 4.1. The position of these sample points was fixed by the location of buoys already present in the reservoir.

4.3.2 Sample collection

Samples were collected using a 10 litre sampler (plate II) - a cuboidal perspex trap with top and bottom lids which closed under their own weight following a sharp tug on the supporting rope when the desired depth was reached. This sampler was constructed at University of Leicester, modified from a design by Patalas (1954), and used by Smith (1988), and will be referred to as a Patalas throughout this study. The Patalas was drawn up to the boat and emptied from its bottom into a 20 litre bucket. The water was poured from the bucket through a large funnel of 0.30m diameter, which had a 140μm mesh screw filter attached. The funnel was then rinsed with tap water to wash all the zooplankton onto the mesh. The screw filter was then removed and the zooplankton washed off with 70% IMS and glycerol into labelled screw-capped Nalgene® containers.



Points represented by an '*' were used initially in 1992. These points were, however, in shallow water (<5m deep) where grazing pressure particularly by fish fry was high. It was, therefore, decided that the data from these sites was not comparable with other points. The data collected from these sites has not been included in this thesis.

Figure 4.1 Sampling sites in south arm of Rutland Water

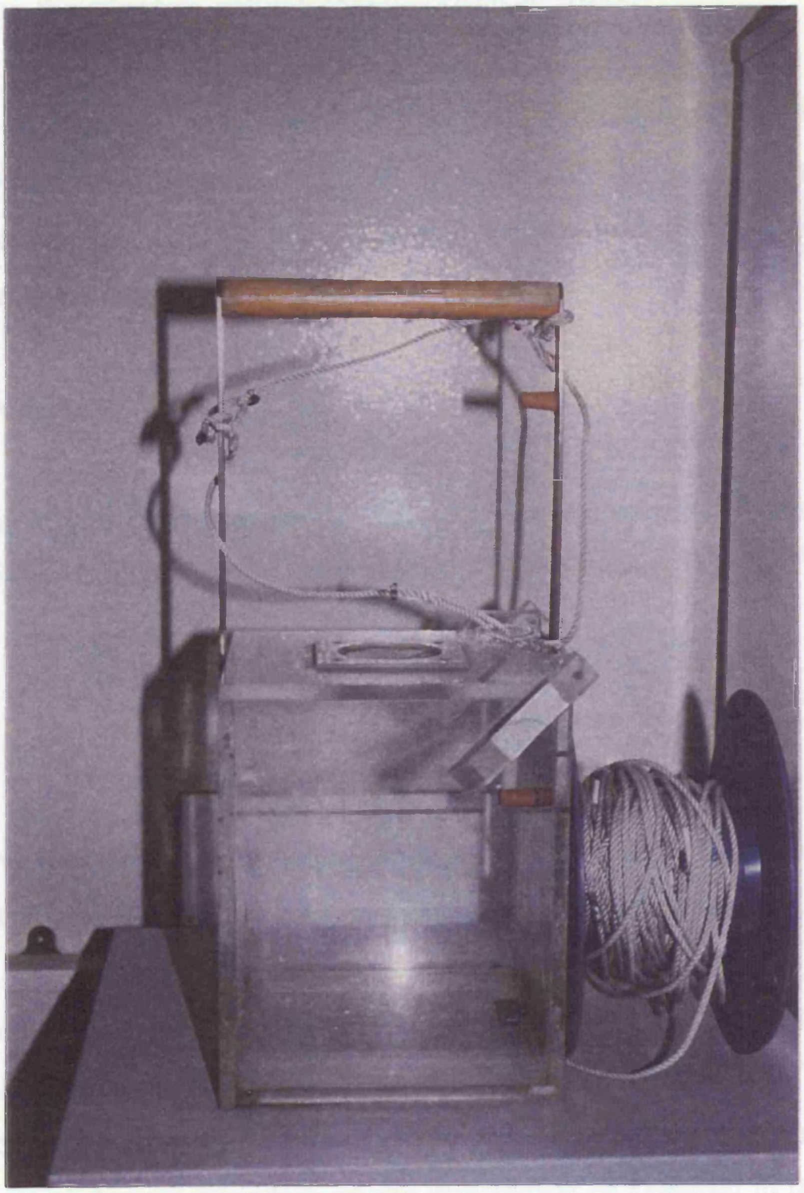


Plate II 10 litre Patalas sampler

This method was chosen since the samples collected were a suitable fixed volume, with small loss of zooplankton associated with them (George, 1972), whereas samples collected with a plankton net have large and unquantifiable loss associated with them, decreasing the effective volume sampled (Ricker, 1938).

Volumetric samples were taken in order that quantitative comparisons could be made between sites, over time and with historical data. In 1992 samples were collected from 3 depths: 2m, 4m, and 8m. In 1993 samples were collected from 5 depths: 2m, 4m, 6m, 8m, 10m.

4.3.3 Number of samples

One sample was collected from each depth and the values integrated for each site, to estimate the population size, using the following equation (Davies, 1984):

$$\sum_{I=1}^{d-1} \left[\frac{(X_i + X_{i+1})}{2} \cdot (X_{i+1} - X_i) \,/\, X_j \right]$$

where X_i is equal to the initial depth sampled and X_j is equal to the total water column sampled. This followed preliminary surveys described in appendix I(f).

Samples from different depths would show whether the daphnids distributed themselves randomly throughout the water column although confidence limits could not be placed on the data. Samples were collected from different depths for two reasons a) to counter the effects of diurnal migration on the distribution of *Daphnia* in the water column and b) to ensure that if stratification occurred it was observed in the daphnid population. Samples were not collected from the surface (<1m) following the observation of Harper (pers. comm.) and George and Edwards (1974) that crustacean zooplankton samples are found in fewer numbers at the surface than at other depths, and due to practical difficulties in sampling at the surface.

4.3.4 Preservation of samples

Zooplankton samples were preserved throughout this study in 70% IMS with glycerol, following a survey investigating the differences associated with four methods of preservation in estimating the egg count within a population (appendix I(g)). Routinely, samples were transported back to the laboratory in a cool box and analysed within 14 days of collection.

4.4 Laboratory analysis

4.4.1 Preparation

Each sample was poured through a 140μm filter (to remove the IMS) and washed with water into a 200ml glass beaker. The sample was then resuspended in a known volume of tap water (50 - 100ml).

4.4.2 Subsampling

When zooplankton were in great abundance (approx. 50 l^{-1}) subsamples were taken for counting, using a technique described by Smith (1988). After suspension in tap water, the sample was poured quickly between two 200ml beakers 6-8 times and a known volume promptly drawn off using an Eppendorf® fixed volume pipette. If the sample was suspended in 100ml, a 1/10 subsample was taken by drawing off 10ml of the mixed sample; a 1/20 subsample by drawing off 5ml; a 1/40 subsample by drawing off 2.5ml etc. Each subsample was diluted with tap water making it up to 25 ml for counting. This sample was adequate for estimating the number of daphnids in a sample (appendix I(h)).

4.4.3 Counting and measuring

Techniques for counting and measuring zooplankton were consistent with those used by Smith (1988), whose raw data have been used throughout this investigation as pre-ferric dosing data. For counting and measuring, the sample was swirled around in a beaker and poured into a Bogorov trough (Plate III), which had a trapezoidal channel. Daphnids were counted using a Nikon SM Z-U dissecting microscope at 35 times magnification. Counting was carried out on the whole contents of the trough, and the count was recorded using a tally counter.

Counts were made of the number of daphnids, number of egg-bearing females, and individual clutch size. In addition, each individual was measured *in situ* to a precision of 0.028mm (equal to one division on the eye-piece graticule) from the top of the head to the base of the tail spine, as shown in figure 4.2. This measurement is referred to as Total Body Length.

4.4.4 Filtering area of third thoracic limb

Following comparative measurements of 'projected filtering area' and 'estimated filtering area' made on laboratory cultured animals (appendix I(i)), the filtering area of the third thoracic limb was measured as follows. The Standard Length of each daphnid was measured from the centre of the eye to the base of the tail spine (figure 4.3). The individual was then placed on its right side on a microscope slide and the left third thoracic limb (figure 4.4) dissected out. Five setae from the centre of the filtering comb were measured at 140 times magnification using a Zeiss (standard 16) phase contrast stage microscope.

4.5 Calculations carried out on *Daphnia* samples

Analysis of Variance was carried out on log (1 + x) transformed population data (Prepas, 1984). The aim of this transformation was to reduce the variance and to obtain values more nearly satisfying the conditions required by ANOVA. Size class data were not transformed.

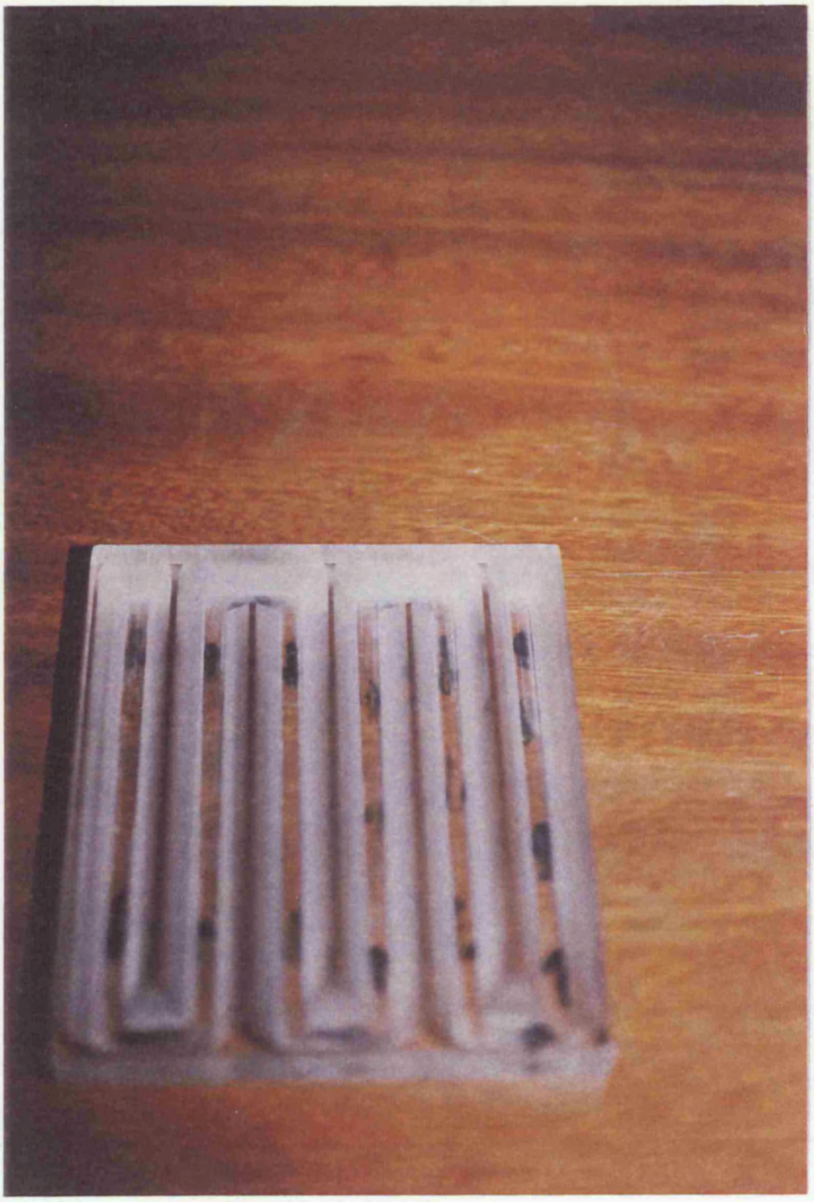


Plate III Bogorov trough

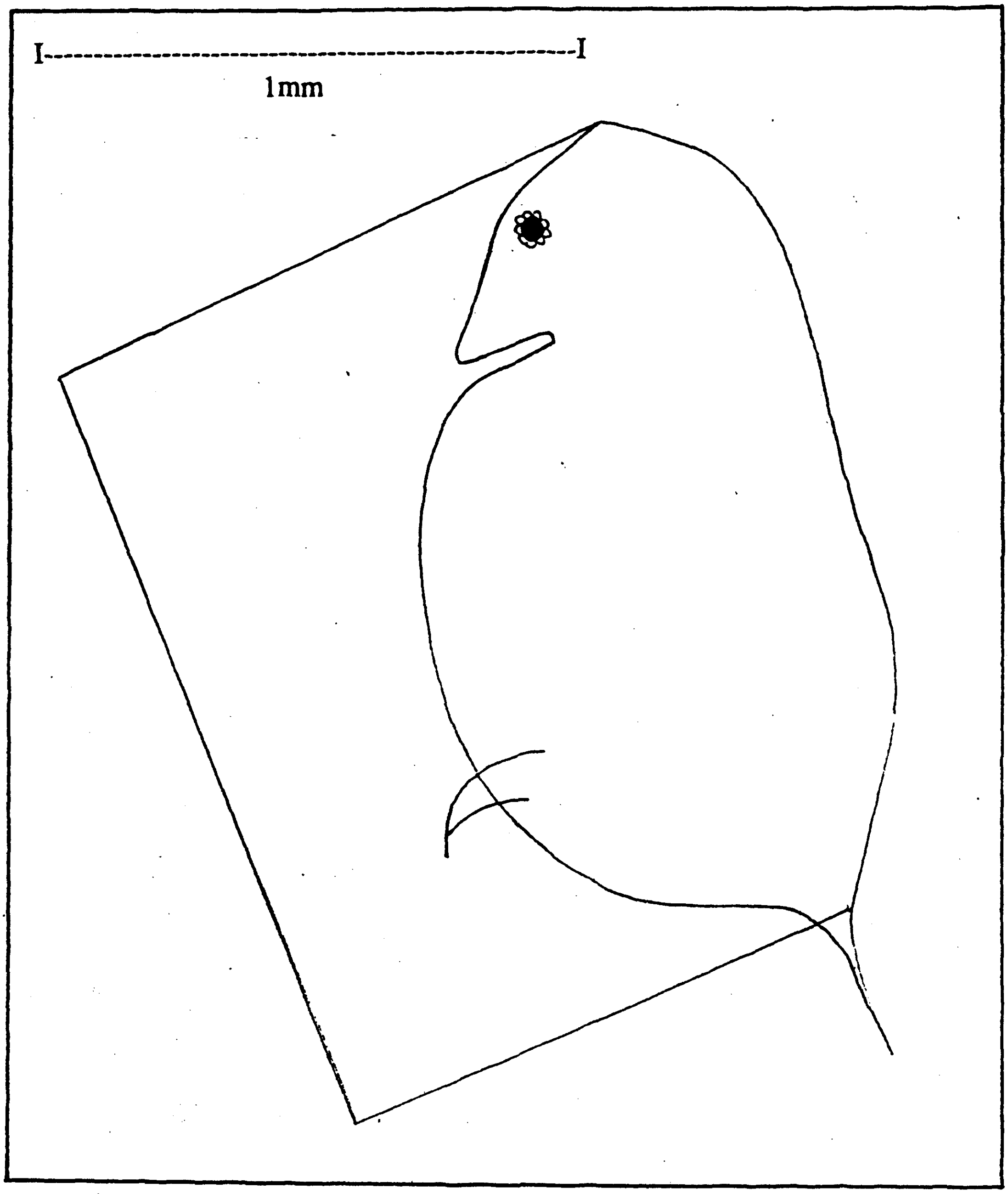


Figure 4.2 Measurement of total body length

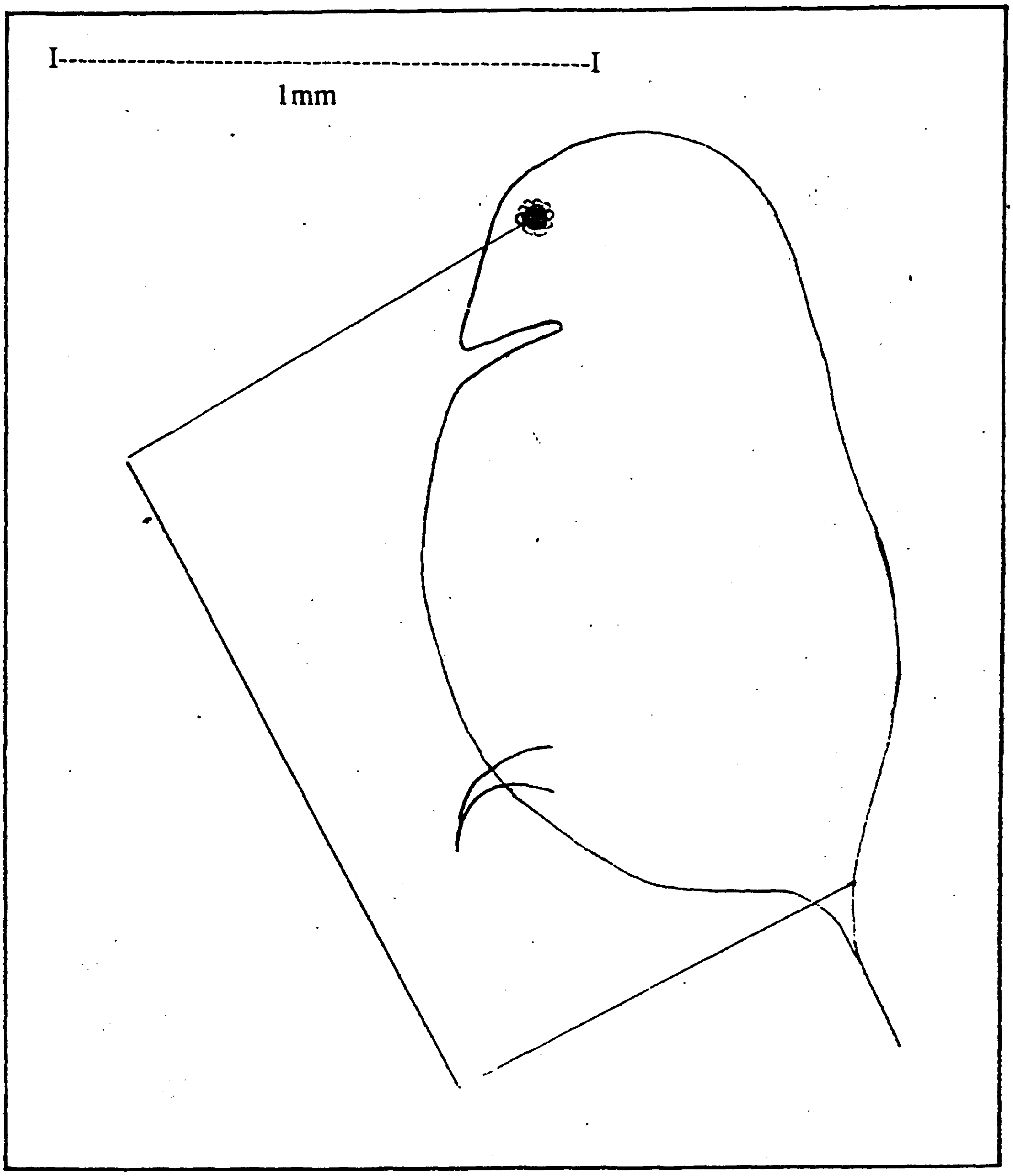


Figure 4.3 Measurement of standard body length

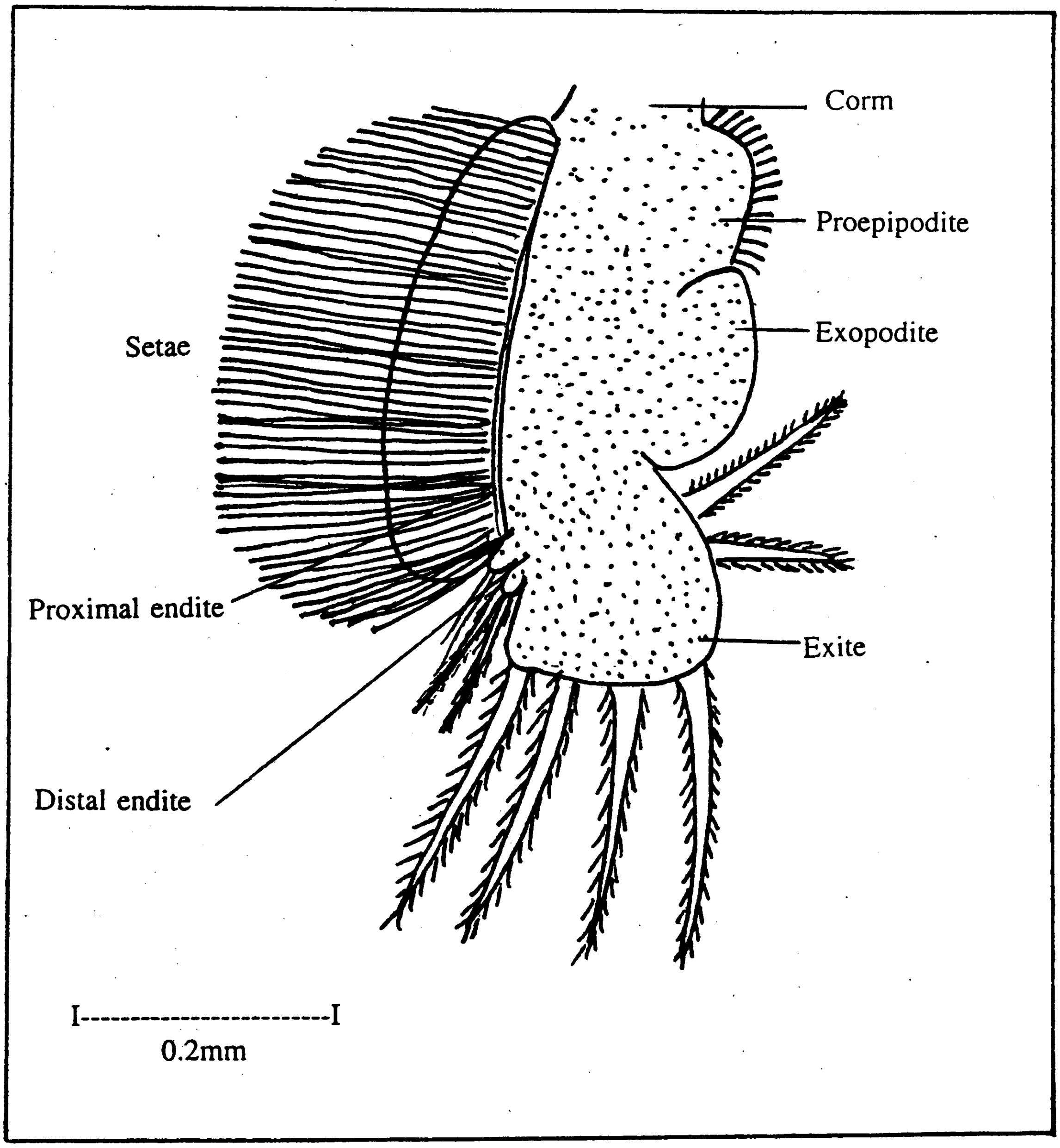


Figure 4.4 Schematic representation of daphnid third thoracic limb

4.5.1 Density

Daphnid densities, expressed as count per litre, were calculated from 10 litre Patalas samples by simple division.

4.5.2 Fecundity

Fecundity is expressed as the number of eggs per egg bearing female. This was determined by counting the number of eggs in the population counted and dividing by the number of gravid females present.

4.5.3 Instantaneous birth rate

Population dynamics were calculated from the daphnid data using the 'egg ratio' method (Paloheimo, 1974). This technique was chosen due to its relative simplicity, and its suitability given the data that were available.

Instantaneous birth rate (b) was calculated from the following equation (Paloheimo, 1974):

$$b = 1 / D \times \ln [(E / N) + 1]$$

where E is equal to the number of eggs in the population of size N (E / N is equal to the egg ratio); D is the time of embryonic development.

D was calculated from the temperature function derived by Bottrell *et al.* (1976) for *Daphnia longispina* from the temperature (°C) of the water at the time of sampling, where D = 16.8 days at 0°C; 10.56 days at 5°C; 6.6 days at 10°C; 4 days at 15°C; and 2.5 days at 20°C.

This calculation assumes that the age structure of the daphnid population is stable, such as that demonstrated by George and Edwards (1974). The shifts in age distribution in the population for this study were tested using Taylor and Slatkin's model (Taylor & Slatkin, 1981):

$$AD / N = e^{-ebj}$$

where D was calculated as for the instantaneous birth rate; and bj = juvenile birth rate.

A correction for the birth rate value (Cor b) was then carried out for the non-stable age distribution according to the equation:

$$\text{Cor } b = b \ . \ (AD / N)_{\text{ACT}} \cdot ebj$$

where $(AD / N)_{\text{ACT}}$ is the actual proportion of adult animals in the population; and e = natural log.

4.5.4 Instantaneous population growth rate

The instantaneous population growth rate (r) was calculated using the exponential growth equation (Edmondson, 1968):

$$N_t = N_o e^{rt}$$

where N_t and N_o are the population size initially and t units of time later; r is the instantaneous rate of population change and e is the base of natural logarithms to the base e.

4.5.5 Instantaneous death rate

It is not possible to measure the instantaneous death rate (d) from field samples (Rigler & Downing, 1984a), so d was estimated from:

$$d = b - r \qquad \text{(Edmondson, 1968)}$$

4.5.6 Size classes

Each daphnid was assigned to the size classes used by Thompson *et al.* (1982), for different instars of *Daphnia hyalina* (which is the same size as *Daphnia longispina* (Hrbacek, 1987)). These were:

I = <1.0mm; II = 1.0-1.29mm; III = 1.3-1.59mm; IV = 1.6-1.89mm; V = >1.9mm .

For 1979-1980, the figures from Harper and Ferguson (1982) were used (with permission) to estimate the numbers of *Daphnia* in various size classes, as the raw data are no longer available. Data from this period were collected using a 10 litre Patalas from 3m depth at the Limnological Tower. Unpublished size class data from Smith for 1985 and the NRA for 1990-1991 were available. These latter daphnid size data came from 50 females from each net haul collected at the Limnological Tower, whilst all other data were collected from the whole sample or subsample.

4.5.7 Length of egg-bearing females

The average total body length of egg-bearing females was compared for the years 1985, 1990-1991 and 1992-1993. At each site the means were determined for all gravid females counted in the sample throughout all depths.

4.5.8 Filtering area of third thoracic limb

The filtering area of animals collected from a site in the north arm was compared with the filtering area measured in animals collected from a site in the south arm in 1992. The filtering area was compared for animals collected from seven sites in the south arm during 1992 and 1993. The filtering area for animals collected during random surveys during 1993 were compared (See appendix I(d) for site locations).

4.6 Limitations of population data

Finite population dynamics were not calculated during this study since the interval between sampling (14 days) was greater than the generation time of this daphnid species and hence subject to inaccuracy (George, 1972).

The accuracy of the birth rate calculations depended on the reliability of the egg counts from a representative sample. Threlkeld (1979) determined that a representative sample was 100 gravid females. In many cases during this study, and in the raw data of Smith (1988), the samples contained fewer than 100 gravid females. Although some of these samples may not be wholly representative, the trends observed would still be indicative of the overall picture in the reservoir.

The instantaneous rate of population change (*r*) is sensitive to errors since it depends on the difference between successive estimates of the population size. That is, it represents an average for a given period.

Death rate is the least reliable statistic associated with the egg ratio method since it depends on the differences between quantities already collected which involve large errors.

4.7 Results

4.7.1 Densities

(I) Depth variation

In figure 4.5, the variation of daphnid densities per 10 litres are shown for three dates in 1993 when the population was at its greatest. Density did vary with depth, in some cases significantly ($p<0.01$; $F=23.5$; $n=99$) with more daphnids in the upper part of the water column.

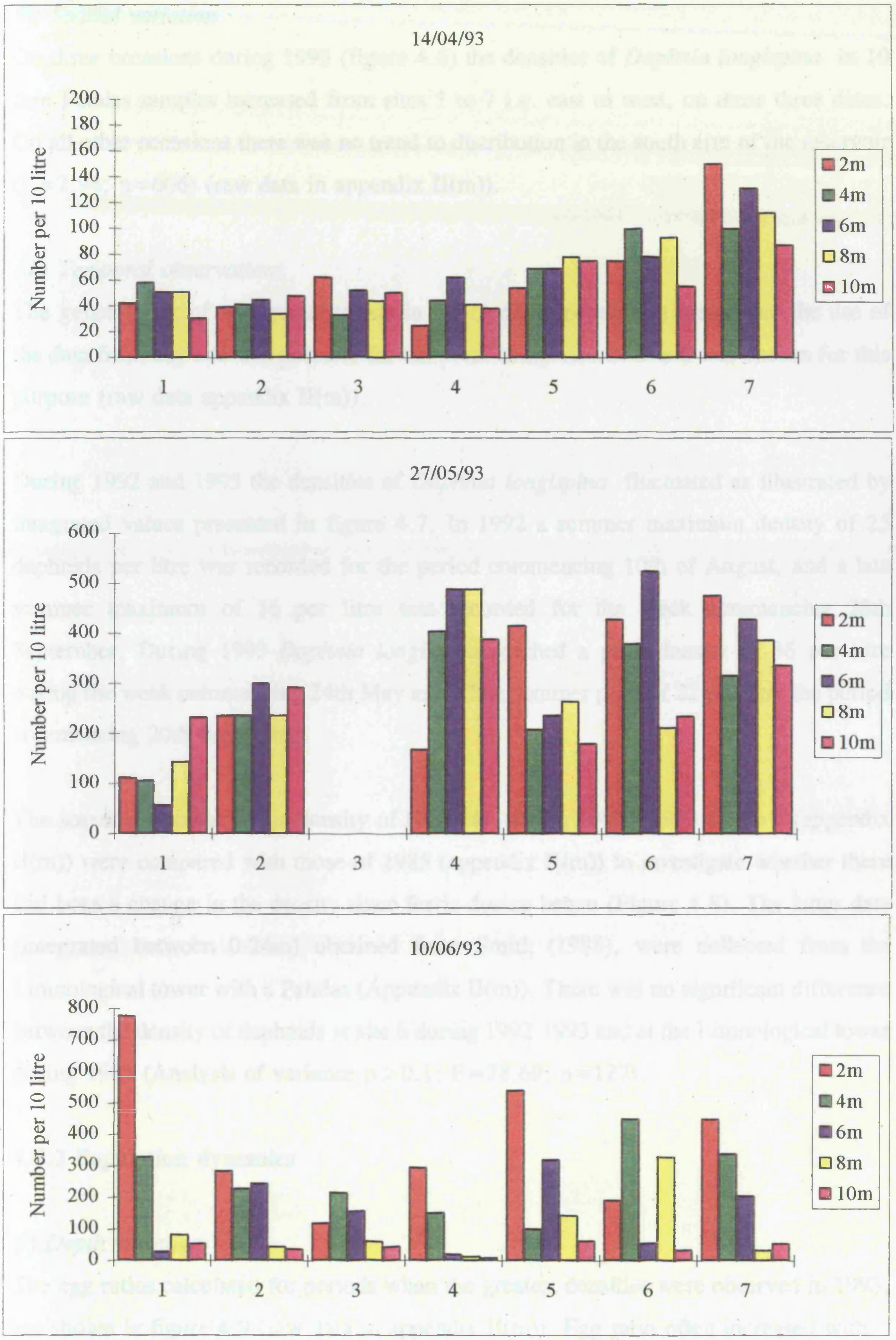


Figure 4.5 Depth variation in Daphnid densities at 7 sites in the south arm of Rutland Water

(ii) Spatial variation

On three occasions during 1993 (figure 4.6) the densities of *Daphnia longispina* in 10 litre Patalas samples increased from sites 1 to 7 i.e. east to west, on these three dates. On all other occasions there was no trend to distribution in the south arm of the reservoir ($F=2.94$; $n=606$) (raw data in appendix II(m)).

(iii) Temporal observations

The general lack of any spatial trends in the *Daphnia* population meant that the use of the data from any site was possible for temporal comparisons. Site 6 was chosen for this purpose (raw data appendix II(m)).

During 1992 and 1993 the densities of *Daphnia longispina* fluctuated as illustrated by integrated values presented in figure 4.7. In 1992 a summer maximum density of 25 daphnids per litre was recorded for the period commencing 10th of August, and a late summer maximum of 16 per litre was recorded for the week commencing 28th September. During 1993 *Daphnia longispina* reached a peak density of 36 per litre during the week commencing 24th May and a late summer peak of 22 per litre the period commencing 20th September.

The seasonal fluctuations in density of *Daphnia* during 1992 - 1993 at site 6 (appendix II(m)) were compared with those of 1985 (appendix II(m)) to investigate whether there had been a change in the density since ferric dosing began (Figure 4.8). The latter data (integrated between 0-24m) obtained from Smith (1988), were collected from the Limnological tower with a Patalas (Appendix II(m)). There was no significant difference between the density of daphnids at site 6 during 1992-1993 and at the Limnological tower during 1985 (Analysis of variance $p>0.1$; $F=78.69$; $n=127$).

4.7.2 Population dynamics

(I) Depth variation

The egg ratios calculated for periods when the greatest densities were observed in 1993, are shown in figure 4.9 (raw data in appendix II(m)). Egg ratio often increased with

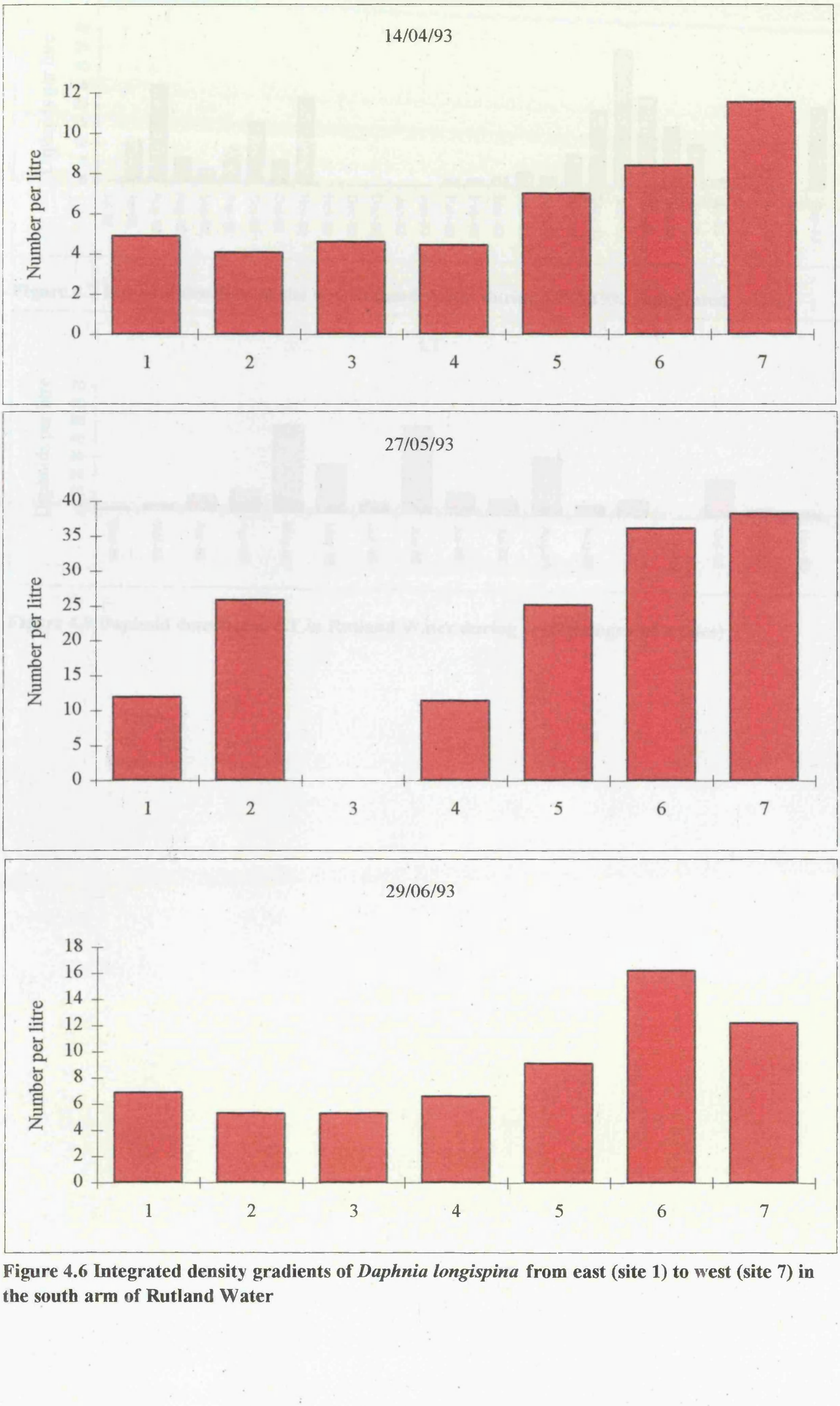


Figure 4.6 Integrated density gradients of *Daphnia longispina* from east (site 1) to west (site 7) in the south arm of Rutland Water

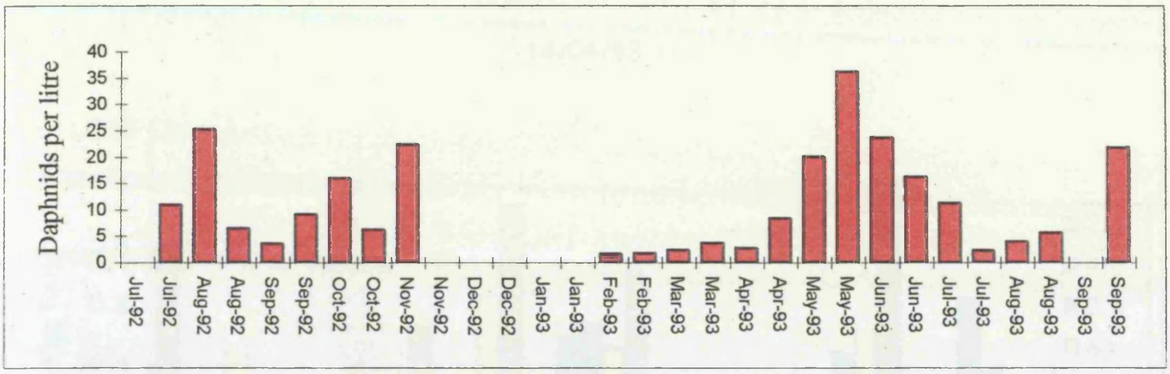


Figure 4.7 Daphnid densities at site 6 in Rutland Water during 1992-1993 (integrated values)

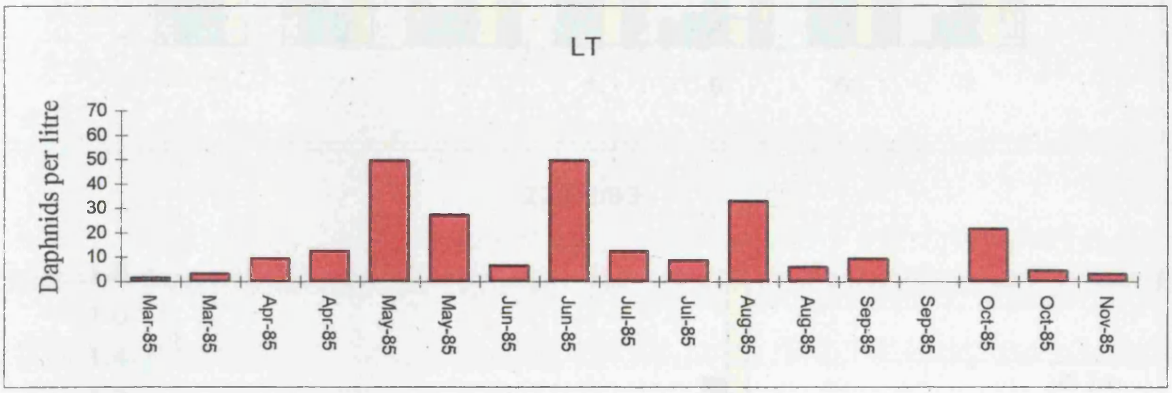


Figure 4.8 Daphnid densities at LT in Rutland Water during 1985 (integrated values)

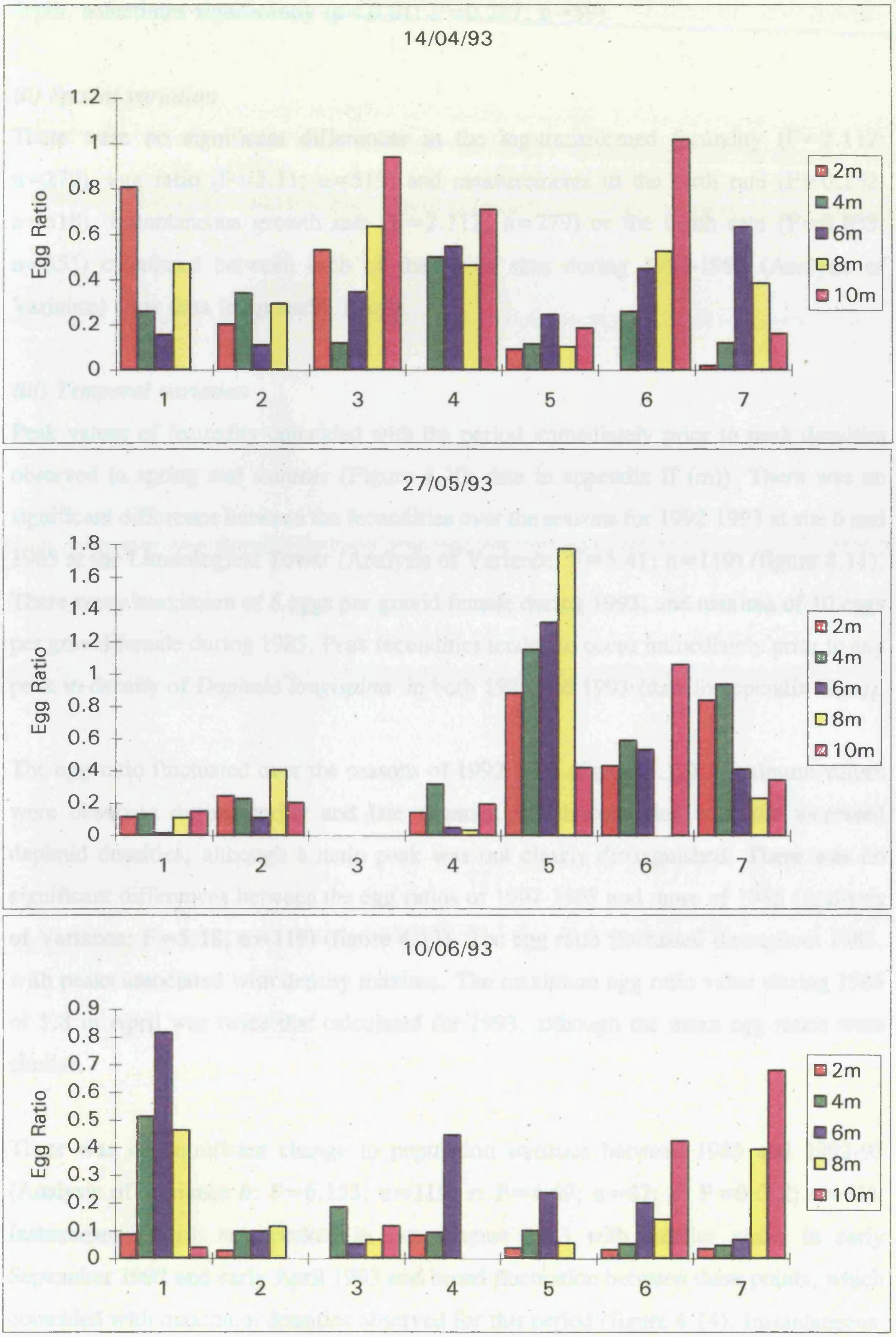


Figure 4.9 Depth variation in Daphnid egg ratios

depth, sometimes significantly ($p<0.01$: $F=0.287$; $n=59$).

(ii) Spatial variation

There were no significant differences in the log-transformed fecundity ($F=2.112$; $n=279$), egg ratio ($F=1.11$; $n=519$) and measurements in the birth rate ($F=0.152$; $n=518$), instantaneous growth rate ($F=2.112$; $n=279$) or the death rate ($F=0.833$; $n=355$) calculated between each of the seven sites during 1992-1993 (Analysis of Variance) (raw data in appendix II(m)).

(iii) Temporal variation

Peak values of fecundity coincided with the period immediately prior to peak densities observed in spring and summer (Figure 4.10; data in appendix II (m)). There was no significant difference between the fecundities over the seasons for 1992-1993 at site 6 and 1985 at the Limnological Tower (Analysis of Variance; $F=5.41$; $n=119$) (figure 4.11). There was a maximum of 8 eggs per gravid female during 1993, and maxima of 10 eggs per gravid female during 1985. Peak fecundities tended to occur immediately prior to any peak in density of *Daphnia longispina* in both 1985 and 1993 (data in appendix II(m)).

The egg ratio fluctuated over the seasons of 1992-1993 (figure 4.12). Maximum values were observed during spring and late summer, which coincided with the increased daphnid densities, although a main peak was not clearly distinguished. There was no significant differences between the egg ratios of 1992-1993 and those of 1985 (Analysis of Variance; $F=5.18$; $n=119$) (figure 4.13). The egg ratio fluctuated throughout 1985, with peaks associated with density maxima. The maximum egg ratio value during 1985 of 1.8 in April was twice that calculated for 1993, although the mean egg ratios were similar.

There was no significant change in population statistics between 1985 and 1992-93 (Analysis of Variance *b*: $F=6.155$; $n=119$; *r*: $F=4.69$; $n=67$; *d*: $F=0.012$; $n=81$). Instantaneous birth rate peaked in late August 1993 with smaller peaks in early September 1992 and early April 1993 and broad fluctuation between these points, which coincided with maximum densities observed for this period (figure 4.14). Instantaneous

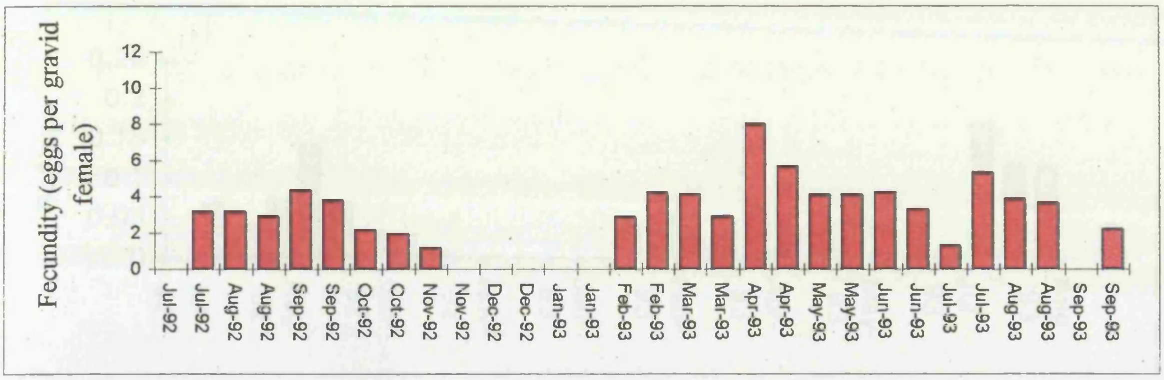


Figure 4.10 Fecundity of daphnids at site 6 in Rutland Water during 1992-1993 (integrated values)

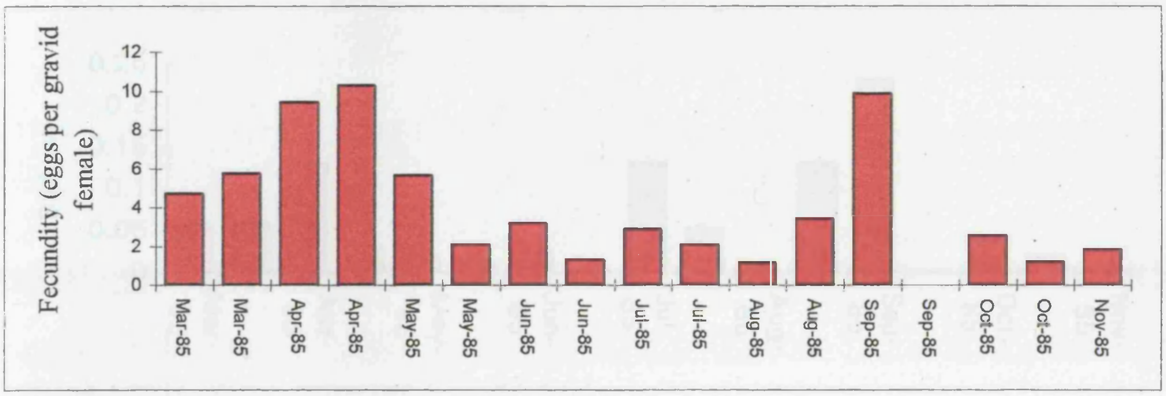


Figure 4.11 Fecundity of daphnids at LT in Rutland Water during 1985 (from integrated net haul)

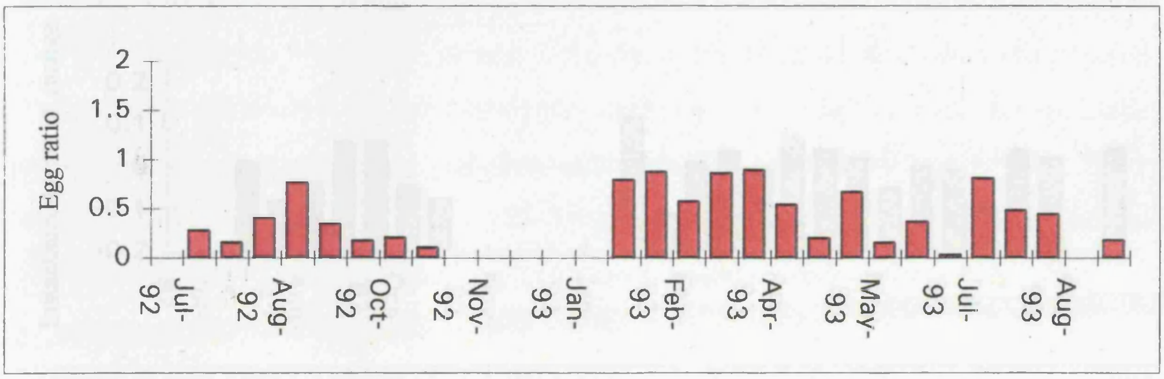


Figure 4.12 Egg ratio for daphnids at site 6 in Rutland Water during 1992-1993 (integrated values)

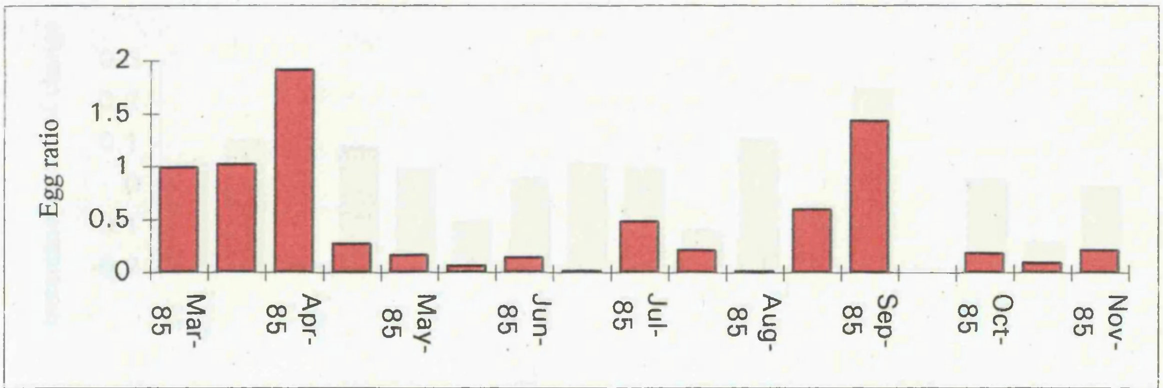


Figure 4.13 Egg ratio for daphnids at LT in Rutland Water during 1985 (integrated net haul)

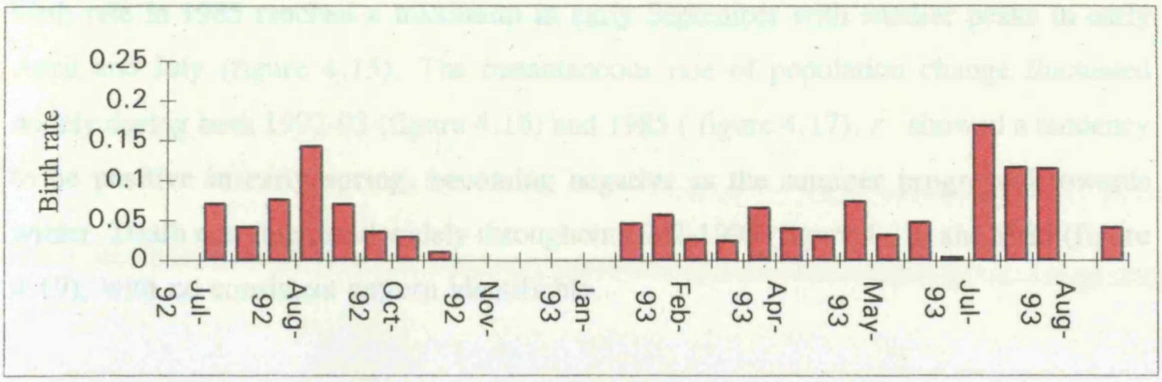


Figure 4.14 Daphnid birth rate at site 6 in Rutland Water during 1992-1993 (integrated values)

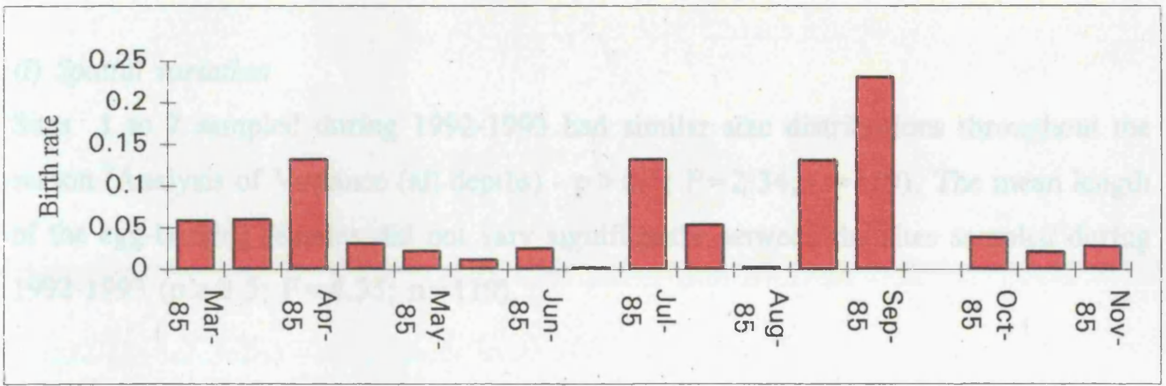


Figure 4.15 Daphnid birth rate at LT in Rutland Water during 1985 (integrated net haul)

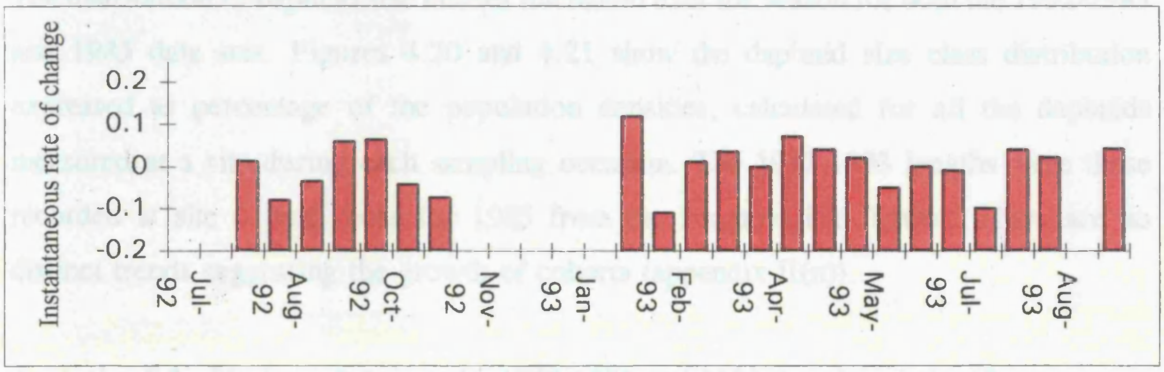


Figure 4.16 Instantaneous population growth rate of daphnids at site 6 1992-93 (integrated values)

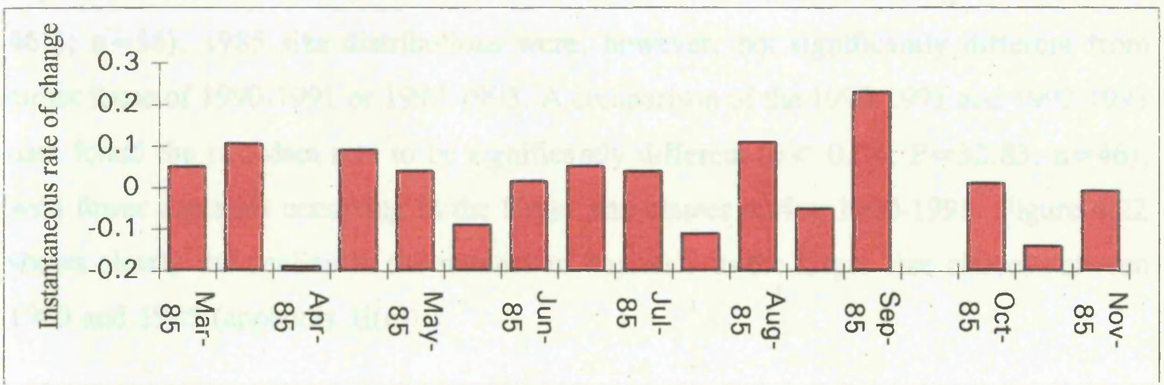


Figure 4.17 Instantaneous population growth rate of daphnids at LT (1985) (integrated net haul)

birth rate in 1985 reached a maximum in early September with smaller peaks in early April and July (figure 4.15). The instantaneous rate of population change fluctuated widely during both 1992-93 (figure 4.16) and 1985 (figure 4.17). *r* showed a tendency to be positive in early spring, becoming negative as the summer progressed towards winter. Death rate fluctuated widely throughout 1992-1993 (figure 4.18) and 1985 (figure 4.19), with no consistent pattern identifiable.

4.7.3 Body size

(I) Spatial variation

Sites 1 to 7 sampled during 1992-1993 had similar size distributions throughout the season (Analysis of Variance (all depths) - $p>0.5$; $F=2.34$; $n=119$). The mean length of the egg-bearing females did not vary significantly between the sites sampled during 1992-1993 ($p>0.5$; $F=4.35$; $n=119$).

(ii) Temporal observations

The distribution of daphnid size classes fluctuated over the season for both the 1992-1993 and 1985 data sets. Figures 4.20 and 4.21 show the daphnid size class distribution expressed as percentage of the population densities, calculated for all the daphnids measured at a site during each sampling occasion. The 1992-1993 lengths were those recorded at site 6, and those for 1985 from the Limnological Tower. There are no distinct trends suggesting the growth of cohorts (appendix II(n)).

Analysis of the Variance between the 1979-1980 and 1985 data found significantly more daphnids occurred in size classes IV and V in 1979-1980 than in 1985 ($p< 0.001$; $F=46.4$; $n=36$). 1985 size distributions were, however, not significantly different from either those of 1990-1991 or 1992-1993. A comparison of the 1990-1991 and 1992-1993 data found the two data sets to be significantly different ($p< 0.01$; $F=32.83$; $n=46$), with fewer daphnids occurring in the larger size classes during 1990-1991. Figure 4.22 shows clearly the decline in the number of daphnids in the larger size classes between 1980 and 1985 (appendix II(n)).

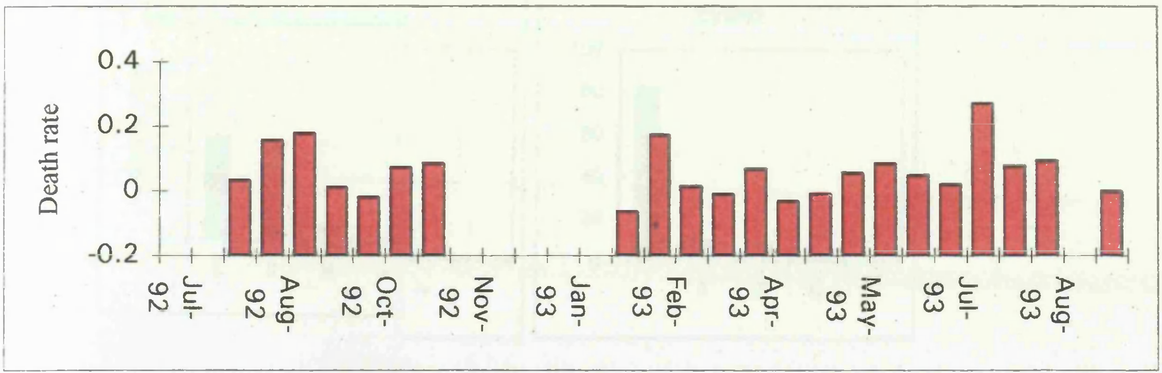


Figure 4.18 Daphnid death rate at site 6 in Rutland Water during 1992-1993 (integrated values)

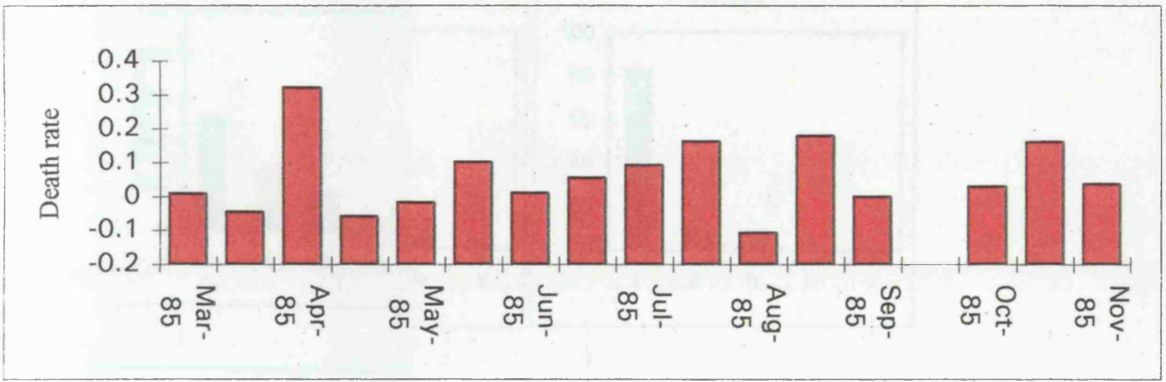


Figure 4.19 Daphnid death rate at LT in Rutland Water during 1985 (integrated net haul)

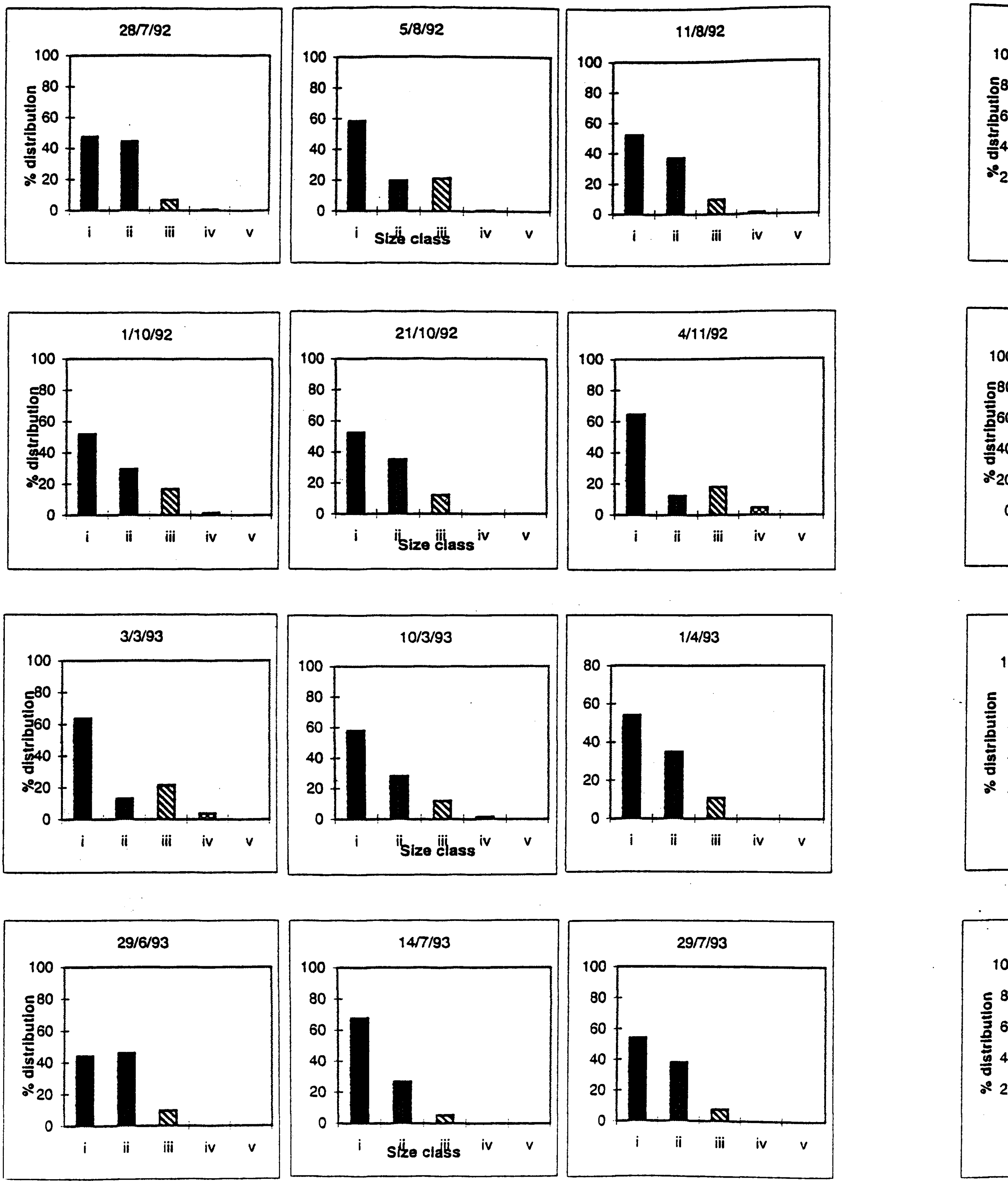


Figure 4.20 Size class distribution of *Daphnia longispina* in Rutland Water during 1992-1993

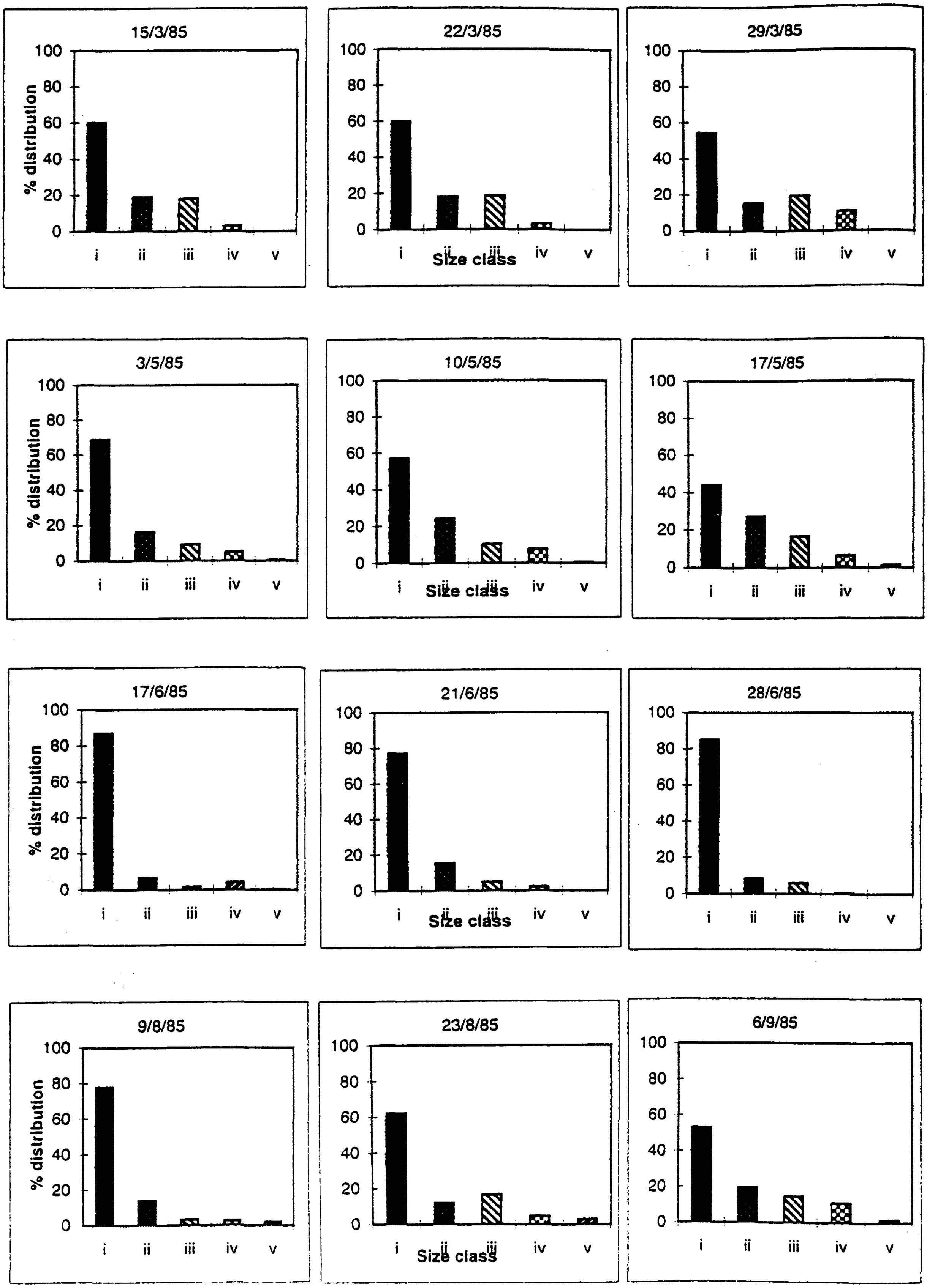


Figure 4.21 Size class distribution of *Daphnia longispina* in Rutland Water during 1985

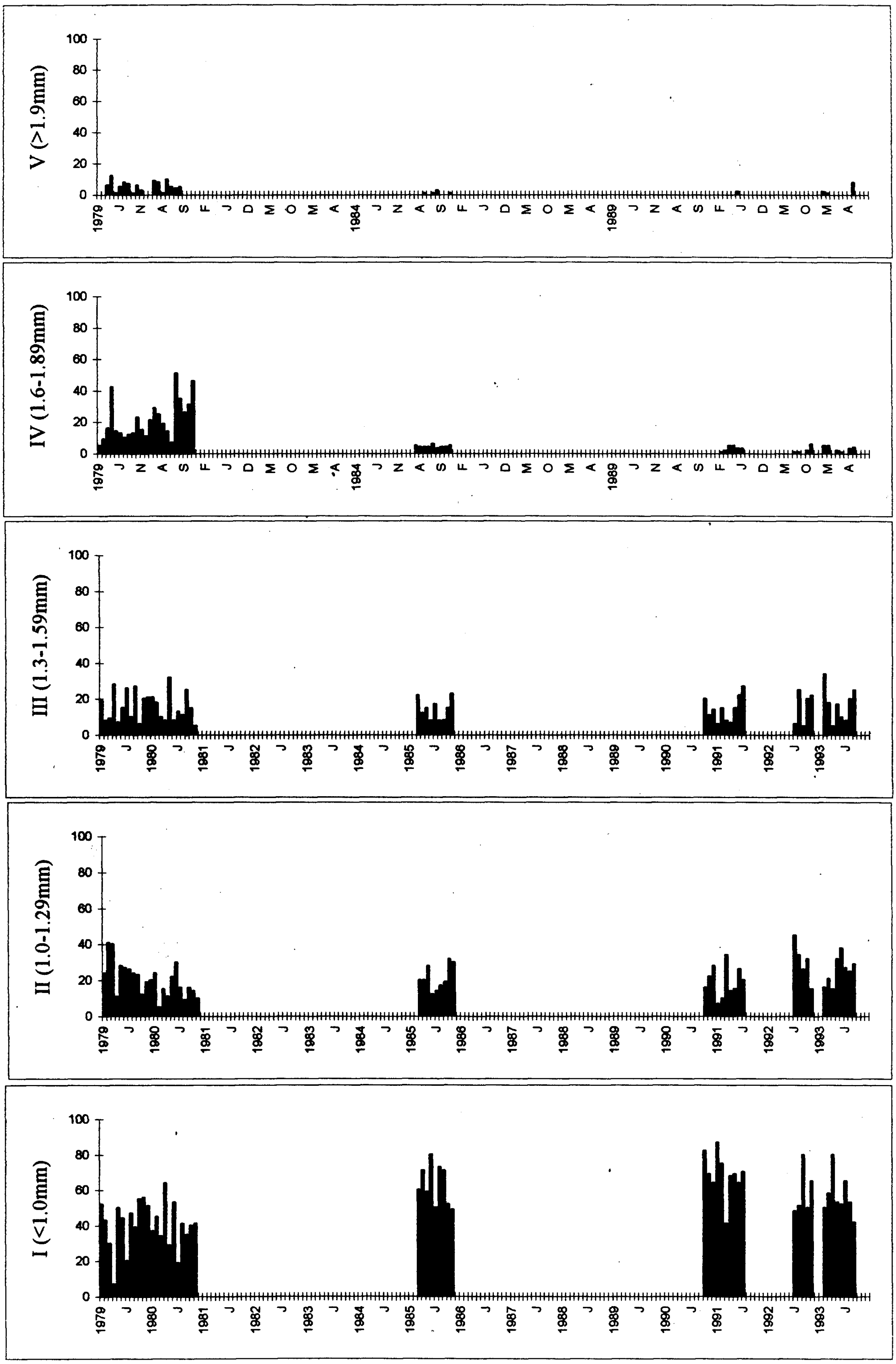


Figure 4.22 Percentage size distribution of daphnids in Rutland Water 1979-1993

The results of the size class analysis led to the formation of a new hypothesis that the size of the egg-bearing females in Rutland was often less than 1.3mm, which is the minimum length of mature adults described by Hrbacek (1987). This hypothesis arose from the reasoning that since the there had been a loss of the larger daphnids in the reservoir, although there had been no apparent decline in densities or birth rate, maturity must occur, in many instances, at a smaller size to maintain the birth rate. The length of each egg-bearing female was compared for the years 1985, 1990-1991 and 1992-1993 (see appendix II(o)). At each site the means were determined for all gravid females counted in the sample throughout all depths.

The mean length of the egg-bearers did not vary significantly between the sites sampled during 1992-1993 ($p>0.5$; $F=0.021$; $n=24$). However, there had been a significant decrease in size since 1985 ($p<0.001$; $F=7.574$; $n=55$). Figure 4.23 shows the mean length of egg bearers at site 6 during 1992-1993, and the length of egg-bearers at the Limnological Tower in 1990-1991 and 1985. To maintain clarity, standard error bars have not been drawn.

The mean length of gravid female daphnids has declined since 1985. Over the season the mean size fluctuates. The mean clutch size, as measured by fecundity has remained unchanged since 1985 (figures 4.10 and 4.11).

4.7.4 Feeding morphology

(I) Spatial variation

Figure 4.24 shows the filtering area of the limbs of animals collected from N1 in the north arm and S12 in the south arm in 1992 (200 animals per site) (raw data in appendix II(p)). Above 1.2mm standard length there was a significant increase ($p<0.001$; $F=422.83$; $n=167$) in the filtering area of daphnids in the south arm. Figure 4.25 (a & b) show the filtering area of daphnids collected from sites 1 to 7 on two occasions in September 1992 (30 animals per site) (raw data in appendix IIq). Sites 1 to 3, closest to the inlet, show significantly larger filtering areas than sites 4-7 ($p<0.01$; $F=107.49$; $n=328$), above 1.2mm.

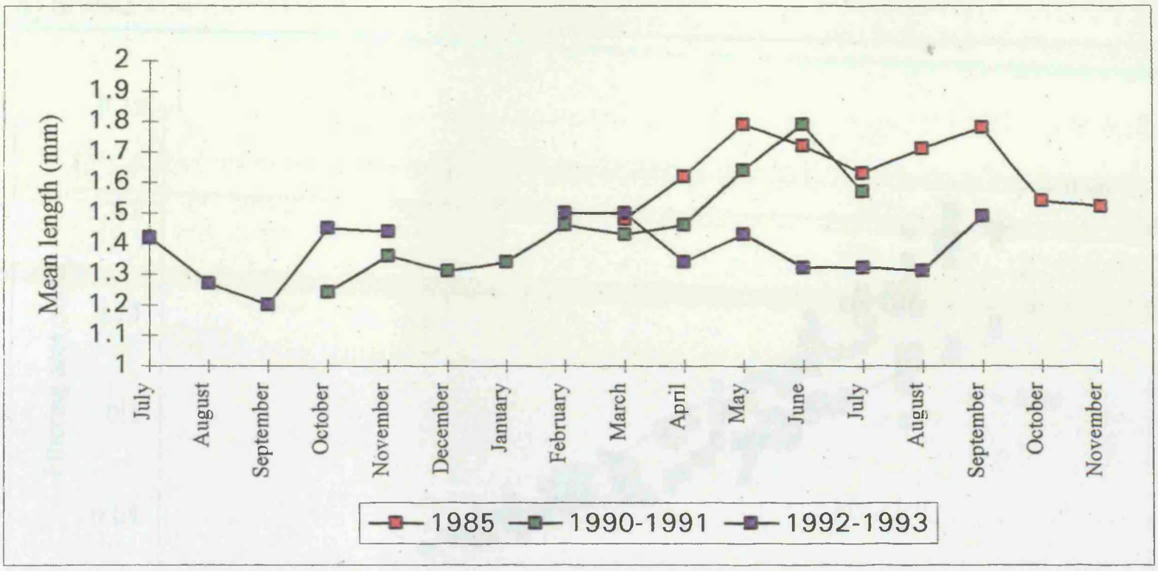


Figure 4.23 Mean length of egg-bearing females in Rutland Water since 1985

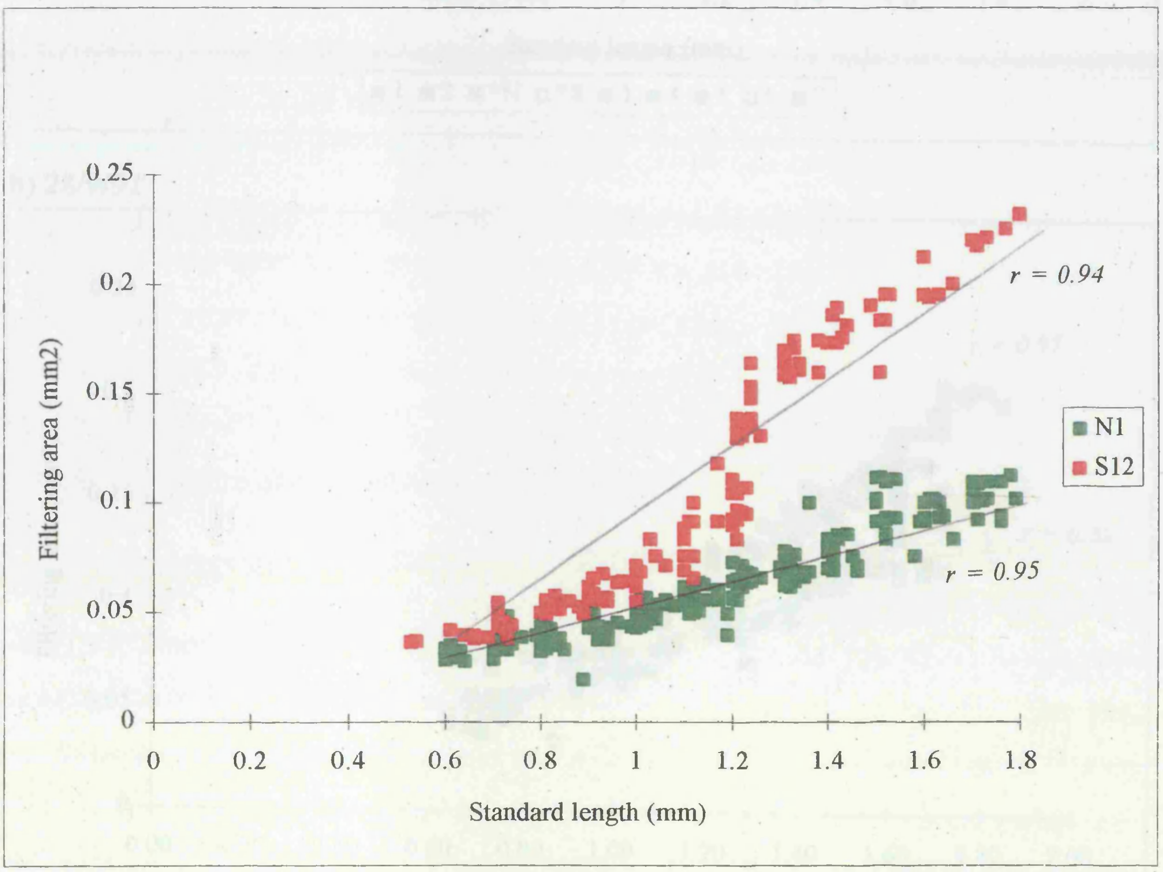
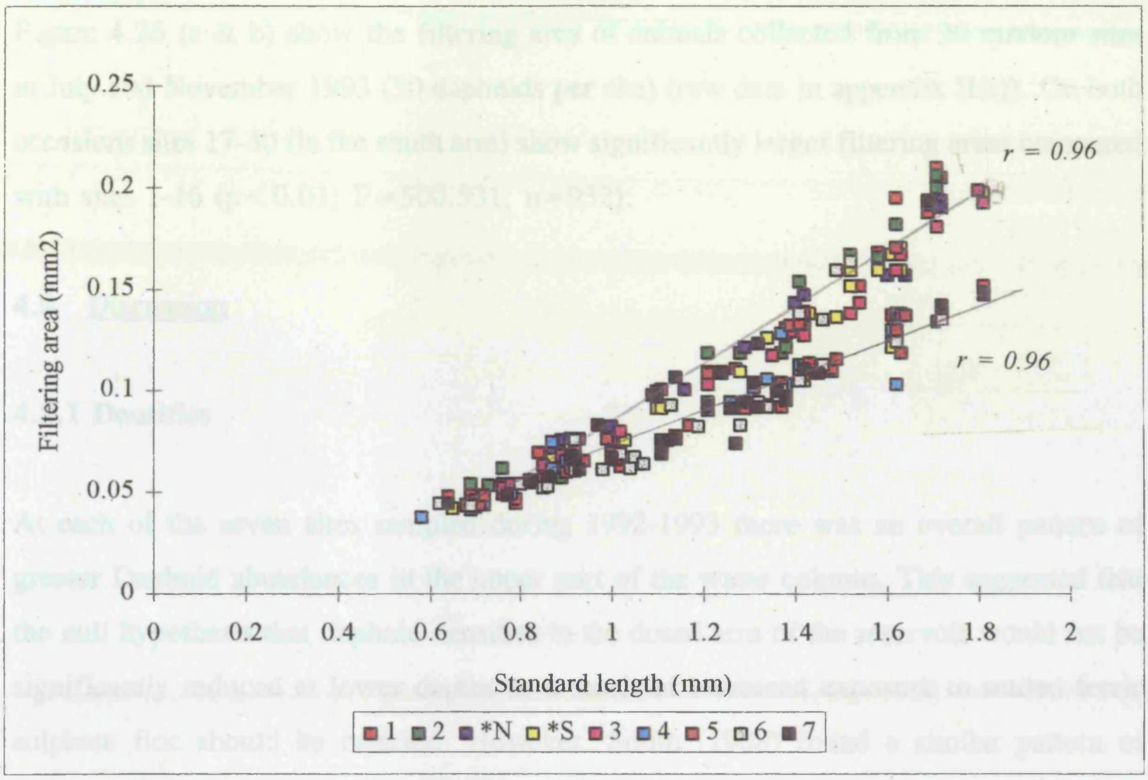


Figure 4.24 Filtering area of third thoracic limb in Daphnids collected from sites N1 and S12 27/5/92 (200 daphnids per site)

a) 8/9/92



b) 28/9/92

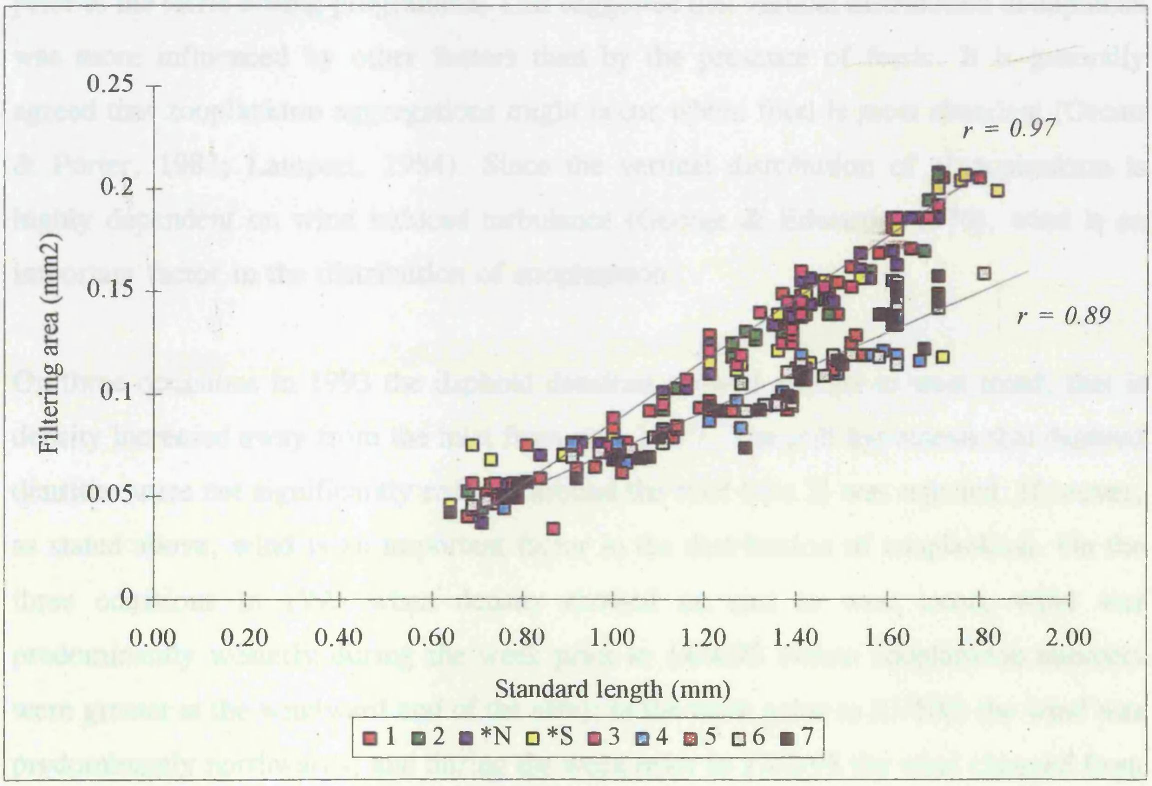


Figure 4.25 Filtering area of third thoracic limb in Daphnids collected from sites 1-7 in 1992 (30 daphnids per site)

(ii) Temporal observations

Figure 4.26 (a & b) show the filtering area of animals collected from 30 random sites in July and November 1993 (30 daphnids per site) (raw data in appendix II(r)). On both occasions sites 17-30 (in the south arm) show significantly larger filtering areas compared with sites 1-16 ($p<0.01$; $F=500.531$; $n=932$).

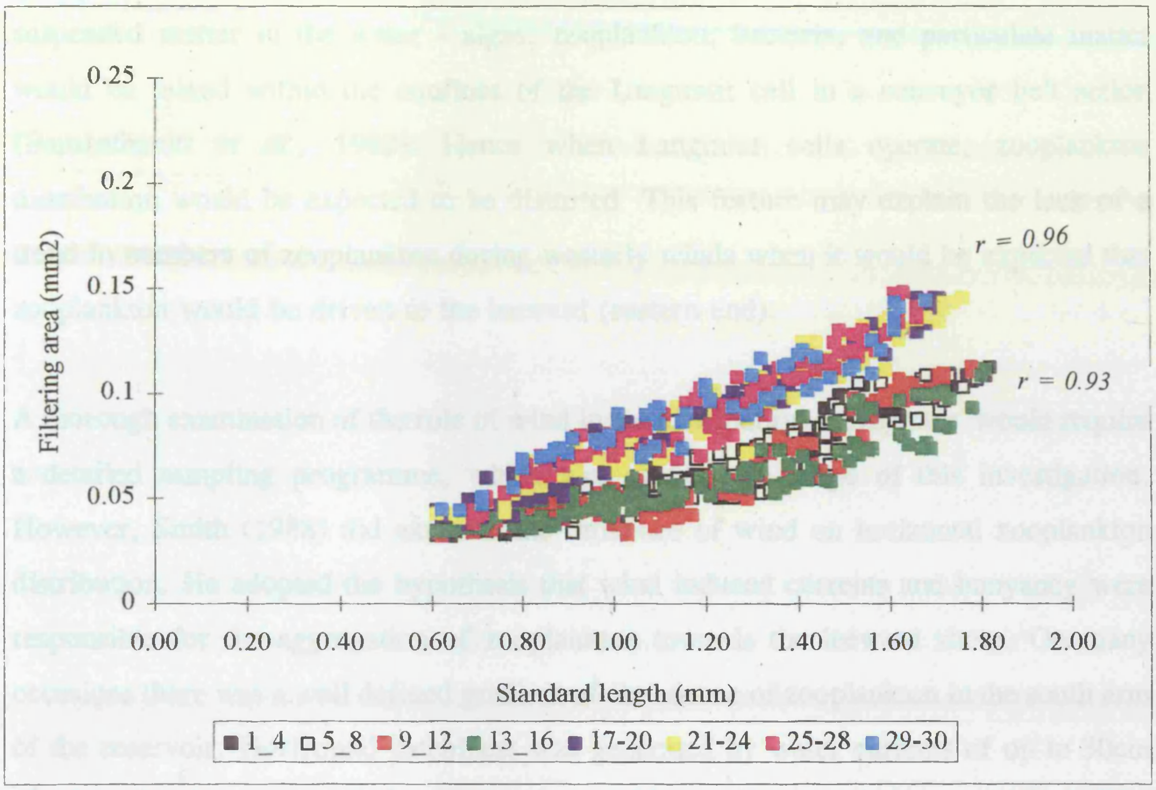
4.8 <u>Discussion</u>

4.8.1 Densities

At each of the seven sites sampled during 1992-1993 there was an overall pattern of greater Daphnid abundances in the upper part of the water column. This suggested that the null hypothesis that daphnid densities in the dosed arm of the reservoir would not be significantly reduced at lower depths as a result of increased exposure to settled ferric sulphate floc should be rejected. However, Smith (1988) found a similar pattern of vertical patchiness amongst *Daphnia* and other crustacean zooplankton in the reservoir prior to the ferric dosing programme. This suggested that vertical distribution of daphnids was more influenced by other factors than by the presence of ferric. It is generally agreed that zooplankton aggregations might occur where food is most abundant (Orcutt & Porter, 1983; Lampert, 1984). Since the vertical distribution of phytoplankton is highly dependent on wind induced turbulence (George & Edwards, 1976), wind is an important factor in the distribution of zooplankton.

On three occasions in 1993 the daphnid densities showed an east to west trend, that is density increased away from the inlet from sites 1 to 7. The null hypothesis that daphnid densities were not significantly reduced around the inlet (site 2) was rejected. However, as stated above, wind is an important factor in the distribution of zooplankton. On the three occasions in 1993 when density showed an east to west trend, wind was predominantly westerly during the week prior to 14/4/93 (when zooplankton numbers were greater at the windward end of the arm); in the week prior to 27/5/93 the wind was predominantly northwards; and during the week prior to 29/6/93 the wind changed from westerly to easterly (when zooplankton numbers were greater at the leeward end). Two

a) July



b) November

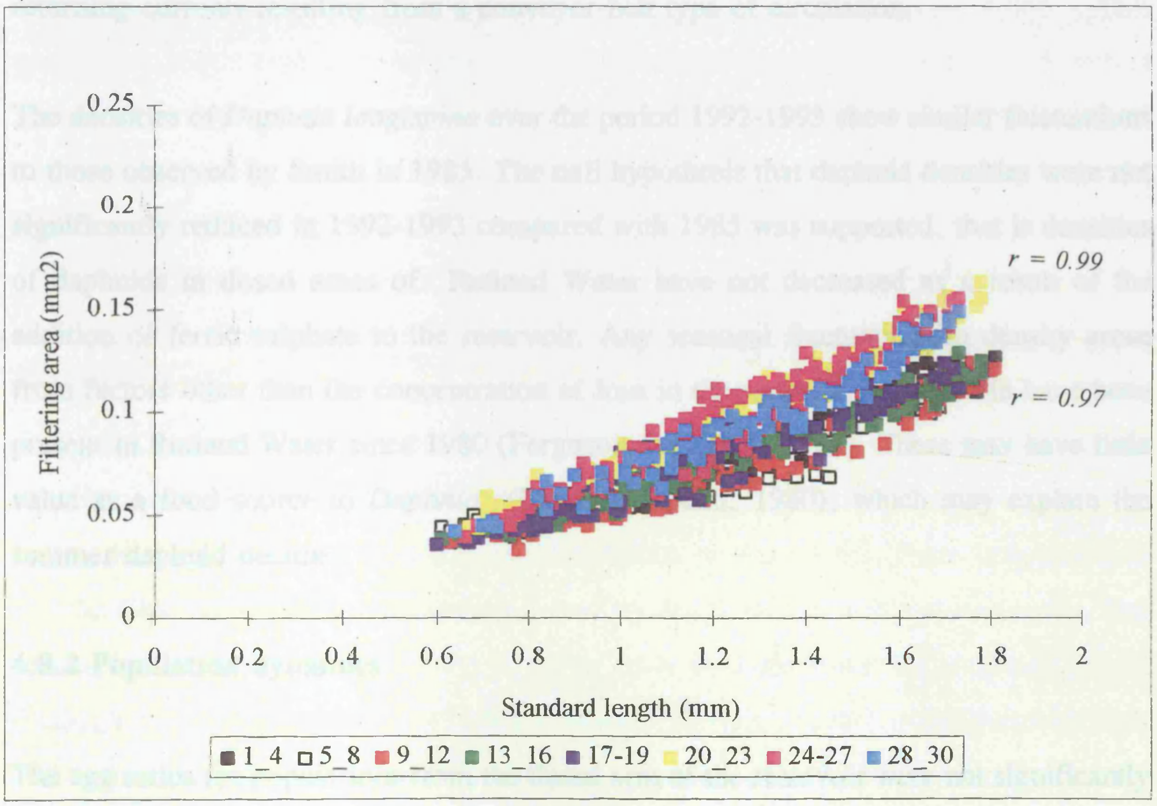


Figure 4.26 Filter area of third thoracic limbs in Daphnids collected from 30 random sites over reservoir in 1993 (30 daphnids per site)

occasions of Langmuir circulation were observed during this investigation. The suspended matter in the water - algae, zooplankton, bacteria, and particulate matter would be mixed within the confines of the Langmuir cell in a conveyor belt action (Baranathanitt *et al.*, 1982). Hence when Langmiur cells operate, zooplankton distribution would be expected to be distorted. This feature may explain the lack of a trend in numbers of zooplankton during westerly winds when it would be expected that zooplankton would be driven to the leeward (eastern end).

A thorough examination of the role of wind in the distribution of *Daphnia* would require a detailed sampling programme, which was outside the scope of this investigation. However, Smith (1988) did examine the influence of wind on horizontal zooplankton distribution. He adopted the hypothesis that wind induced currents and buoyancy were responsible for the aggregation of zooplankton towards the leeward shore. On many occasions there was a well defined gradient of abundance of zooplankton in the south arm of the reservoir. Horizontal patchiness was generated by water currents of up to 30cm s^{-1} over the short term, and was transient, with aggregations being redistributed by returning currents resulting from a conveyor-belt type of circulation.

The densities of *Daphnia longispina* over the period 1992-1993 show similar fluctuations to those observed by Smith in 1985. The null hypothesis that daphnid densities were not significantly reduced in 1992-1993 compared with 1985 was supported, that is densities of daphnids in dosed areas of Rutland Water have not decreased as a result of the addition of ferric sulphate to the reservoir. Any seasonal fluctuations in density arose from factors other than the concentration of iron in the water. Cyanobacteria have been present in Rutland Water since 1980 (Ferguson & Harper, 1982). These may have little value as a food source to *Daphnia* (Porter & Orcutt, 1980), which may explain the summer daphnid decline.

4.8.2 Population dynamics

The egg ratios for populations from the dosed arm of the reservoir were not significantly reduced at lower depths due to greater exposure to settled ferric sulphate floc supporting the null hypothesis (4.2.2). Similarly, the null hypothesis that fecundity, egg ratio, birth rate and instantaneous growth rate were not significantly reduced, and death rate did not increase at sites close to the dosed inlet were also supported. The populations of 1992-1993 and 1985 did not show any significant differences in population statistics, supporting the null hypothesis that fecundity, egg ratio, birth rate and instantaneous growth rate were not significantly reduced and death rate was not increased at site 6 in 1992-1993 compared with site LT during 1985. The results suggest that the addition of ferric sulphate to the reservoir has had neither a direct (toxicity or mechanical interference) or indirect effect (impact on food source) on the population dynamics of *Daphnia longispina* in Rutland Water.

The populations of 1992-1993 and 1985 did not show any significant differences in the calculated population statistics, suggesting that the birth and death rates have not declined as either a direct (toxicity or mechanical interference) or indirect result (impact on food species or concentration) of the addition of ferric sulphate to the reservoir. This was a suprising result since ferric precipitates have been shown to clump algal cells together (Mackenthun & Keup, 1970; Lynch, 1981; Vollenweider & Kerekes, 1982). This coagulation might lead to faster removal of algal particles from the water column so that less adherent algal species or those that include buoyancy mechanisms dominate, which may not be suitable as food for *Daphnia*. Coagulated particles may be too large for *Daphnia* to handle.

Any reduction in availability of suitably sized palatable species might be expected to have an impact on the growth and reproduction of the zooplankton feeding them. Hart (1992) found that populations in enriched food conditions live longer and have a greater number of clutches than those in low food densities. As discussed in Chapter Three, the cyanobacteria populations have increased in dominance since 1985. There is no evidence that the daphnid population has been affected by the change in species dominance. The chlorophyll *a* concentrations in the reservoir have declined since ferric dosing began, although not to concentrations sufficient to cause a daphnid population decline, that is not below the incipient limiting level (McMahon, 1965).

4.8.3 Body size

The null hypothesis that the body size of daphnids was not significantly reduced at sites around the dosed inlet, was supported by the results. The null hypothesis that there would be no significant reductions in body size of daphnids at site 6 in 1992-1993, LT 1990-1991, LT 1985 and LT 1979-1980 was rejected however. Since historical records in Rutland Water began in 1979 there has been a reduction in the size of *Daphnia longispina*. However, this size change occurred between 1980 and 1985, a minimum of 5 years prior to commencement of ferric dosing. This means that ferric dosing has not been responsible for the reduction in the size of *Daphnia longispina*. One possible explanation for the reduction in size of *Daphnia longispina* since 1980 was the increase in dominance of the cyanobacteria species throughout the year. In the USA, Hart (1992) associated body length in daphnids with food availability and suitability. Increased food availability or suitability gave greater growth and conversely, a decline in food availability led to less growth. In enriched food conditions larger females and larger clutches were observed. Tessier *et al.* (1992) found that a decrease in food resources may cause a smaller size at maturity.

The mean length of egg-bearing females in Rutland Water has declined since 1985, so the null hypothesis was rejected (4.2.3). Egg-bearing daphnids collected from 1990-1991, following the advent of ferric dosing at a ratio of 20:1 Fe:P, had a statistically significant smaller mean size than those collected during 1992-1993, when dosing was carried out at a ratio of 15:1 Fe:P (P. Daldorph, pers. comm.). Although this suggests that the size of mature females is inversely proportional to the amount of ferric sulphate added to the reservoir, it seems unlikely. The mean size during 1990-1991 was calculated from those egg-bearing females found in 50 animals, with a greater standard error than the mean size during 1992-1993 calculated from those egg-bearing females in a whole sample (often >250 animals) with a smaller standard error.

The second, and most likely explanation for this observed size reduction is the increase in biomass of coarse fish in the reservoir, although this factor has not been investigated since the reservoir was constructed. Visual predators such as roach and perch have been shown in studies in other reservoirs to predate on the larger bodied zooplankton so the daphnid population becomes dominated by small sized daphnids (Benndorf *et al.*, 1988; Galbraith, 1967; Vijverberg & van Densen, 1984; Sed'a & Duncan, 1994). The need to maintain the population drives the onset of maturity at a smaller size (Gliwicz & Rykowska, 1972).

4.8.4 Feeding morphology

The addition of ferric sulphate was considered to 'dilute' the food, as well as being unsuitable food for zooplankton. One response to such low food conditions that has been observed is an increase in filtering area of the third thoracic limb (Coker & Hayes, 1940; Fott *et al.*, 1974; Hrbacek *et al.*, 1979; Korinek & Machacek, 1979; Korinek *et al.*, 1985; Lampert, 1974; Lampert & Brendelberger, 1996). The filtering area of the daphnid population within the south arm of the reservoir increased compared with that of daphnids in the north arm rejecting the null hypothesis that there would be no such significant difference. The null hypothesis that the filtering area of daphnids collected during November when low food concentrations would have been available, was not significantly reduced compared with daphnids collected during July in plentiful food concentrations was supported.

These results suggest that there are differences in the north and south arm, great enough to induce such a response in the *Daphnia* population. As an adaptive function in field populations this mechanism will decrease the chances of daphnid mortalities occurring due to starvation.

4.8.5 Conclusions

This study has shown that the addition of ferric sulphate to the south arm of Rutland Water has had no impact on the zooplankton population dynamics. There is evidence of a loss of larger daphnids in the reservoir, although this occurred before dosing began, and could not be attributed to the addition of ferric sulphate. However, the size of mature (egg-bearing) daphnids has declined since 1985, which may be the result of ferric dosing, although predation by coarse fish probably plays an important role in this size reduction. Filtering area in the daphnids was greater in animals collected from the south arm of the reservoir compared with the north arm, which may be the result of ferric sulphate additions to this arm. Both the phenomena of reduced size at maturity and increased filtering area are adaptive functions which may reduce the impact of the chemical addition of ferric sulphate.

Chapter Five - Experimental investigation of ferric sulphate dosing on *Daphnia* and a potential algal food species, *Chlorella*

5.1 Introduction

Laboratory investigations using ferric sulphate were carried out on two organisms: the Chlorophyte *Chlorella vulgaris* and the cladoceran *Daphnia longispina*, dominant in Rutland Water. *Chlorella vulgaris* was cultured for use as a food source for *Daphnia*, and for growth inhibition experiments in its own right.

The literature reviewed in Chapter Two showed that although toxicity tests using iron compounds have been conducted on *Daphnia*, these only examined ferrous iron (Biesinger & Christensen, 1972; Khangarot and Ray, 1989) which is of a different chemical nature to ferric iron. Ferrous iron is generally dissolved in water and so more easily ingested than particulate ferric compounds. Although safe levels for ferric iron have been established for other fauna, the wide range of sensitivities of different taxa described in the literature suggested that it was inappropriate to apply those findings in Rutland Water without conducting comparative toxicity tests using ferric iron and *Daphnia longispina*. Toxicity tests would not only answer the question whether ferric iron was toxic to *Daphnia* but also provide animals exposed to known concentrations over a known period of time for comparative examination of their morphology.

One study in the literature (Becker & Keller, 1973) identified the toxicity of ferrous sulphate to *Chlorella vulgaris*, but gave unqualified nominal concentrations and also did not identify the mechanism by which growth inhibition occurred. The tests described in this chapter attempt to establish whether growth inhibition occurred also in ferric iron, and to examine the mechanisms involved.

Chlorella vulgaris is a small unicellular algae, and a suitable food source for *Daphnia* (Unilever, 1985). Although literature on its culture is sparse, it has been used in growth inhibition tests and as a food source for zooplankton in the chemical development industry for decades, due to the ease with which it may be cultured (OECD, 1981). Since 1981, the algae species used in compliance with International Standard ISO 8692 are the Chlorophyta *Scenedesmus subspicatus* and *Selenastrum capricornutum* (S. Marshall, pers comm.). However the author found these two species difficult to maintain successfully in artificial conditions.

Daphnia longispina O.F Müller, the most common daphnid in Rutland Water, was cultured in the laboratory for use in toxicological, morphological and behavioural investigations into the effects of ferric sulphate. *Daphnia* have been used for decades in the testing of substances in the aquatic environment. They are relatively easy to culture under laboratory conditions; are easily obtained from their wild habitat; bear many young parthenogenetically; and have successive broods as little as three days apart (Adema, 1978). As a result there is literature available about daphnid culture (Adema, 1978; Biesinger & Christensen, 1972; Cowgill, 1987; Donaghay, 1985; Enserink *et al.,* 1990; Jones *et al.*, 1991; Langeland *et al.*, 1985; Milbrink & Bengtsson, 1991; Ten Berge, 1978; Tevlin, 1978; Vijverberg, 1989; Winner & Farrell, 1976). Additionally, their sensitivity to substances in the water apparently corresponds to the sensitivity of other fauna (Murphy, 1979). Hence, *Daphnia* have become a popular choice as subjects for toxicity testing, although only two studies, those of Biesinger and Christensen (1972) and Khangarot and Ray (1989), have investigated the toxicity of iron salts.

Culturing methods for both the alga and *Daphnia* were derived from Unilever, Port Sunlight, and the IFE, Cumbria (Stuart Marshall; Colin Reynolds, pers. comm.), and are detailed in the technical appendices (I (k) & I (p).

5.2 Hypotheses tested

5.2.1 Growth inhibition of *Chlorella vulgaris* (Investigation I)

Experiments testing the effects of ferric sulphate on the growth of the Chlorophyte *Chlorella vulgaris* were carried out. The role of ferric sulphate in sewage treatment works is to precipitate algae and suspended material (Mackenthun & Keup, 1970; Lynch, 1981;

Vollenweider & Kerekes, 1982). The growth of *Chlorella vulgaris* was measured to investigate the hypothesis that this precipitation of algae is achieved by aggregation of the algae cells, which lead to growth inhibition of *Chlorella.* The null hypotheses investigated were:

Growth inhihition of *Chlorella* would not occur in ferric sulphate;

Aggregation of *Chlorella* would not occur in ferric sulphate.

The consequences of growth inhibition of *Chlorella vulgaris* on *Daphnia* are two-fold. Firstly, growth inhibition of algae might lead to diminished food availability to *Daphnia*, and secondly any aggregation of algal cells may reduce the range of particle sizes that *Daphnia* are able to filter.

5.2.2 Toxicity of ferric sulphate to *Daphnia longispina* (Investigations II &III)

The most common daphnid in Rutland Water, *Daphnia longispina* was chosen as a test organism for investigating the effect of ferric sulphate dosing on planktonic invertebrates. The null hypotheses investigated were:

Ferric sulphate would not have a toxic effect on *Daphnia longispina* individuals in acute tests;

Ferric sulphate would not have sublethal effects (represented by reduced reproduction) on *Daphnia longispina* populations in chronic tests .

Both these hypotheses were investigated by means of two types of toxicity test: acute toxicity tests, over 48 hours; and chronic tests, over 21 days. After pilot studies to find the range of concentrations within which survivors and mortalities were recorded, tests were carried out using dissolved and particulate iron (III). Additional tests were carried out using china clay, which is inert chemically but insoluble in water producing a floc. This provided a non-toxic particulate control.

5.2.3 Behavioural responses to the chemical or particulate nature of ferric sulphate (Investigation IV)

Daphnid filtering rate increases or decreases in response to a number of factors (Rigler, 1961; Lampert & Schober, 1980; Philipova & Postnov, 1988; Urabe, 1991). The impact of particle size, taste, food concentration, temperature, hunger, food quality and nutrient limitation on filtering rate are reviewed in Chapter Two. The particulate nature of ferric sulphate was thought to causes mechanical interference with daphnid collection and ingestion of algal cells leading to starvation and eventual mortality. Hence the null hypotheses investigated were as follows:

> Feeding rate (measured by thoracic appendage beat rate) would not be higher in the presence of ferric sulphate compared with a control;
>
> The number of times particles were rejected from the food groove would not be higher in ferric sulphate compared with a control.

5.2.4 Morphological adaptation of third thoracic limb of *Daphnia longispina* (Investigation V)

Comparisons of the filtering combs on the 3rd and 4th thoracic limbs in several species of *Daphnia* and *Ceriodaphnia* from many habitats indicated that the 3rd pair of limbs were most likely to show an increase in size in response to declining phytoplankton concentrations (Korinek *et al.,* 1985). Pop (1991) found this adaptation occurred in individuals during moulting, rather than in successive clones coexisting in one population.

The presence of ferric sulphate precipitates or china clay in this study were thought to effectively 'dilute' the suitable food available to *Daphnia longispina* during chronic toxicity tests. The impact on *Daphnia* of dilution of food by ferric sulphate was investigated by testing the following null hypothesis:

The morphological adaptation of greater filtering area in relation to body length would not occur in ferric sulphate or china clay in when compared with a control.

5.3 Investigation I - Impacts of ferric sulphate on *Chlorella vulgaris*

5.3.1 Methods

(I) Test concentrations

An appropriate volume of the stock ferric suspension was added to a 1000ml volumetric flask and made up to 1000ml with Jaworski's medium (see appendix I (j) for composition) to produce the following nominal concentrations:

a) 0.00, 0.05, 0.085, 0.1, 1.25, 1.5, 2.0 mg Fe^{3+} l^{-1} dissolved

b) 0.00, 50, 100, 150, 200, 250, 300 mg Fe^{3+} l^{-1} particulate

These nominal values were derived from replicate atomic absorption spectrophotometry (AAS) measurements shown in appendix II(v). Dissolved iron was the dominant fraction obtained after removal of the flocculated iron by filtration through a Whatman® cellulose nitrate membrane (0.45μm) using a Buchner funnel; particulate iron was the dominant fraction on addition of ferric sulphate to Jaworski's medium. Two replicates of each filtered test medium were poured into 250ml conical flasks. An additional 250ml sample was fixed with 2.5 $\pm$ 0.05ml 'PrimaR' grade fumic nitric acid for later digestion and dissolved iron determination by AAS (method described in appendix I(b). The media were buffered with either calcium carbonate or sodium hydroxide. At the end of each test a 250ml sample of each test concentration was fixed with nitric acid for AAS determination of the iron concentration.

(ii) Test alga

Each vessel was then inoculated with 10^4 cells from the stock *Chlorella vulgaris* cultures (Strain no. CCAP 211/11b from Institute of Freshwater Ecology Culture Centre for Algea and Protozoa). These stock cultures were in the exponential phase of growth when the inoculum was removed (appendix II(s)).

(iii) Experimental conditions

250ml conical flasks with two-holed stoppers were used to carry out the tests. Test vessels were maintained for 7 days in an environmental cabinet under the same conditions as the cultures. They received continuous light at 20$\pm$2°C with air bubbling through each vessel (which maintained any floc in suspension. Each vessel was rotated daily to give equal exposure to the light, and its position in series receiving the air supply changed over the 7 days, since there was limited space on each shelf of the environmental cabinet.

(iv) Experimental monitoring

Algal growth was monitored at 24, 48, 72, 96, 120, 144 and 168 hours. 5.0 $\pm$ 0.01ml of the test culture was removed from each vessel and counted using the Lund Cell chamber (see appendices I(k) and I(l)). This volume was not replaced.

5.3.2 Results

The growth rates from all tests are summarised in table 5.1. In each case the number of cells ml^{-1} of the algae in the control increased by >16 times over 72 hours so the test results were accepted. The results from each pair of replicate vessels were averaged. Raw data are given in appendix II(t).

Growth rates were calculated using the following equation:

$$\text{Growth rate } \mu = \frac{\ln Nn - \ln No}{tn}$$

Where N_o = no cells ml^{-1} in inoculum; N_o = no. cells ml^{-1} after n days; and t_n is the number of days over which the test was carried out i.e. 7.

The results indicate that dissolved ferric sulphate in concentrations of < 2.0mg l^{-1} did not cause growth inhibition in *Chlorella vulgaris.*

Table 5.1 Summary of growth inhibition experiments on *Chlorella vulgaris* in ferric sulphate

Nominal iron mg/l	Iron T_0 mg/l	Iron T_i mg/l	Dissolved/ partic Fe	Buffer	$\ln N_n$	$\ln N_o$	$\mu(d^{-1})$
0.000	0.00	0.00	D	Na(OH)	14.58	10.18	0.628
0.050	0.08	0.05	D	Na(OH)	14.55	10.18	0.624
0.085	0.09	0.07	D	Na(OH)	14.53	10.18	0.621
0.100	0.13	0.11	D	Na(OH)	14.62	10.18	0.634
1.250	1.20	0.38	D	Na(OH)	14.60	10.18	0.631
1.500	1.54	0.72	D	Na(OH)	14.60	10.18	0.631
2.000	2.03	1.06	D	Na(OH)	14.64	10.18	0.637
0.000	0.05	0.05	D	$CaCO_3$	14.60	9.90	0.671
0.050	0.07	0.06	D	$CaCO_3$	14.60	9.90	0.671
0.085	0.08	0.07	D	$CaCO_3$	14.60	9.90	0.671
0.100	0.11	0.09	D	$CaCO_3$	14.60	9.90	0.671
1.250	1.29	0.41	D	$CaCO_3$	14.60	9.90	0.671
1.500	1.53	0.79	D	$CaCO_3$	14.60	9.90	0.671
2.000	2.11	1.02	D	$CaCO_3$	14.60	9.90	0.671
0.000	0.05	0.05	P	$CaCO_3$	14.78	9.48	0.750
50.00	57.2	59.4	P	$CaCO_3$	14.96	9.48	0.780
100.0	113.1	114.3	P	$CaCO_3$	14.29	9.48	0.680
150.0	162.8	171.3	P	$CaCO_3$	13.92	9.48	0.630
200.0	239.6	241.6	P	$CaCO_3$	13.68	9.48	0.600
250.0	265.9	273.8	P	$CaCO_3$	13.56	9.48	0.580
300.0	371.4	379.6	P	$CaCO_3$	13.45	9.48	0.560
0.000	0.05	0.05	P	$CaCO_3$	14.10	9.95	0.690
50.00	54.1	61.3	P	$CaCO_3$	14.21	9.95	0.710
100.0	126.0	129.3	P	$CaCO_3$	13.86	9.95	0.650
150.0	173.4	177.2	P	$CaCO_3$	13.65	9.95	0.610
200.0	221.9	226.4	P	$CaCO_3$	13.55	9.95	0.600
250.0	274.3	277.4	P	$CaCO_3$	13.36	9.95	0.560
300.0	301.4	306.8	P	$CaCO_3$	13.13	9.95	0.530
0.000	0.05	0.05	P	Na(OH)	15.76	10.5	0.750
50.00	53.6	55.4	P	Na(OH)	15.01	10.5	0.640
100.0	118.3	123.6	P	Na(OH)	14.22	10.5	0.530
150.0	159.4	164.5	P	Na(OH)	13.80	10.5	0.470
200.0	211.7	217.6	P	Na(OH)	13.66	10.5	0.450
250.0	272.4	281.3	P	Na(OH)	13.54	10.5	0.430
300.0	284.1	298.6	P	Na(OH)	13.19	10.5	0.380

(D = dissolved iron; P = particulate iron; N_o= no cells ml^{-1} in inoculum; N_o= no. cells ml^{-1} after *n* days; μ = growth rate)

The reduction in the amount of dissolved iron in the medium over the 7 day period may have occurred for two reasons. Firstly, dissolved iron may have been taken up by the algae as part of its nutrition. Secondly, dissolved iron may have precipitated out of solution. It was not possible to ascertain which of these reasons was correct, since it was not feasible to separate the algal cells from the particulate iron.

Figure 5.1 shows the cell counts of *Chlorella vulgaris* in increasing concentrations of particulate iron. The area under the graph was calculated using the following equation:

$$\text{Area A} = \frac{N_1 - N_0 \times 24\text{hr}}{2} + \frac{N_1 + N_2 - N_2 - 2(N_0) \times 24}{2} + \frac{N_2 + N_3 - 2(N_0) \times 24}{2}$$

$$+ \frac{N_3 + N_4 - 2(N_0) \times 24}{2} + \frac{N_4 + N_5 - 2(N_0) \times 24}{2} + \frac{N_5 + N_6 - 2(N_0) \times 24}{2}$$

The results of this calculation for each replicate are displayed in appendix. The results of this test indicated that particulate ferric sulphate affected the growth of *Chlorella vulgaris* in comparison with a control in which particulate ferric was absent. Table 5.2 shows the calculated inhibition of growth by particulate iron.

Table 5.2 Percentage inhibition of growth rate by particulate iron

Nominal iron mg/l	Test	Area (Mean of 2 replicates) x 10^7	% Inhibition (I_{AI})
0.00	A	13.7	
	B	10.1	
	C	53.4	
50.00	A	15.8	+15%
	B	11.2	+10%
	C	27.5	-48%
100.00	A	9.58	-30%
	B	7.19	-29%
	C	1.21	-77%
150.00	A	6.91	-49%
	B	5.48	-45%
	C	6.36	-88%
200.00	A	6.52	-52%
	B	5.38	-46%
	C	5.23	-90%
250.00	A	5.89	-57%
	B	4.58	-45%
	C	4.26	-92%
300.00	A	5.5	-59%
	B	3.7	-63%
	C	2.72	-94%

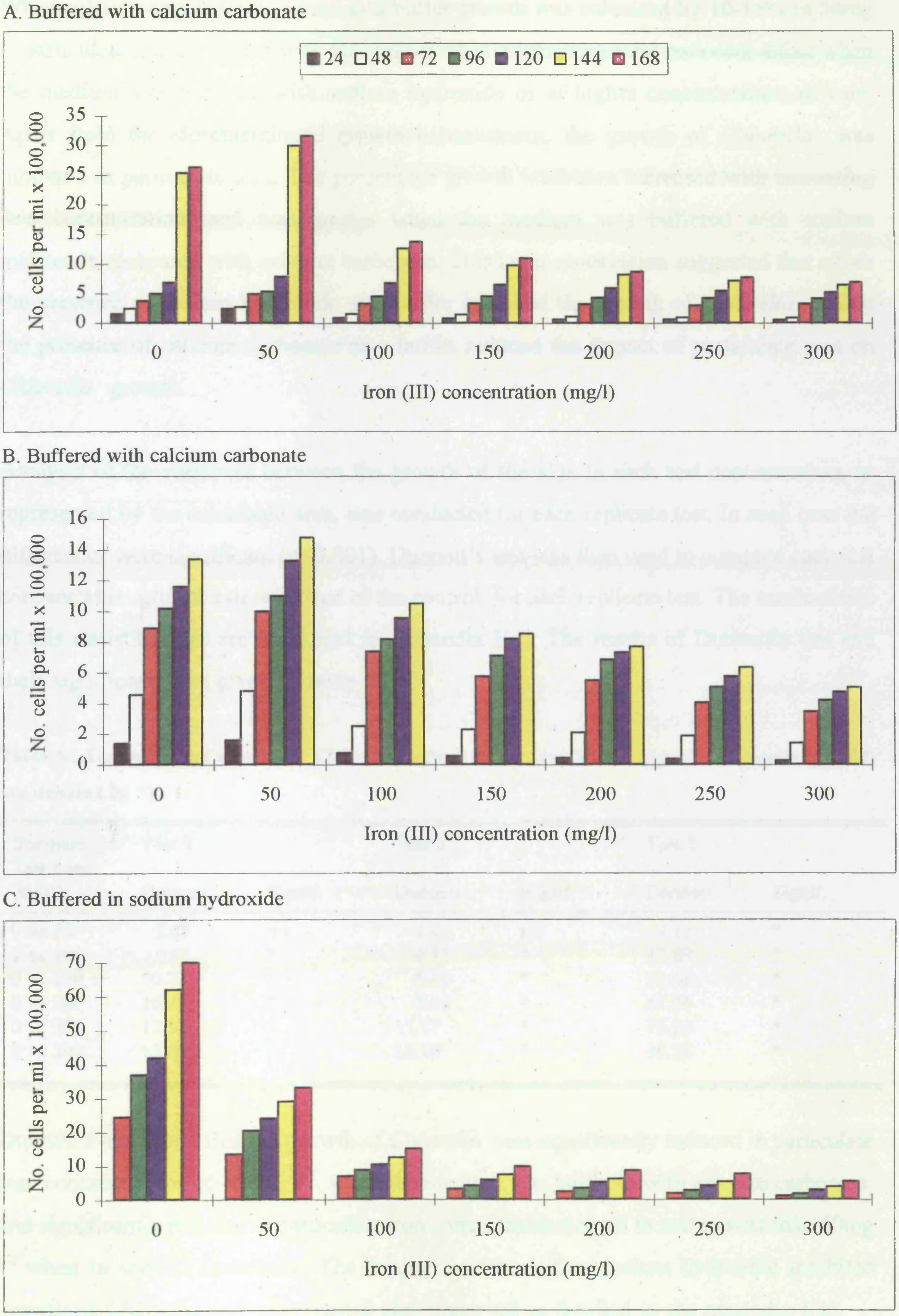


Figure 5.1 Daily growth rate of Chlorella vulgaris in particulate iron

When calcium carbonate was used as a buffer growth was enhanced by 10-15% in 50mg l^{-1} particulate iron compared with the control. This enhancement did not occur either when the medium was buffered with sodium hydroxide or at higher concentrations of iron. Apart from the aforementioned growth enhancement, the growth of *Chlorella* was inhibited in particulate iron. The percentage growth inhibition increased with increasing iron concentration, and was greater when the medium was buffered with sodium hydroxide compared with calcium carbonate. This latter observation suggested that either the presence of sodium hydroxide as a buffer inhibited the growth of *Chlorella* or that the presence of calcium carbonate as a buffer reduced the impact of particulate iron on *Chlorella* growth.

Analysis of the variances between the growth of the alga in each test concentration, as represented by the calculated area, was conducted for each replicate test. In each case the differences were significant ($p<0.001$). Dunnett's test was then used to compare each test concentration growth rate with that of the control, for each replicate test. The mechanisms of this statistical test are explained in Appendix I(q). The results of Dunnett's test and their significance are given in table 5.3

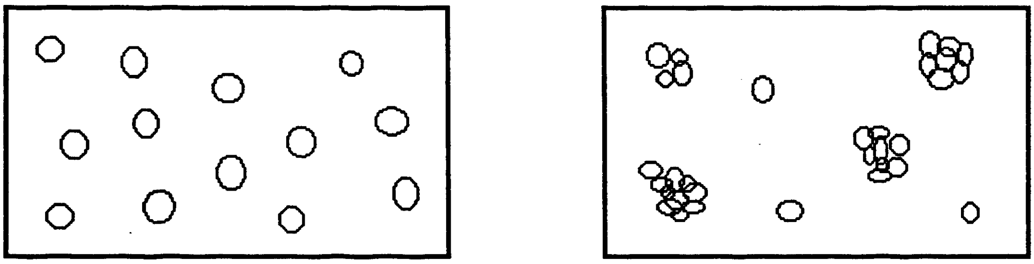
Table 5.3 Dunnett's test results for *Chlorella vulgaris* in particulate iron (significant results ($p<0.05$) are denoted by *)

Compare Test conc (mg/l)	Test 1 Dunnett	Signif.	Test 2 Dunnett	Signif.	Test 3 Dunnett	Signif.
0 vs 50	2.08	n.s	1.49	n.s	19.17	*
0 vs 100	5.03	*	4.83	*	42.89	*
0 vs 150	10.22	*	8.62	*	61.61	*
0 vs 200	10.99	*	8.90	*	67.26	*
0 vs 250	12.51	*	11.17	*	73.23	*
0 vs 300	13.80	*	14.16	*	86.23	*

Dunnett's test found that the growth of *Chlorella* was significantly reduced in particulate iron concentrations of >50mg l^{-1}, when the medium was buffered with calcium carbonate, and significantly reduced in particulate iron concentrations equal to and greater than 50mg l^{-1} when in sodium hydroxide. The arising hypothesis that sodium hydroxide inhibited growth of *Chlorella* was investigated and disproved as detailed in the appendix I(n).

In each test the particulate iron concentration increased over the 7 days. This was assumed to be dissolved iron coming out of solution into a particulate form. This increase was random and only a small percentage of the initial volume. Dissolved iron was assumed to pass through a 0.45µm cellulose nitrate filter.

Samples of *Chlorella* grown in ferric sulphate examined under the microscope (Zeiss standard 16) showed aggregation (figure 5.2). This aggregation occurred in all concentrations of iron, but was most obvious in samples containing a nominal concentration of 150 mg l^{-1}. Aggregation was not quantified.



a) no ferric sulphate **b) in 150mg/l iron (III)**

Figure 5.2 Aggregation of *Chlorella vulgaris* in ferric sulphate

5.4 <u>Investigation II - The short-term impact of ferric sulphate and china clay on the survival of *Daphnia longispina*</u>

5.4.1 Methods

(I) Experimental media

3.57g of ferric sulphate was suspended in 1 litre of daphnid medium (for chemical composition see appendix I(f) to give a stock suspension containing 500mg Fe^{3+} l^{-1}. Addition of ferric to the medium depressed the pH to pH6. In initial experiments calcium carbonate was added as a buffer; latterly, it was found that leaving the stock suspension with air bubbling through it for one week raised the pH to 7.5 - 8. A china clay stock suspension was made up in daphnid medium so that it contained the same dry weight of suspended solids as the ferric sulphate stock suspension. A stock suspension of china clay was made up using the relationship 357mg l^{-1} ferric is equivalent to 162mg l^{-1} china clay. The suspensions were placed in an environmental cabinet in order that it equilibrated to the temperature of the cultures.

(ii) Test concentrations

An appropriate volume of stock suspension, which had been well shaken, was added to a 1 litre volumetric flask and made up to 1 litre with daphnid medium to produce the following nominal concentrations:

0.00, 0.1, 0.3, 0.45, 0.55, 0.85, 1.0 mg Fe^{3+} l^{-1} dissolved iron

0.0, 1.0, 2.0, 8.0, 10.0, 15.0, 25.0 30.0, 50.0 mg Fe^{3+} l^{-1} particulate iron

0.00, 0.70, 1.40, 6.30, 8.40, 21.0 mg l^{-1} china clay (dry weight)

These nominal values were derived from replicate AAS measurements given in appendix IIv. To obtain dissolved iron each test concentration was filtered using 0.45μm Whatman® cellulose nitrate filters to remove the floc. A 100ml aliquot of each test concentration was poured into one of four duplicate 100ml beakers. A 100ml sample of each test concentration was then fixed with 1.0 ± 0.01ml of 'PrimaR' nitric acid for later AAS analysis of the iron content. Two additional 100ml samples of each filtered test concentration were kept under the same conditions as the test vessels but in the absence of daphnids, which were filtered and fixed for later iron analysis. A sample of each china clay test concentration was retained at the beginning of the test and filtered using 0.45μm Whatman® cellulose nitrate membranes and dry weights determined.

(iii) Controls and replicates

All tests included controls which contained the synthetic medium only and which in all other respects were treated identically to the test concentrations. In each acute test 3 neonate daphnids (less than 24 hours old) were placed in each test and control vessel, and there were four replicates of each test concentration and control. Foil lids were placed over the top of each 100ml beaker to minimise evaporation.

(iv) Source of neonates

The tests commenced with neonate *Daphnia* obtained from laboratory cultures. On the day of the test, the neonates were taken from the cultures and placed in a 200ml beaker containing daphnid medium (within 2°C of that of the culture vessels) prior to use. If insufficient neonates were obtained these were either used to maintain the cultures or discarded, and the start of the test delayed until adequate numbers were available. Neonates were transferred to the test vessels using a wide bore pipette (approx. 6mm diameter).

(v) Feeding

During acute tests (48 hours) the daphnids were not fed, and the medium was not replaced.

(vi) Environmental conditions

The environmental conditions during the tests were the same as for the stock daphnid cultures. That is, they were maintained in an environmental cabinet at 20 $\pm$ 2°C under a 16 hour light and 8 hour dark light regime, in media that had been saturated in oxygen prior to the test in order that an air saturation value of at least 80% was maintained. The ferric floc was periodically resuspended, to simulate conditions in the reservoir, by gentle agitation of the vessels (including controls) twice a day.

(vii) Monitoring

At 24 hours the number of immobile *Daphnia* were recorded, but not removed. Immobile *Daphnia* were those which were not able to swim within 15 seconds after gentle agitation of the test container. At 48 hours the numbers of both immobile and mobile *Daphnia* were recorded.

(viii) Analyses

Tests at each concentration were carried out at least twice. To test the comparability of each repeated test ie. to determine whether the test results could be combined, two way analysis of Variance was carried out on arcsine transformed data. This method of transformation is used on data which are expressed as percentages or proportions and lie between 0-30% and 70-100% and are usually non-normal, i.e. there are too many values at the tails of the distribution relative to the centre (Prepas, 1984):

$$X'_{\mathrm{I}} = \text{arcsine}\sqrt{X_{\mathrm{I}}}$$

This reduces the scale in the middle of the distribution and extends the tails.

5.4.2 Results

The results of toxicity tests are summarised in appendix II(u). In toxicity tests investigating dissolved iron, particulate iron and china clay, replicate tests were found to have no significant differences ($p>0.05$) between them and so the results from each replicate test at each test concentration for each investigated chemical were combined.

There were no significant mortalities under dissolved iron conditions (fig. 5.3). Mortalities were below 20% in all iron concentrations. Atomic absorption spectrophotometric analyses of the iron content revealed that the amount of dissolved iron declined over 48 hours, and at the end of the test there was no significant difference between the dissolved iron content in the samples (figure 5.4). It was assumed that dissolved iron had come out of solution into a particulate form. The transient nature of the dissolved iron in the medium may explain why there was no impact by dissolved iron on the *Daphnia.*

The results from particulate iron tests, expressed as composites from all tests are displayed in figure 5.5. Mortalities at different test concentrations of particulate iron were significantly different from one another ($P<0.01$). Percentage mortality increased with increasing concentration of iron, suggesting that particulate iron was having a detrimental effect. Dunnett's test (described in appendix I(q)) was used to compare the mortalities (transformed data combined from each test) in each test concentration with the mortalities occurring in the control (see table 5.4). Significant mortalities occurred in nominal concentrations of 10mg l^{-1} and above. Atomic absorption spectrophotometric analyses of the iron content of each test media showed that over the 48 hour test period, the amount of particulate iron increased by up to 22μg (see Table 5.5) an increase of

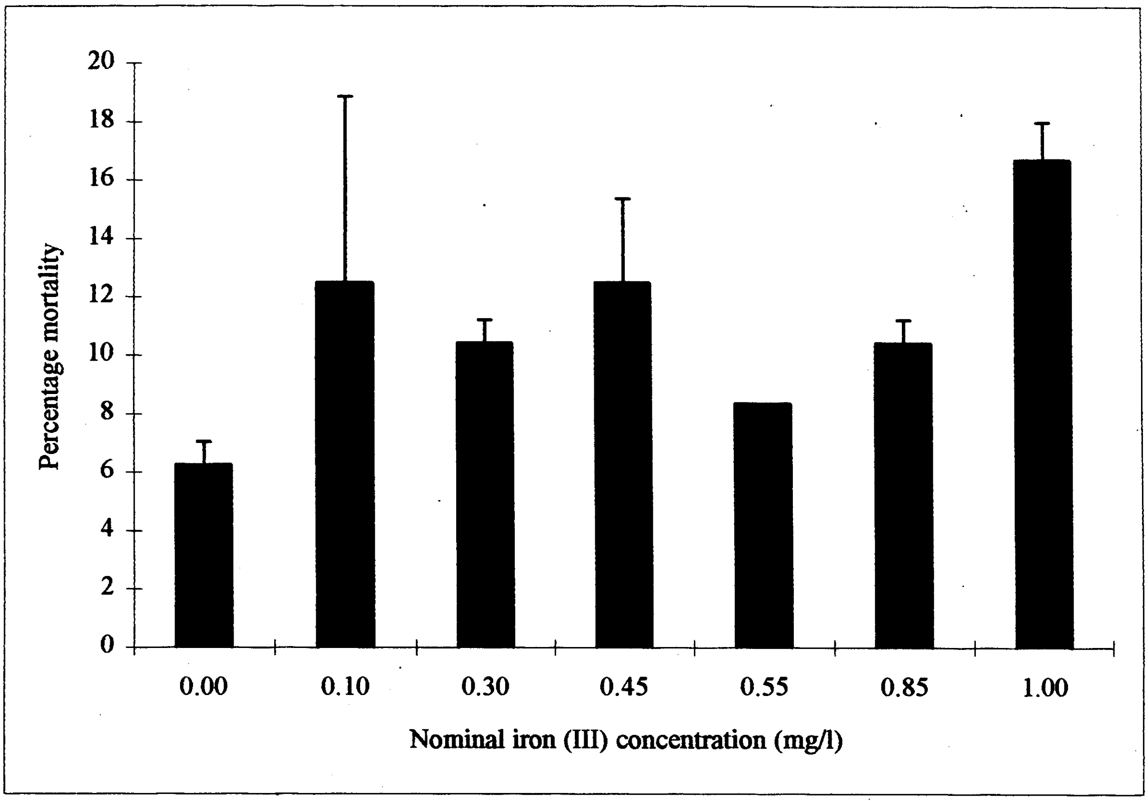


Figure 5.3 Daphnid mortalities in dissolved iron (48 hours) (95% error bars)

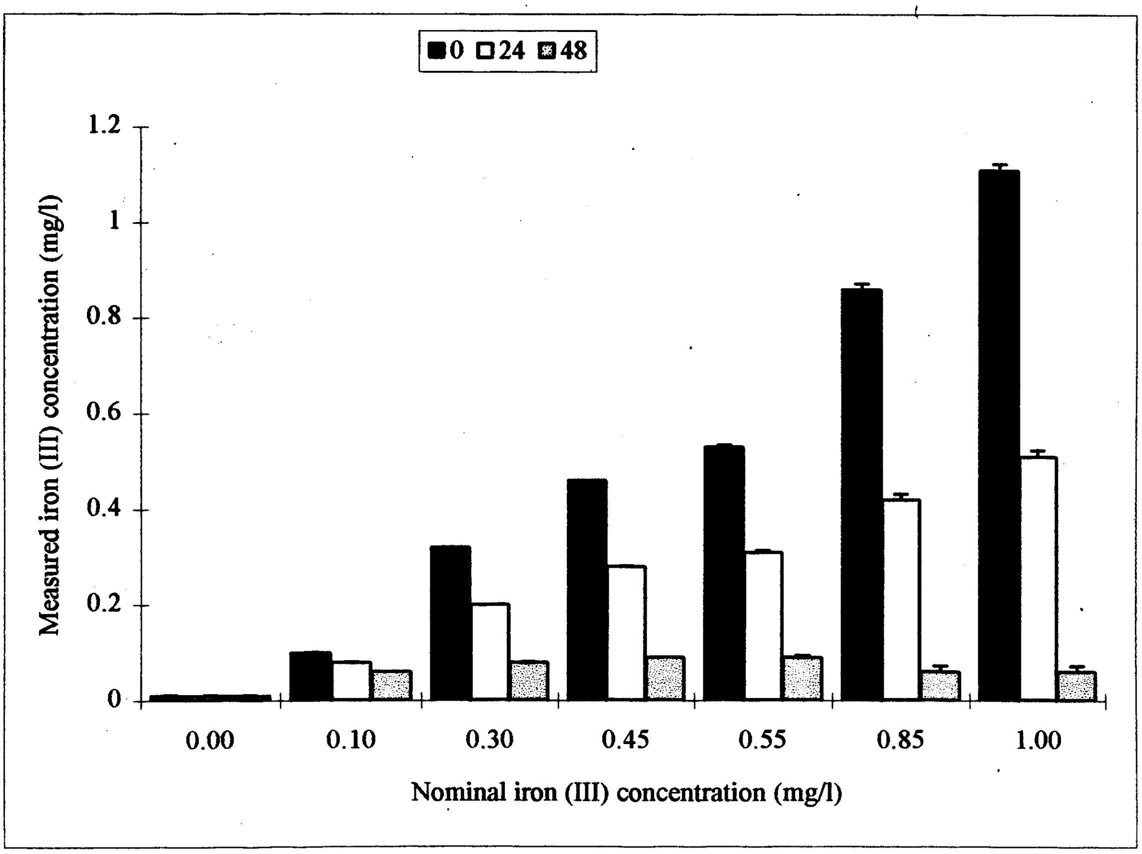


Figure 5.4 Dissolved iron concentration in acute tests over 48 hours (95% error bars)

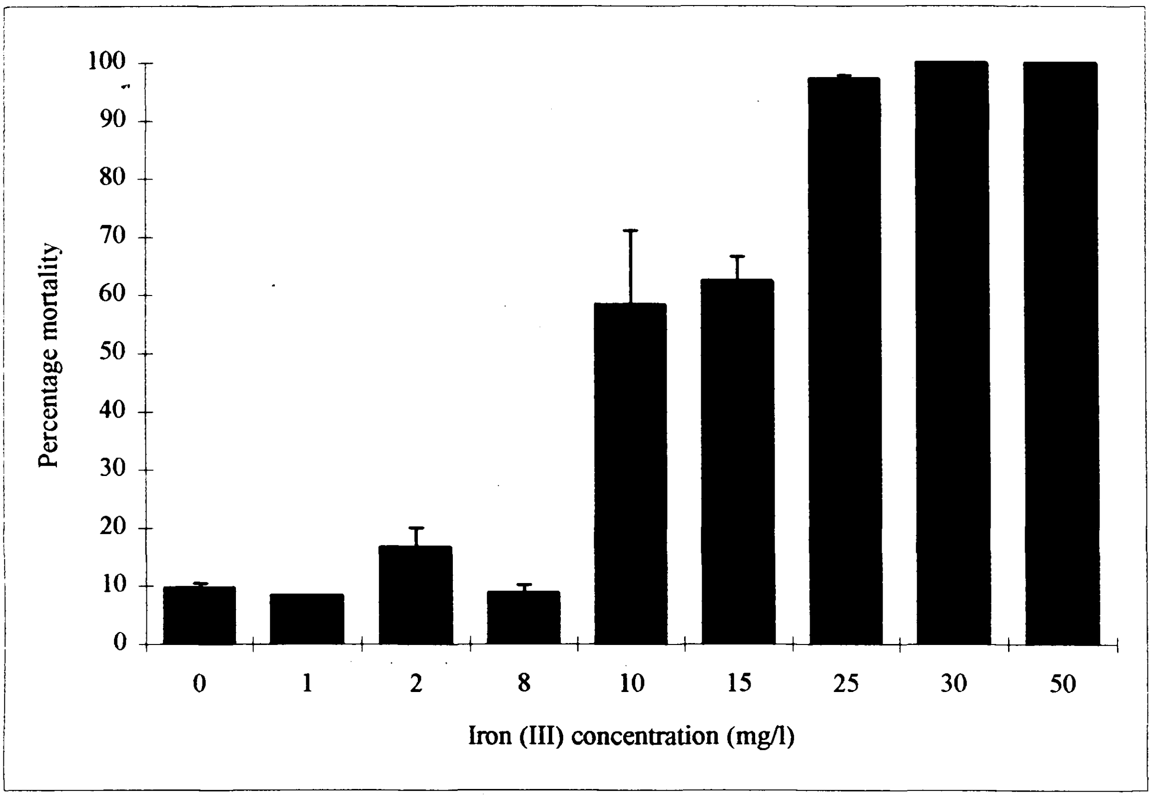


Figure 5.5 Percentage mortality in particulate iron (48 hours) (9%% error bars)

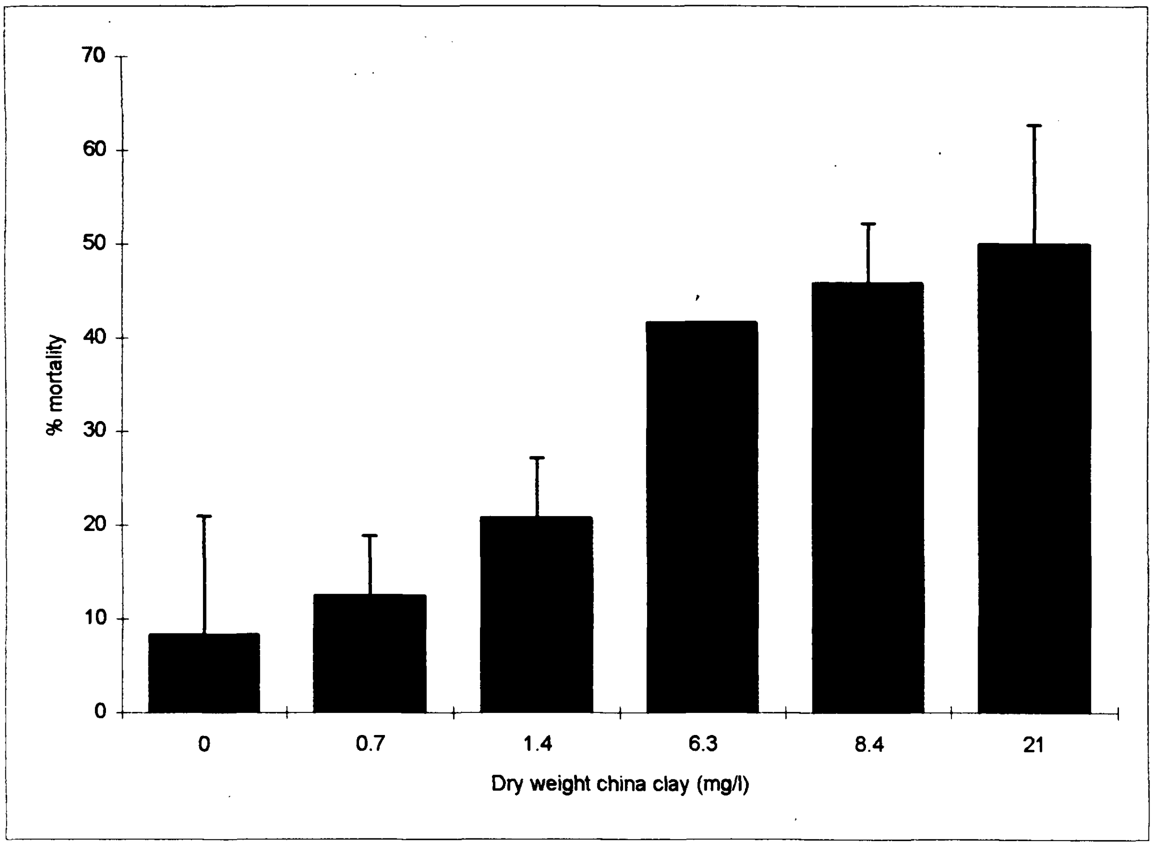


Figure 5.6 Percentage mortalities in china clay (48 hours) (95% error bars)

0.14%, as dissolved iron came out of solution.

Table 5.4 Dunnett's test values calculated for combined data from particulate iron acute tests (significance ($p<0.05$) is denoted by *)

Comparison (Fe mg/l)	*n*	Dunnett's value	Significance
0 vs 1.00	96	0.035	n.s
0 vs 2.00	120	0.678	n.s
0 vs 8.00	120	0.251	n.s
0 vs 10.0	96	3.069	*
0 vs 15.0	144	5.493	*
0 vs 25.0	144	9.413	*
0 vs 30.0	120	9.205	*
0 vs 50.0	96	7.277	*

Table 5.5 Particulate iron concentrations in 48 hour tests

Nominal iron (Fe mg/l)	Particulate iron mg/l 0hour	Particulate iron mg/l 48hour
0.00	0.000	0.000
1.00	1.036	1.037
2.00	1.976	1.977
8.00	8.285	8.288
10.00	10.835	10.837
15.00	15.923	15.945
25.00	25.502	25.503
30.00	31.138	31.139
50.00	50.562	50.565

Microscopic examination, using a Nikon SM Z-U dissecting microscope, of the thoracic appendages of the dead daphnids after exposure to ferric sulphate revealed them to have become clogged with ferric precipitates, and in some cases had guts full of orange matter. The *Daphnia* that did survive had clear appendages, but full guts.

In china clay the differences between the test concentrations was significant ($p<0.01$) (figure 5.6). No mortalities occurred at 24 hours. The results of the dry weight determination of the test concentrations are given in table 5.6.

The mortalities observed in china clay were associated with the presence of suspended matter and could not be attributed to toxicity since china clay is inert and the grade of substance was pure. Dunnett's test was carried out on the combined data as described in appendix , see table 5.7. Significant mortalities were observed in concentrations of china clay concentrations greater than 1.4 mg l^{-1} which had the same dry weight of particulate matter as 2mgl^{-1} particulate iron.

Table 5.6 Dry weight of china clay in acute tests

Equivalent nominal iron (Fe mg/l)	*n*	Dry weight china clay mg/l Test 1	Dry weight china clay mg/l Test 2	Dry weight china clay mg/l Mean
0.00	48	0.00	0.00	0.00
1.00	48	0.70	0.70	0.70
2.00	48	1.60	1.20	1.40
8.00	48	6.40	6.20	6.30
11.00	48	8.70	8.10	8.40
25.00	48	21.3	20.7	21.0

Table 5.7 Results from Dunnett's test and their significance for p<0.05 (*) for china clay acute tests.

Comparison china clay mg/l	Dunnett's value	Significance
0 vs 0.7	1.062	n.s
0 vs 1.4	1.525	n.s
0 vs 6.3	3.570	*
0 vs 8.4	3.874	*
0 vs 21	4.177	*

5.5 Investigation III - Impacts of ferric sulphate and china clay on long-term survival and reproduction of *Daphnia longispina*

5.5.1 Methods

An appropriate volume of well-shaken ferric sulphate stock suspension (5.4.1) was added to a 1 litre volumetric flask and made up to 1 litre with daphnid medium and food (as detailed in appendix Ip) to produce the following nominal concentrations:

0.0, 0.5, 2.0, 3.0, 9.0, 15.0 mg Fe^{3+} l^{-1} particulate iron

0.0, 0.1, 1.2, 1.9, 7.0 mg l^{-1} china clay (dry weight)

Ten 200ml aliquots of each test concentration were poured into duplicate 200ml glass screw-capped bottles. To each of these one daphnid neonate was added using a wide bore pipette (approx. 6mm diameter). The tests proceeded and were monitored as described in section 5.3.1. On two occasions during the tests, when the medium was renewed 250ml samples of each test concentration was filtered and digested for AAS determination of the iron content (see appendix II(v)). A sample of each test concentration of china clay was kept and the dry weight determined.

5.5.2 Results

A summary of the results of the tests in particulate iron is given in Table 5.8. Detailed results are given in appendix IIw. The mortalities recorded in the two tests after 21 days are shown in figure 5.7. Mortality increased with increasing particulate iron concentration. The number of broods and the mean clutch size (figure 5.8) decreased with increasing iron. In addition the day of the first brood became later with increasing iron concentration. No neonates were born in 15.9mg l^{-1} particulate iron. No neonates were born dead, and there were no aborted eggs during the tests.

Two way Analysis of Variance was carried out on arcsine transformed data to determine the comparability of the tests, and whether there were significant differences between the number of daphnids surviving in each test concentration. The two tests were comparable ($p>0.5$) and there were significant differences between the survivorship in each test concentration ($p<0.05$). Dunnett's test was carried out on the combined data (see table 5.9). Significant mortalities occurred in a nominal iron concentration of 15mg l^{-1}. Table 5.10 summarises the results from chronic tests in china clay.

The number of mortalities increased as the amount of china clay increased (figure 5.9). The number of days passed before the first brood was released increased with increasing china clay in the test vessels. Additionally, the number of broods and the mean clutch size (figure 5.10) decreased as the china clay increased. No neonates were born in 7.0mg l^{-1} dry weight of china clay. During these tests no neonates were born dead and there were no aborted eggs. Two way Analysis of Variance determined that the two tests were comparable ($p>0.5$) and there was a significant difference in the survivorship in each test

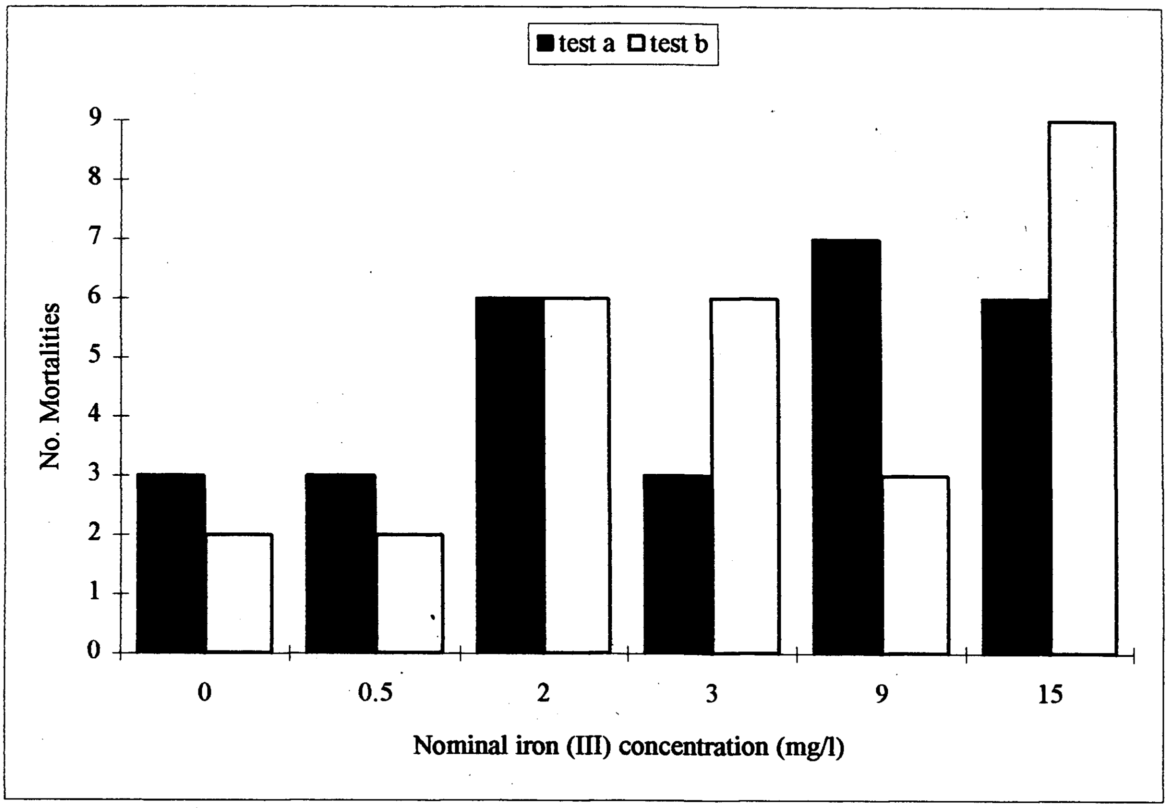


Figure 5.7 Daphnid mortalities in particulate iron (21 days)

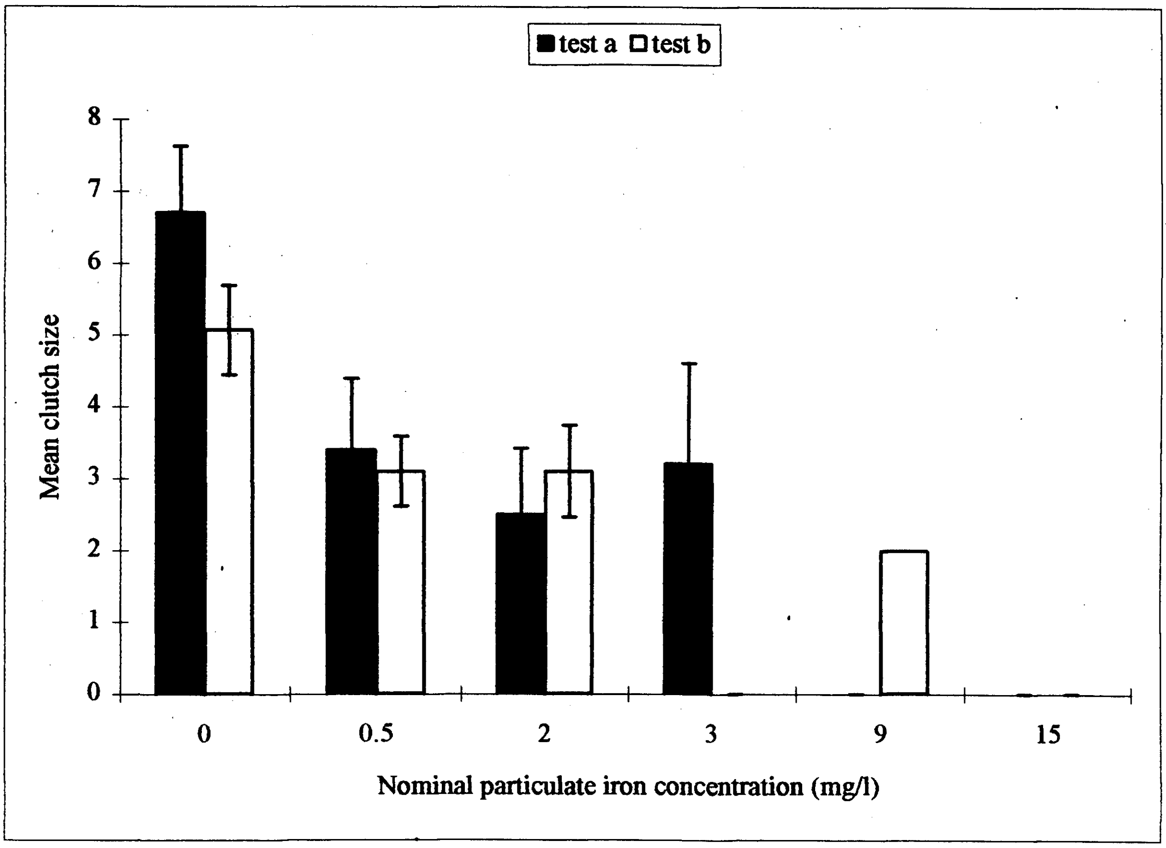


Figure 5.8 Mean daphnid clutch size in particulate iron (21 days)

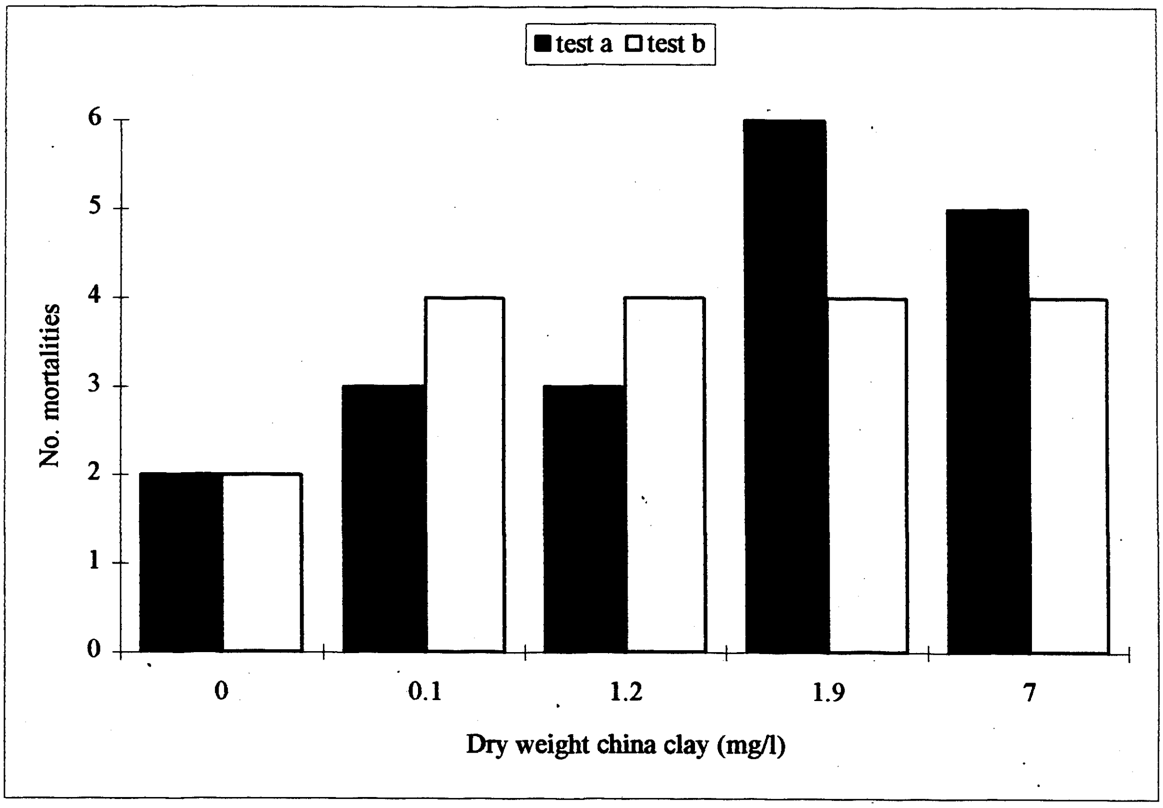


Figure 5.9 Daphnid mortalities in china clay (21 days) (95% error bars)

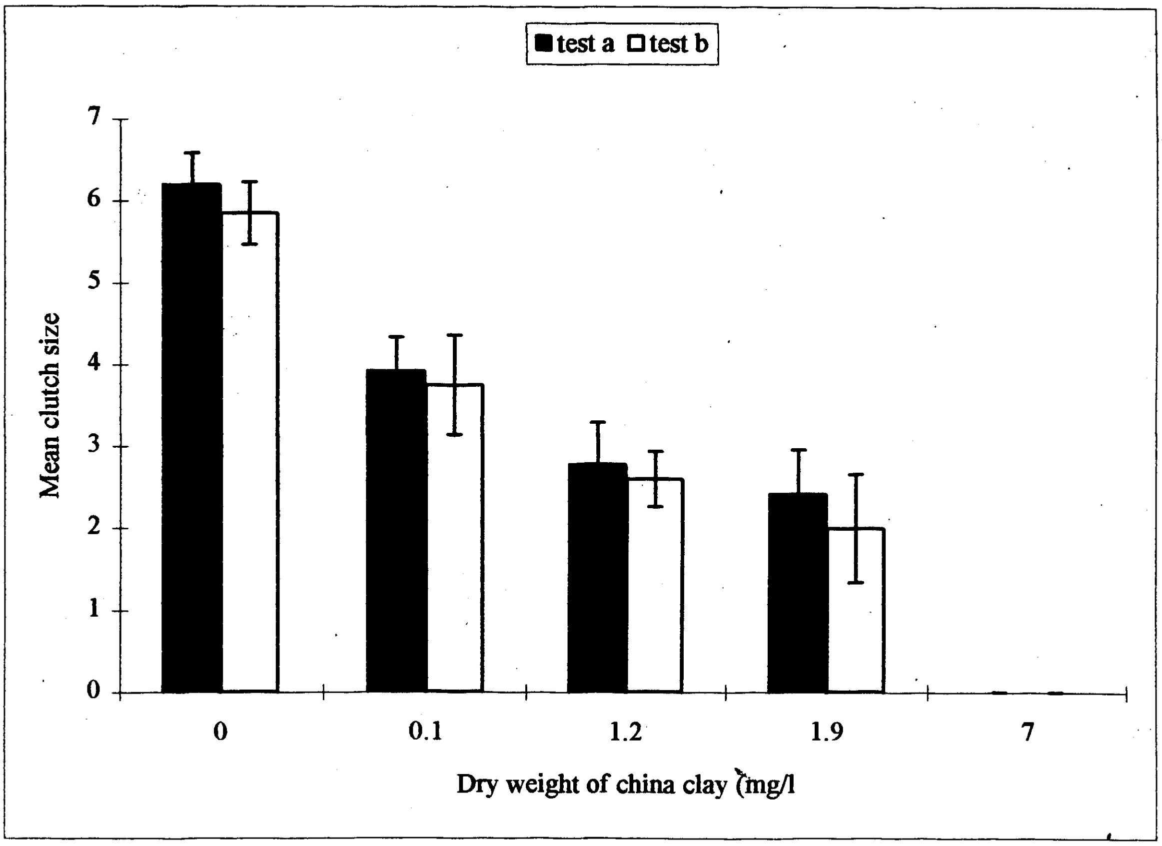


Figure 5.10 Mean daphnid clutch size in china clay (21 days) (95% error bars)

concentration ($p<0.05$). Dunnett's test was carried out on the combined data (table 5.11).

Table 5.8 Summary of chronic tests in ferric sulphate

Nominal iron mg/l	Mean iron mg/l	Test	Day 1st brood	No. Broods	Mean Clutch	Mortalities
0.00	0.070	A	6	2	6.7	3
	0.070	B	6	3	5.1	2
0.50	0.678	A	8	2	3.4	3
	0.669	B	8	2	3.1	2
2.00	1.049	A	9	1	2.5	6
	1.976	B	12	1	3.1	6
3.00	2.828	A	13	1	3.2	3
	2.848	B	0	0	0	6
9.00	8.724	A	0	0	0	7
	8.816	B	18	1	2	3
15.0	15.94	A	0	0	0	6
	15.93	B	0	0	0	9

Table 5.9 Dunnett's test values and significance for particulate iron chronic tests (significance ($p<0.05$) denoted by *)

Comparison (Fe mg/l)	*n*	Dunnett's value	Significance
0 vs 0.50	20	0.0	n.s
0 vs 2.00	20	1.944	n.s
0 vs 3.00	20	1.126	n.s
0 vs 9.00	20	1.407	n.s
0 vs 15.0	20	2.912	*

Table 5.10 Summary of chronic tests in china clay

mg/l DW China clay	Equivalent iron mg/l	Test	Day 1st brood	No. Broods	Mean clutch	Mortalities
0.0	0.07	a	6	2	6.2	2
0.0		b	7	3	5.9	2
0.1	0.5	a	8	2	3.9	3
0.1		b	8	2	3.8	4
1.3	2.0	a	9	2	2.8	3
1.1		b	8	1	2.6	4
2.0	3.0	a	12	1	2.4	6
1.8		b	11	1	2.0	4
6.8	9.0	a	0	0	0.0	5
7.2		b	0	0	0.0	4

Table 5.11 Dunnett's test results and significance from china clay chronic tests (* denotes significance ($p<0.05$))

DW china clay mg/l	*n*	Dunnett's value	Significance
0.0 vs 0.1	20	1.074	n.s
0.0 vs 1.2	20	1.974	n.s
0.0 vs 1.9	20	3.77	*
0.0 vs 7.0	20	3.18	*

Significant results were observed in 1.9 mg l^{-1} china clay equivalent to 3mg l^{-1} particulate iron.

5.6 Calculation of effect concentrations and safe levels

The median effective dose, that is the concentration at which 50% of animals were immobilised in acute and chronic toxicity tests in particulate iron (III), were calculated using the method detailed in Litchfield and Wilcoxen (1949). Log dose (particulate iron) was plotted against percentage mortality from the summarised data, on probability paper (Chartwell ref 5571) omitting 0 or 100% effects. A straight line was fitted to the data and tested for goodness of fit with a chi-squared test, using the nomograph method of determination of chi-squared values (Litchfield & Wilcoxen, 1949). The line was adjusted until the best fit was achieved. The resulting graph is reproduced in appendix II(z).

The dose was read from the graph to obtain 16 (ED_{16}), 50 (ED_{50}), and 84 (ED_{84}) % effects. From acute toxicity tests these graph readings were as follows: $ED_{16} = 7.58$, $ED_{50} = 11.48$, and $ED_{84} = 16.98$mg l^{-1}.

The slope of the line was calculated to be equal to 1.49 from:

$$S = \frac{ED(84)/ED(50) + ED(50)/ED(16)}{2}$$

Confidence limits were calculated from:

$$FED_{50} = S^{2.77 / \sqrt{N'}}$$

Where FED_{50} refers to a factorial of the ED_{50}; and N' refers to the number of animals tested that fall between 16 and 84% mortality .

90% confidence limits were calculated using the FED_{50} value as follows:

$$ED_{50} \times FED_{50} = \text{upper C.L.}$$
$$ED_{50} \;/\; FED_{50} = \text{lower C.L.}$$

For acute toxicity tests using ferric sulphate the ED_{50} was 11.48mg l^{-1} particulate iron, between 90% confidence limits of 12.39 and 10.63mg l^{-1}. For chronic toxicity tests (21 days) in ferric sulphate the ED_{50} was 4.45mg l^{-1} between 90% confidence limits of 6.51 and 3.09 mg l^{-1}.

The median effective doses from the acute and chronic tests were used to calculate safe limits of particulate iron using a method established by Sprague (1971). Above this level it was expected that *Daphnia longispina* would experience reproductive impairment, and below it normal life histories would be expected. An application factor (A.F.) was calculated from the equation:

$$\text{A.F.} = ED_{50}\text{ (21 day)} \;/\; ED_{50}\text{ (48 hour)}$$

The ED_{50} from the chronic tests of 4.45mg l^{-1} was then multiplied by this application factor to give a safe level of 1.69mg l^{-1} particulate iron (III), a concentration of particulate iron below which no harmful effects would be expected in *Daphnia longispina.*

5.7 <u>Investigation IV - The effect of particulate ferric sulphate and china clay on the feeding behaviour of *Daphnia longispina*</u>

5.7.1 Methods

A range of culture media were prepared as in table 5.12. The composition of the daphnid medium is described in appendix Ip, and the method for algae addition is also detailed in appendix I(p). Ferric sulphate and china clay stock suspensions were made up as described in section 5.4.1.

Table 5.12 Test media for filtering rate investigations

Medium	*n*	Food (cells/ml)	Ferric sulphate mg/l	China clay mg/l
Daphnid	5	0	0.0	0.0
Daphnid	5	1.25×10^6	0.0	0.0
Daphnid	5	1.25×10^6	0.5	0.0
Daphnid	5	1.25×10^6	1.0	0.0
Daphnid	5	1.25×10^6	2.0	0.0
Daphnid	5	1.25×10^6	8.5	0.0
Daphnid	5	1.25×10^6	17.0	0.0
Daphnid	5	1.25×10^6	30.0	0.0
Daphnid	5	1.25×10^6	0.0	1.2
Daphnid	5	1.25×10^6	0.0	21.3

To investigate the effects of each test concentration on filtering rate, the hanging-droplet method was used (Edmondson, 1965). A daphnid was removed from a stock culture in a small droplet of medium on a cover slip. This medium was then carefully drawn off using a Pasteur pipette, and replaced with the test concentration. The cover slip was then inverted over a microscope slide, supported on a ring 1-1.5cm diameter of Bluetack™ (figure 5.11). This technique ensured that the daphnid was unable to swim around but continued filtering. The microscope slide was placed on the stage of a Nikon SM-ZU dissecting microscope and the filtering activity of the daphnid filmed for 2 minutes using a JVC TK-1281 colour video camera attached to the microscope. The time taken to set up the slide and begin filming was estimated to be 20 seconds.

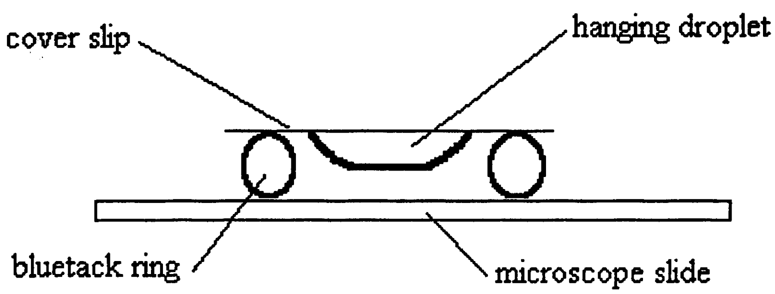


Figure 5.11 Cross-section through hanging droplet

A Kombo 14 combined TV and JVC video recorder was used to record the filtering activity and to monitor the daphnid behaviour. Those daphnids that appeared agitated (trying to swim around) and those in which filtering ceased were rejected. 5 daphnids were recorded in each test concentration. The recordings were analysed using a Panasonic NV 8200 video machine at 1/4 the original speed. In this way the number of thoracic appendage beats per minute and the number of post-abdominal rejections could be determined for each animal.

5.7.2 Results

The mean number of thoracic beats per minute declined as concentrations of iron precipitate increased (figure 5.12). The results are described in full in appendix II(x).

Analyses of Variance were carried out on log transformed data (Prepas, 1984) of the thoracic beats per minute and the number of rejection motions per minute in the absence of ferric sulphate and china clay with and without food. This was to establish what 'baseline' behaviour might be expected by the daphnids, and whether the presence of food made a significant difference to the feeding rate. There were no significant differences between either the thoracic beat rate per minute or the number of rejections in the presence or absence of food.

There were significant differences between the thoracic beat rate per minute in increasing concentrations of ferric ($p<0.01$). Dunnett's test (described in appendix I(q)) showed that above 0.5mg Fe l^{-1} there was a significant reduction in the thoracic beat (table 5.13). Above this concentration a number of daphnids ceased to beat at all - a rapid fluttering of the thoracic appendages was observed which was not possible to count even at 1/8th speed (these animals were not included in the Analysis of Variance tests).

In china clay there was no significant reduction in the thoracic beat rate compared with the

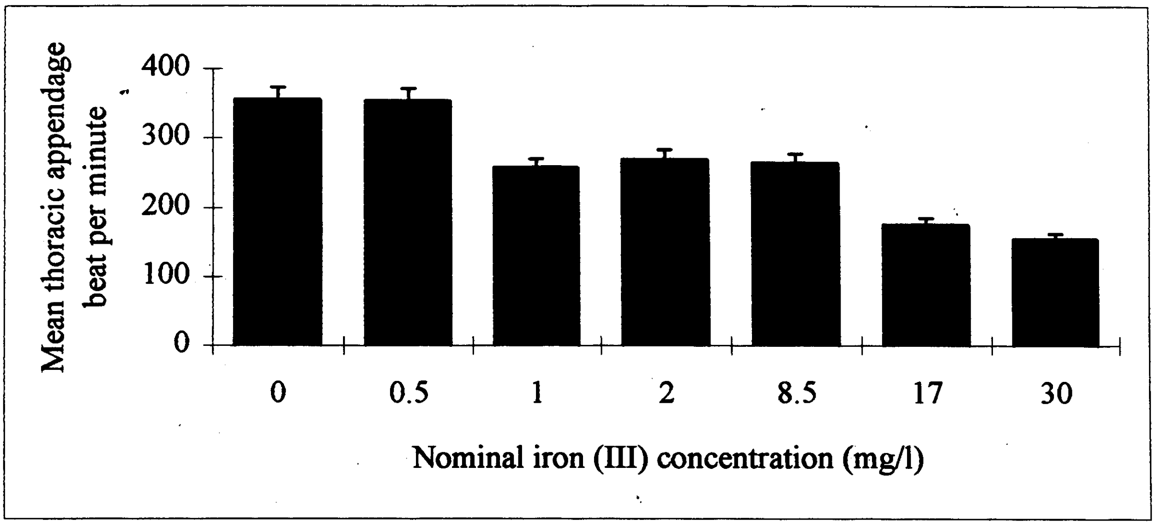


Figure 5.12 Thoracic beats per minute in particulate iron (95% error bars)

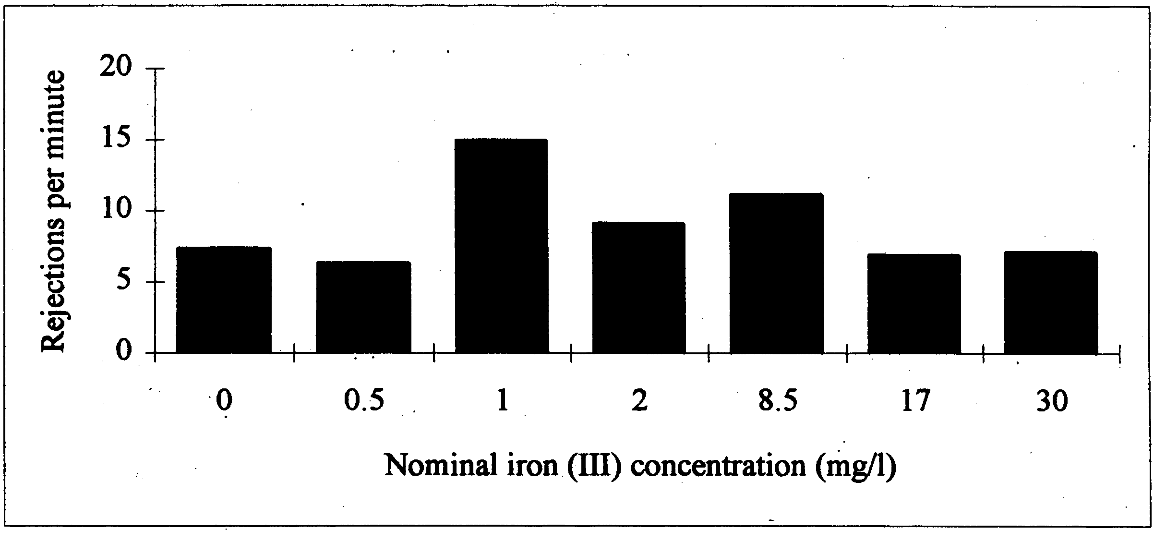


Figure 5.13 Rejections per minute in particulate iron

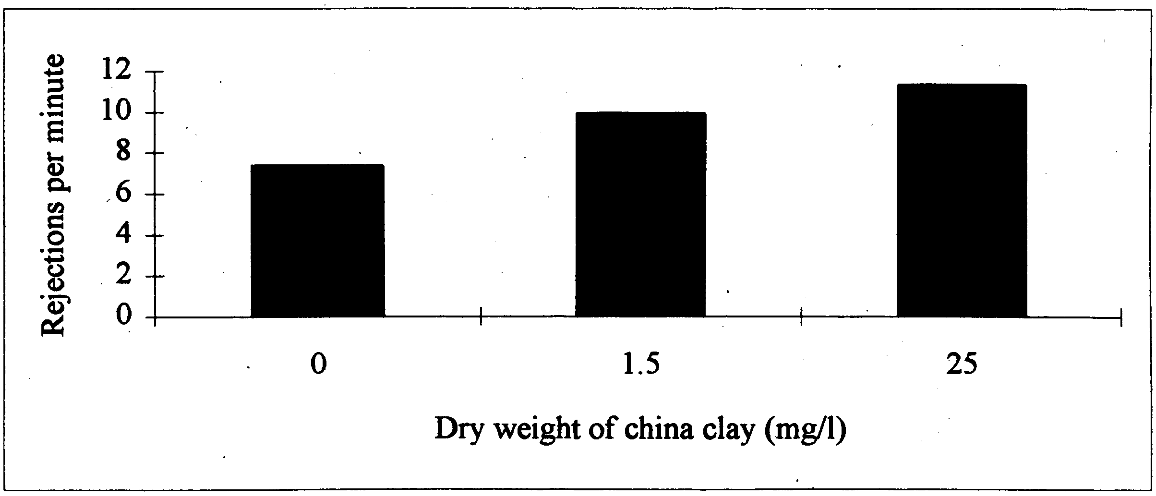


Figure 5.14 Rejections per minute in china clay

Table 5.13 Dunnett's test results for thoracic beat rate per minute in ferric sulphate (and food) (significance ($p<0.05$) denoted by *)

Comparison (Fe mg/l)	*n*	Dunnett's value	Significance
0 vs 0.5	5	0.204	n.s
0 vs 1.0	5	3.389	*
0 vs 2.0	5	2.707	n.s
0 vs 8.5	5	3.028	*
0 vs 17	5	6.805	*
0 vs 30	5	7.785	*

control media containing no suspended material ($p>0.1$) (for results see appendix II(x)). Cessation of thoracic beat did not occur in china clay.

Post-abdominal rejection rate per minute in ferric sulphate increased above 0.5mg Fe l^{-1} and then declined to levels observed in the control concentration (figure 5.13). These observations were significant (Analysis of Variance - $p<0.01$). However Dunnett's test established that only the rejection rates in 0.5mg l^{-1} and 8.5mg l^{-1} ferric sulphate were significant when compared with the control (table 5.14). In daphnids in which the thoracic beat ceased, post-abdominal rejections did too.

Table 5.14 Dunnett's test results for the number of rejections per minute in ferric sulphate (significance ($p<0.05$) denoted by *)

Comparison (Fe mg/l)	*n*	Dunnett's value	Significance
0 vs 0.5	5	0.762	n.s
0 vs 1.0	5	3.963	*
0 vs 2.0	5	1.258	n.s
0 vs 8.5	5	2.977	*
0 vs 17	5	0.076	n.s
0 vs 30	5	0.011	n.s

Post-abdominal rejection rate per minute increased in china clay (figure 5.14). This increase was significant (analysis of variance - $p<0.001$). Dunnett's test values of 3.938 and 5.535 respectively were determined for 1.5mg l^{-1} and 25.0mgl^{-1} dry weight when compared with a control.

5.8 Investigation V - The effect of ferric sulphate and china clay on the filtering area of *Daphnia longispina*

5.8.1 Methods

The individual daphnids used in the chronic toxicity tests were preserved in 4% formalin once mortality occurred or at the end of each test. The standard length of each daphnid was measured and the filtering area of the third thoracic limb estimated using the equation of Egloff and Palmer (1971) and Crittenden (1981) as described in appendix I(i). The mean setae length were determined for 20 animals from two tests, from each test concentration.

5.8.2 Results

The relationship between standard length and the filtering area in ferric sulphate precipitate is displayed in figure 5.15. Two way Analysis of Variance, conducted on log (1 + x) transformed filtering area values, established that the two chronic tests in ferric sulphate were comparable ($p>0.5$) and that the results could be combined. With increasing concentration of precipitated iron the slope of the regression line through the data became steeper suggesting that the filtering area had increased during the test.

The relationship between standard length and the filtering area in china clay is displayed in figure 5.16. Two way Analysis of Variance conducted on log (1 + x) transformed projected filtering area data established that the two chronic tests in china clay were comparable and that the results could be combined ($p>0.5$).

There were no significant differences between the controls and increasing concentrations of precipitated iron ($p>0.1$) or china clay ($p>0.5$). Analysis of Variance was repeated using only data for daphnids above a standard length of 1.2mm. This removed from the analysis those daphnids which had died early in the tests and had therefore not gone through many moults during which morphological change could occur. There was now a significant difference between the projected filtering area of daphnids in ferric sulphate concentrations above 9mg Fe l^{-1} compared with the control daphnids ($p<0.01$). Dunnett's

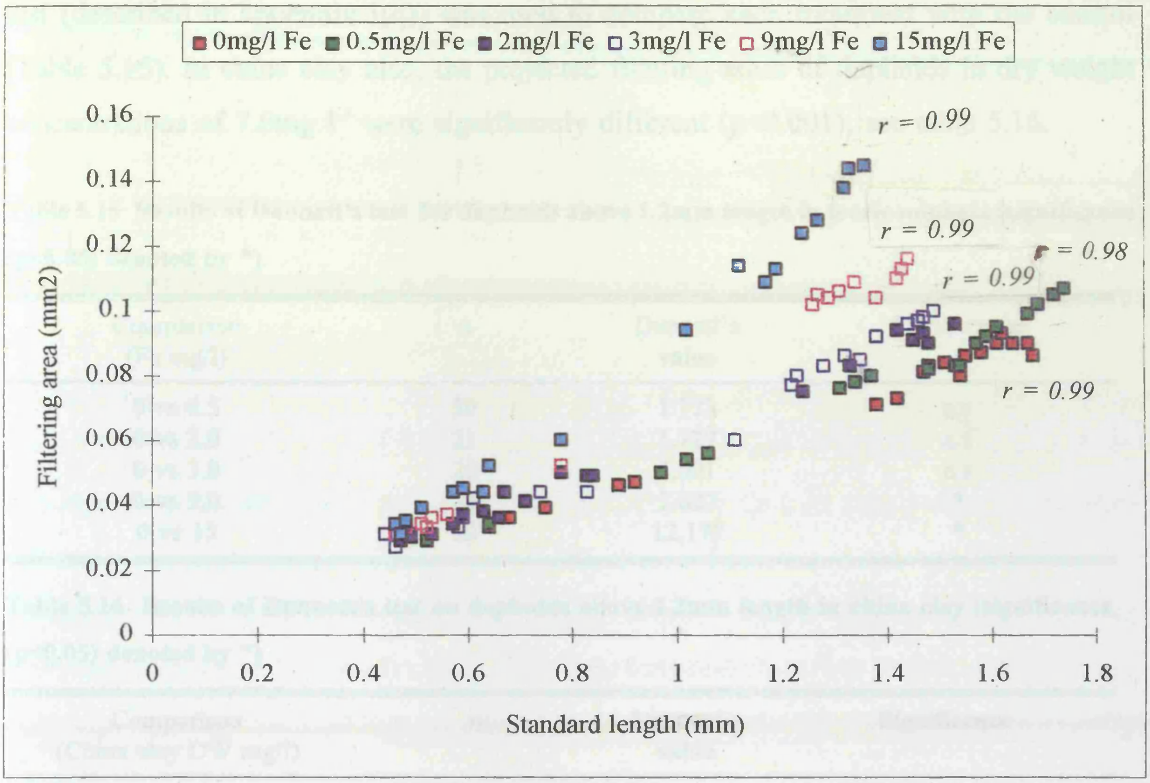


Figure 5.15 Relationship between standard length an filtering area in iron (III)

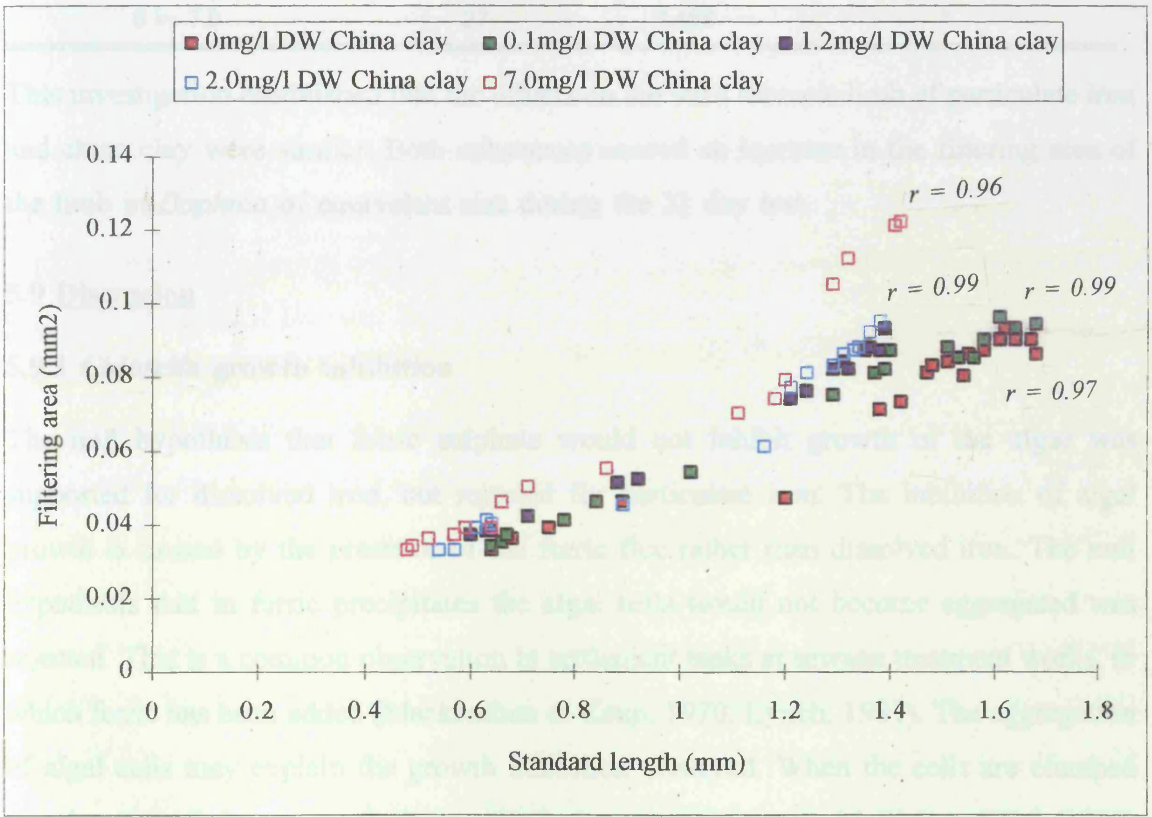


Figure 5.16 Relationship between standard length and filtering area in china clay

test (described in appendix I(q)) was used to compare each treatment with the control (Table 5.15). In china clay also, the projected filtering areas of daphnids in dry weight concentrations of 7.0mg l^{-1} were significantly different ($p<0.001$), see table 5.16.

Table 5.15 Results of Dunnett's test for daphnids above 1.2mm length in ferric sulphate (significance ($p<0.05$) denoted by *)

Comparison (Fe mg/l)	*n*	Dunnett's value	Significance
0 vs 0.5	30	1.773	n.s
0 vs 2.0	21	1.127	n.s
0 vs 3.0	25	1.001	n.s
0 vs 9.0	26	7.027	*
0 vs 15	20	12.177	*

Table 5.16 Results of Dunnett's test on daphnids above 1.2mm length in china clay (significance ($p<0.05$) denoted by *)

Comparison (China clay DW mg/l)	*n*	Dunnett's value	Significance
0 vs 0.1	30	2.063	n.s
0 vs 1.2	31	1.069	n.s
0 vs 2.0	30	1.943	n.s
0 vs 7.0	27	7.498	*

This investigation established that the effects on the third thoracic limb of particulate iron and china clay were similar. Both substances caused an increase in the filtering area of the limb in *Daphnia* of equivalent size during the 21 day test.

5.9 <u>Discussion</u>

5.9.1 *Chlorella* growth inhibition

The null hypothesis that ferric sulphate would not inhibit growth of the algae was supported for dissolved iron, but rejected for particulate iron. The inhibition of algal growth is caused by the presence of the ferric floc rather than dissolved iron. The null hypothesis that in ferric precipitates the algal cells would not become aggregated was rejected. This is a common observation in settlement tanks at sewage treatment works, in which ferric has been added (Mackenthun & Keup, 1970; Lynch, 1981). The aggregation of algal cells may explain the growth inhibition observed. When the cells are clumped together little light can reach those cells innermost in a clump. Mallick and Rai (1992) found that 20mg l^{-1} iron inhibited *Chlorella vulgaris* growth under yellow and red light, indicating that metal toxicity to phytoplankton is dependent on spectral quality, in which loading by suspended matter plays a large part .

The growth inhibition found during these investigations is supported by the work of others into the effects of iron, although no other studies used iron as ferric sulphate. Becker and Keller (1973) carried out investigations on *Chlorella vulgaris* using ferrous sulphate. This would have been present principally as Fe (III) when dissolved in oxygenated waters. Their laboratory study indicated that a nominal concentration of 520mg l^{-1} gave an 86% decrease in population growth, considerably more iron than in this study. These very different results are not easily explained, but may be accounted for by differences in procedure. For example, Becker and Keller did not buffer the medium, so their observations may be the result of falling pH as ferric sulphate was added. Additionally, both this investigation and that of Becker and Keller used only one clone of *Chlorella* throughout all the tests. Enhanced resistance or sensitivity by either clone may account for different results. No literature was available on the responses of different clones of *Chlorella* to metals.

Some growth enhancement (10-15%) was observed in 50mg l^{-1} particulate iron. This observation was also made by Buma *et al* (1991) who found that there was an increase in chlorophyll synthesis and nutrient assimilation after the addition of iron in laboratory studies. Iron is an essential nutrient to algae, *Chlorella* tis known to take up iron by ferric reduction (Allnutt & Bonner, 1987).

The impact of iron on algae is different in saline and fresh waters. In saline waters Brand (1991) and Coale (1991) found that new production of cyanobacterial biomass was iron limited, but new production of eukaryotic algal biomass was not. In freshwaters, Morton and Lee (1974) found that in concentrations of 0.1 - 1.0 mg l^{-1} iron caused a shift in the dominant type of algae grown in batch cultures from green to scum-forming blue-greens without a significant change in total biomass, independent of the phosphorus concentration. This may explain why, although phosphate concentrations have been reduced in Rutland Water, the cyanobacterial dominance of the algal population shows no sign of being reduced. Investigations in eutrophic Clear Lake, California by Wurtsburgh and Horne (1983) found that the growth of cyanobacteria and green algae was usually directly limited by combined nitrogen and occasionally by iron or phosphorus. Low iron levels aggravate the effects of low nitrogen by limiting nitrogen fixation, thus reducing cyanobacterial growth. Hence the addition of ferric sulphate to Rutland Water may enhance the value of nitrate in the reservoir, which is not being controlled, despite the reduction in phosphate concentration.

5.9.2 *Daphnia* mortalities and reproductive inhibition

The null hypothesis that ferric sulphate would not have a toxic effect on *Daphnia longispina* was rejected, a conclusion reached from the observation that no mortalities occurred after 48 hours in china clay, although they did in ferric sulphate. The observation that both particulate iron and china clay caused mortalities suggested that the deaths were caused by the presence of suspended material in the medium. The reasons why suspended material should cause mortality are unclear. Particles in the medium were ingested as food and with algae. This would lead to dilution of the food supply (by reduced energy intake per unit time) and eventual starvation of the animals. Microscopic examination of *Daphnia* revealed that during acute and chronic tests they ingested the floc. Gerhardt (1992) found that the larvae of mayfly *Leptophlebia marginata* became 'constipated' during iron exposure when their guts became blocked. However, constipation and resulting starvation could not explain the mortalities occurring during acute tests since it is unlikely that *Daphnia* would starve over 48 hours.

An alternative explanation is that in the presence of particulate material the *Daphnia* became stressed to the point at which other physiological functions were reduced to life-threatening levels. For example, if a daphnid stopped feeding to prevent intake of particulate material that was clogging the food groove, it would also stop renewal of oxygen in the water within the carapace and the circulation system.

In chronic tests it was theorised that ferric precipitates would be ingested with algae as food. Although iron is essential to *Daphnia* and they store and excrete it (Smaridge, 1956; Perkins, 1985; Tazima *et al.,* 1975), it would have little nutritional value in large quantities. If this was the case then the presence of ferric precipitates would effectively dilute the suitable food available so that *Daphnia* growth rates may be reduced or they may then compensate by physiologically or behaviourally adjusting feeding behaviour in some way.

The null hypothesis that ferric sulphate would not have sublethal effects on *Daphnia longispina*, represented by reduced reproduction was rejected. Reproduction is of primary importance to *Daphnia*, for the continuation of species (Lampert, 1974). The mean clutch size and the number of clutches borne were reduced with increasing iron concentration and increasing dry weight of china clay. The first brood occurred later in ferric compared with the control which supported the idea that *Daphnia* growth was reduced or negligible, since a size of 1.2 - 1.4mm (total body length) needed to be reached before young could be borne (Urabe, 1991). The absence of clutches above 3mg Fe l^{-1} could be explained by the toxic impact of this amount of iron to developing eggs in the brood chamber. Above this concentration *Daphnia* had eggs in the ovary, which had not progressed to the brood chamber. Delay in the development of young and reduction of the brood size has been associated with low or unsuitable food conditions (Lampert, 1974).

A safe level of 1.69mg Fe l^{-1} as particulate iron was determined, above which harmful effects such as inhibition of reproduction would be expected. This is similar but 15% lower than the Environmental Quality Standard (EQS) for the protection of freshwater life of 2mg total iron l^{-1} recommended by the Water Research Centre (Mance & Campbell, 1988). This study supported their recommendation that the deposition of iron should be avoided.

The results of these investigations are supported the findings of others. A study by Biesinger and Christensen (1972) found an LC_{50} (48 hr) for iron (II) as ferrous chloride ($FeCl_3.6H_2O$) of 9.6mg Fe l^{-1}, and that by Khangarot and Ray (1989) found an EC_{50} (48 hr) of 7.2mg Fe l^{-1} for iron (II) as ferrous sulphate ($FeSO_4.7H_2O$). Both these values are lower than that found during this study although they are within the range of the data, and iron (II) is considered more toxic than iron (III) (Mance & Campbell, 1988).

These toxicity tests showed that particulate material may cause mortalities in *Daphnia* populations. Few studies in the literature have studied mortality rates of *Daphnia* in suspended material although there have been some laboratory investigations on its effects on body growth and reproduction. Kirk (1991) measured significantly lower body lengths and reduced fecundity in 50mg l^{-1} suspended clay in *Daphnia ambigua*, and Hart (1992) established high diversity in the response of different daphnid species to suspended sediment at concentrations above 10mg l^{-1}. The latter study found that species cultured in turbid water were influenced less adversely than species from clear waters, indicating the existence of environmentally appropriate adaptive responses. Robinson (1957) found that the presence of suspended material up to 30ppm was essential to the optimum survival and reproduction of *Daphnia magna*. Above this concentration the nature of the material became more important and toxic responses were observed in 100ppm charcoal and montmorillonite. These concentrations greatly exceed 1.9mg l^{-1} dry weight of china clay above which significant mortalities were observed in this study, a disparity which cannot be accounted for by the size difference between *Daphnia longispina* and the larger *D. magna*, since the size of the individual particles would be more important than the dose.

The question of clonal resistance to ferric sulphate and china clay was not addressed in this study - the clone that gave the most consistent reproductive results (clutch size, days between broods) was used throughout all the tests. This ensured that the responses of the *Daphnia* to the test substances were to the substances themselves, not the genetic fitness of the animals. However, genetic fitness will be highly variable in natural populations (Carvalho & Hughes, 1983; Carvalho & Crisp, 1987; Cowgill, 1987).

This study has highlighted some of the difficulties associated with using suspended material in toxicity tests. Neither ferric sulphate or china clay remained in suspension for more than a few hours. This introduced an element of chance into the exposure of *Daphnia* to the material. In between the times that the medium was agitated to resuspend the ferric sulphate or china clay the particulate material was settled on the bottom, and the *Daphnia* swimming in the medium above were not exposed to it. However, during the tests it was observed that the *Daphnia* tended to swim down to the bottom of the vessel and actively 'feed' from the sediment. This increased the exposure of the animal to ferric sulphate or china clay.

The addition of ferric sulphate to daphnid cultures led to rapid precipitation of ferric hydroxides and colloidal iron. In an attempt to reduce precipitation occurring during toxicity tests, and to simulate conditions occurring in the field, ferric sulphate was added to daphnid medium as a stock solution and the pH neutralised prior to addition to the test cultures. This stock was then shaken well to mix the precipitate, before test concentrations were made up. During the tests the amount of particulate iron increased and some dissolved iron came out of solution. A small amount of iron (III) remained in solution. Stability of iron as iron (III) in the media depends on the redox potential (Mayer, 1982). Although redox was not measured during the tests oxygen saturated media were used throughout and this was not reduced by more than 80% in any test. pH remained within the range 7.5 - 8 throughout all tests. Oxygen levels below 40% may have promoted the reduction of iron (III) to iron (II), which would have been recognised through acidic pH.

5.9.3 Behaviour responses of *Daphnia* to ferric sulphate and china clay

The behavioural responses of *Daphnia longispina* to ferric sulphate and china clay were different. The null hypothesis that feeding rate would not increase in ferric sulphate as a result of 'dilution' of the food supply was supported. The hypothesis that ferric sulphate would not cause an increase in the number of post-abdominal rejections per minute was rejected. Feeding rates decreased in ferric sulphate, although no such response was seen in china clay. Rejection rates increased by 51% in china clay, and by 73% in ferric sulphate (21% more than in china clay). The particulate nature of ferric sulphate was considered to be responsible for the increase in rejection rate, since similar increases were observed in china clay.

Measurements of the precipitates under a Zeiss Axioskop stage microscope calibrated at 400 times magnification found the individual particle size of ferric sulphate and china clay precipitates to be approximately 1µm. The clumps (aggregated precipitate) ranged in size between 8µm and 64µm diameter in ferric sulphate with numerous larger clumps; and between 8µm and 48µm in china clay, with larger clumps less numerous (observed, not calculated). The larger clumps of both substances were greater than 20µm, the particle size above which Gliwicz (1977) observed a decrease in the ingestion rate of *Daphnia longispina*. Kirk (1991) found that suspended clay up to 1µm diameter had no effect on the feeding rate, but 2μm size clay particles reduced thoracic beat rate by 27% in 20 x 10^3 cells ml^{-1} algae.

Exposure to >0.5mg l^{-1} ferric sulphate in this study led to a reduction in thoracic beat, although no such reduction was observed in china clay. The findings of Gliwicz suggest that this reduction resulted from exposure to clumps of ferric sulphate. The number of occasions that clumps larger than 20μm were encountered by *Daphnia longispina* was probably greater in ferric sulphate than in china clay. However, this reasoning does not explain why the filtering rate in china clay did not decline.

A decline in the thoracic feeding appendage beat rate decreases the volume of water filtered for food particles (Kirk, 1991). Inert china clay did not decrease the volume of water filtered during this study, suggesting that *Daphnia* considered china clay to be food. The fact that beating ceased altogether in some animals led to the conclusion that the daphnids were able to detect something in the ferric sulphate to be harmful and possibly toxic. This toxic effect was detected within 30 seconds of exposure and at concentrations above 0.5mg Fe l^{-1}. Both the increase in rejection rate and the decrease in appendage beat rate would reduce exposure of daphnids to iron and any toxic influences on survival and reproduction.

5.9.4 Morphological adaptations of *Daphnia* to ferric sulphate and china clay

The null hypothesis that filtering area of *Daphnia* thoracic limbs would not increase in ferric sulphate was rejected. The increase in size of the filtering area of the third thoracic limb of *Daphnia longispina* in response to the addition of precipitated iron at concentrations above 9mg Fe l^{-1} or china clay above dry weights of 7.0mgl^{-1}, was the same as that observed in decreased concentrations of food (Lampert, 1971; Fott *et al.*, 1974; Korinek *et al.*, 1985). This adaptive mechanism of *Daphnia* is a meaningful feeding strategy amongst populations where the concentrations of food may fluctuate by several orders of magnitude from year to year or throughout the season, and would decrease the chances of *Daphnia* mortalities occurring due to starvation. The findings of this study agree with those of Pop (1991) that the changes occur within the life-history of an individual.

The value of this mechanism in the presence of iron precipitates or china clay is that the increased size of the filtering area multiplies the amount of food which may be ingested. This will include the precipitates, but will increase the nutritional food ingested with each thoracic beat, perhaps decreasing the amount of time and energy spent feeding.

5.9.5 Conclusions

These laboratory investigations showed that ferric sulphate had both short-term and long-term impacts on *Daphnia* in a number of ways. In the short term, ferric sulphate was toxic to *Daphnia longispina* at similar concentrations to ferrous iron (Biesinger and Christensen, 1972; Khangarot and Ray, 1989), If concentrations above 11mg Fe l^{-1} were reached in the reservoir, then significant deaths might occur. Ferric precipitates caused *Daphnia* to reduce the rate of feeding (measured by the number of thoracic appendage movements) and in some cases to cease feeding altogether in response to the toxic properties of the ferric precipitate. This response was observed at concentrations above 0.5mg Fe l^{-1}, and might be an immediate response by *Daphnia* to periodic exposure within a water body. Rejections by *Daphnia* of unsuitably large or 'toxic' particles is a defence mechanism to prolong survival in unsuitable conditions.

Longer-term responses of *Daphnia* populations to ferric sulphate might be expected in concentrations above 3mg Fe l^{-1}, at which eggs failed to progress to the brood chamber. The cessation of effective population growth could lead to a population crash if such concentrations of iron persisted within a water body.

Ferric sulphate had two effects on an algal food source, *Chlorella vulgaris*: firstly, growth was inhibited above 50mg Fe l^{-1}, and secondly above 150mg Fe l^{-1} the algal cells became aggregated into large clumps. Growth inhibition has the obvious impact on *Daphnia* of reducing the available food. Aggregations of algae might settle out of the water column faster than individual cells and may be less manageable as a food source, that is too large for *Daphnia* to ingest. The concentrations at which these effects on the alga were observed are high and probably rare in nature, and certainly were not observed to date in Rutland Water, so the impact of the effects of ferric on *Chlorella* and thus *Daphnia* in a water body are likely to be small.

Another longer term effect observed, was the increase in thoracic limb filtering area in the presence of ferric sulphate over the lifetime of the *Daphnia*. The increase in filtering area with increasing concentration of ferric sulphate, suggested that ferric did dilute the food available to the daphnids, and the *Daphnia* were able to make a suitable response to the environmental conditions and probably prolong survival.

It was clear that although ferric sulphate had a deleterious effect on *Daphnia*, they were able to make behavioural or morphological adaptations to compensate for the conditions or reduce their exposure to the damaging element in their environment.

The implications of these laboratory investigations for the field populations of *Daphnia* are that below 1.69mg Fe l^{-1}, no direct toxic effect would be observed in populations measured as reduced numbers or reduced birth rate or fecundity, although once concentrations above 3mg Fe l^{-1} are reached, population growth rates might be reduced. However, adaptive responses, such as feeding rate reduction (to reduce the amount of iron ingested) might be observed in concentrations as low as 0.5mg Fe l^{-1}. An increase in filtering area will occur in concentrations above 9mg Fe l^{-1}. The occurrence of such concentrations in the natural environment is discussed in Chapter Six.

Chapter Six - General discussion

6.1 Introduction

The direct and indirect impacts of ferric sulphate application in a reservoir on daphnid populations were investigated through field studies and laboratory experiments under controlled conditions. Ferric sulphate has been added to reservoirs to reduce the incidence of nuisance cyanobacterial blooms through phosphate removal by chemical means. In addition to any impacts on the physical and chemical environment, examination of the available literature suggested that ferric sulphate could have toxic effects on the daphnid population; it might reduce their food supply; and could induce behavioural and morphological adaptations in the *Daphnia.*

This discussion brings together the predictions made from literature studies with the findings of field and laboratory investigations and assesses the safety and practicality of adding ferric sulphate to reservoirs to manage cyanobacterial blooms.

6.2 Predictions arising from studying the literature

The limitedavailable literature on the toxicity of iron and other metals provided an insight into the possible impacts that ferric sulphate might have on reservoir plankton. The studies of Biesinger and Christensen (1972) and Khangarot and Ray (1989) on the toxicity of ferrous iron to *Daphnia*, suggested that the population growth rate of *Daphnia* could decline and that the mortality rate might increase at concentrations of iron less than 10 mg Fe l^{-1}. Literature on the effects of iron on macroinvertebrates and fish, and from studies into the effects of other metals on *Daphnia* suggested that young life stages might be more vulnerable to chronic toxic impacts of iron, that is clutch size and survival rate of neonates could decline in ferric iron.

In high concentrations of iron (>100mg Fe l^{-1}) such as those used in experiments conducted by Becker and Keller (1973) on the alga *Chlorella vulgaris*, algal growth was expected to diminish. Iron compounds are often used in water treatment processes as a coagulant (Mackenthun & Keup, 1970; Lynch, 1981; Vollenweider & Kerekes, 1982). From observations made during such use it was expected that individual algal cells might aggregate into larger clumps, that could settle out of the water column.

A decline in algal growth rate and aggregation and consequent settling out of algal cells could lead to less than ideal food concentrations in a daphnid's environment. Aggregated algal cells could be unavailable to filter-feeding zooplankton since these large clumps would be too large to handle. The presence of ferric sulphate particles suspended in the water column with algae, bacteria and other potential food might result in dilution of the suitable food particles.

Reduced food concentrations induce several responses in *Daphnia* that overcome the less than ideal conditions and maintain growth rates in the individual and in the population. One such response is an increase in feeding rate, that is, an increase in the number of food gathering sweeps made by the thoracic feeding arms (Rigler, 1961; Lampert & Schober, 1980; Phillipova & Postnov, 1988; Kirk, 1991; Urabe, 1991). The rejection rate of particles might increase as a result of the presence of inedible food or large food particles entering the food groove (McMahon & Rigler, 1965; Gliwicz 1977; Kirk, 1991; Urabe, 1991). Another response to reduced food conditions apparent from the literature was increased filtering area in *Daphnia*. This morphological adaptation could increase the food filtered with each sweep of the filtering limbs (Lampert, 1974; Fott *et al.*, 1974; Hrbacek *et al.*, 1979; Korinek *et al.*, 1985; Lampert & Brendelberger, 1996).

6.3 Physical and chemical impacts of ferric sulphate in Rutland Water

Field investigations conducted on Rutland Water showed that the iron concentrations in the reservoir were generally below 0.5 mg Fe l^{-1}, although concentrations of up to 17.5mf Fe l^{-1} were recorded in the reservoir in 1991. The literature suggested that such concentrations of iron should have little effect on daphnids. Healthy populations of lentic invertebrate and fish populations have been observed at such concentrations (Letterman & Mitsch, 1978; Scullion & Edwards, 1980a & b) and reported LC_{50}s for lentic invertebrates and fish and for laboratory populations in ferrous iron are generally at higher concentrations (Sykora *et al.*, 1972; Biesinger & Christensen, 1972;Khangarot & Ray, 1989; Maltby *et al.*, 1987). However, ferric iron has been found to be more toxic than ferrous iron (Decker & Menendez, 1974; Abraham & Collins, 1981). Additionally, the literature described no sub-lethal effects in *Daphnia* populations that might cause a decline in population with long-term exposure. Hence, field and laboratory investigations to investigate lethal and sub-lethal effects were necessary.

Most of the iron released into the reservoir overlay the sediments in the vicinity of the inlet in the south arm of the reservoir. Investigations by the NRA (Radford, 1994) have shown that the density and diversity of macroinvertebrate populations was reduced in sediments overlain by ferric floc (estimated to be 10% of the reservoir floor by area) (S. Brierley, pers. comm.), and that in concentrations of iron above 90mg Fe l^{-1}, the sediments were sparsely populated. As an important food resource for the trout fishery, the loss of macroinvertbrates from such an area may have serious economic implications to the reservoir owners. Overlaying the sediment, ferric floc may potentially be incorporated into the sediments through bioturbation by those fauna that may survive in high concentrations of iron such as chironomids (Radford, 1994). The sediments act as a store for iron, from which unconsolidated particulate iron may be recirculated into the water column by wind and circulating currents, where plankton may be exposed to it.

There was little evidence in the data of any effects of iron on parameters such as oxygen concentration, temperature and light, although light was often lower in the south arm of the reservoir. Phosphorus concentrations have declined since dosing (and the reduced pumping regime) began, with a coincident reduction in the mean concentration of chlorophyll *a*, suggesting that the available food to zooplankton has diminished. Although the chlorophyll *a* concentration has declined, it has not declined below the incipient limiting level. However, a decline in available food may potentially lead to fewer zooplankton in the reservoir and a lower birth rate.

6.4 Impact of ferric sulphate on *Daphnia* in Rutland Water

Field investigations in Rutland Water found no impact of ferric sulphate additions on daphnid population dynamics, that is, there has been no reduction in the population growth rate, or an increase in death rate. Comparisons with historic data collected prior to dosing found no difference in seasonal trends. These findings suggested that the iron in the reservoir was below concentrations impacting on daphnids. Alternatively, the resident daphnid population is able to avoid being harmed by exposure to iron by behavioural modifications or morphological adaptations.

There has been a loss of larger-bodied daphnids from the reservoir, although this occurred before ferric dosing began, and so cannot be attributed to the addition of ferric sulphate to the reservoir. Mature, that is egg-bearing females, have also declined in size in the reservoir. This size reduction has occurred since ferric dosing began, and so may be attributable to ferric sulphate additions, although the literature suggests that predation is a strong driving force in the body size of daphnid populations.

There is some evidence of an increase in the filtering area of daphnids from the south arm of the reservoir, compared with daphnids from other parts of the reservoir. Observations in other localities suggest that such an increase occurs as a result of a reduction in the food available to *Daphnia* (Lampert, 1974; Fott *et al.,* 1974; Hrbacek *et al.,* 1979; Korinek *et al.*, 1985; Lampert & Brendelberger, 1996). The filtering area of daphnids in the south arm of Rutland Water was found to be greater than other parts of the reservoir in this study, and the filtering areas were greatest in populations around the inlet. This could not be related to algal concentration since concentrations of Chlorophyll *a* were no lower in this arm of the reservoir than elsewhere, although there has been a general decline in Chlorophyll concentration. However, the concentration of Chlorophyll *a* in relation to ferric particles may be less in this arm. The NRA has no data for suspended solids that might answer this, but secchi depths are often less in the south arm, that may indicate that particulate material and therefore food dilution was greatest in this arm.

The observed decrease in size of daphnids and the increased size of their filtering area are mechanisms by which daphnid populations might reduce the impact of the chemical addition of ferric sulphate on the continued survival of the population. These effects were further investigated under controlled conditions in the laboratory.

6.5 Findings of laboratory investigations of the impacts of ferric sulphate on plankton

Laboratory studies showed that iron inhibited growth of a potential food source of *Daphnia*, *Chlorella vulgaris*, at concentrations above 50mg Fe l^{-1}. Above 150 mg Fe l^{-1} individual algal cells became clumped together.

In laboratory experiments, ferric sulphate had both short and long-term impacts on *Daphnia*. Significant mortalities were recorded in iron concentrations above 11mg Fe l^{-1} following short-term exposure (48 hours). A reduction in feeding rate was observed in concentrations above 0.5mg Fe l^{-1} within 30 seconds of exposure. The expected result was that there might be an increase in feeding rate, due to dilution of the food supply. The observed reduction in feeding rate suggested that some toxic property in the ferric sulphate induced an immediate response in *Daphnia* to protect them from the harmful effects of periodic exposure to iron. There was also an increase in the rate of rejection of particles from the food groove, as daphnids cleared unsuitable food particles from their feeding apparatus.

In long-term tests (21 days), a reduction in the population growth rate was observed in concentrations greater than 3mg Fe l^{-1}. Eggs failed to proceed from the ovary to the brood chamber at this concentration. Another long-term effect of ferric sulphate on *Daphnia* was an increase in the filtering area of the thoracic limbs at concentrations above 9mg Fe l^{-1}.

Long and short-term toxicity tests on *Daphnial* led to the derivation of a 'safe limit' for exposure to iron. Below this safe limit the population would suffer no harmful effects, that might lead to a decline in the population growth rate (reproduction), or an increase in mortality rate. The derived safe limit is 1.69mg Fe l^{-1}, 15% less than the Environmental Quality Standard for the protection of freshwater life of 2mg Fe l^{-1} suggested by WRc.

6.6 Occurrence of iron in Rutland Water at concentrations that might impact on the plankton population

Concentrations of iron in Rutland Water were generally below 0.5mg Fe l^{-1} much less than the derived safe limit of 1.69mg Fe l^{-1}. Peaks as high as 18mg Fe l^{-1} have occurred in Rutland Water, but peaks were more generally below 5mg Fe l^{-1}. The duration of such concentrations in the reservoir is unknown, since samples were only taken weekly, but high concentrations were not maintained from week to week.

Concentrations greater than 0.5mg Fe l^{-1} above which reductions in feeding rate were observed, occur quite frequently in the reservoir, so it is likely that the daphnid population in Rutland Water have used such behaviour to reduce the harmful impacts of iron on the individual. An increase in filtering area in daphnids occurred at concentrations above 9mg Fe l^{-1} in the laboratory, concentrations which have not been observed for any long period of time, although the phenomena of increased filtering area has occurred in the reservoir during periods of much lower concentrations of iron. This may be the result of longer term exposure to lower concentrations of iron, which have the same result as short-term exposure to higher concentrations. Concentrations of iron above 50mg Fe l^{-1}, the concentration above which algal growth was inhibited, have never been recorded in the reservoir, so it is likely that any changes in the algal population in the reservoir did not result from growth inhibition by iron.

The higher peaks in concentration of iron occurred during 1991 and 1992, when ferric sulphate was dosed (and less river water was pumped in) at a rate of 20:1 Fe: P (P. Daldorph, pers. comm.), peaks above 0.5mg Fe l^{-1} were not observed in 1993 and 1994 when ferric sulphate was dosed at a rate of 15:1 Fe:P, in response to total phosphorus concentrations that had by then declined below 0.3mg P l^{-1}. Dosing occurs only when the reservoir is being filled, which occurs mostly between autumn and spring, and only after periods of heavy rainfall in summer. As a result, the addition of ferric sulphate is periodic, and in varying concentrations, which makes it difficult to predict the timing and degree of impacts on the plankton population.

It is likely that the nature of the reservoir itself, being largely well mixed, and of neutral to alkaline pH has prevented iron from reaching persistently high levels in the water body. On some occasions conditions have been suitable for the mixing of iron into the water column, although under the redox conditions of the reservoir, it is likely that any dissolved iron would have been quickly precipitated, and any particulate iron would have soon settled to the sediment. The danger to planktonic life of the addition of iron, in this particular location was likely to be minimal.

The mean concentrations of iron in Rutland Water appear to be quite normal for European waters, although concentrations above 2mg Fe l^{-1} would be considered polluting. Jørgensen *et al.* (1991) reported that the concentration of iron in natural freshwater lakes in the Europe varied between 0.01 to 1.4mg Fe l^{-1}. Higher concentrations have been observed downstream of mine workings (Maltby *et al.*, 1987). Rasmussen & Lindegaard (1988) recorded concentrations up to 32mg Fe l^{-1} in a polluted river in Denmark.

Research by the NRA has established that macroinvertebrate populations have been reduced in sediments where there was ferric floc present (Radford, 1994). The sediments act as a sink for the iron, from where it might be circulated into the overlying water column where plankton may be exposed to it. If this sediment is recirculated to the water column, some of the phosphorus bound to iron in the sediments may become available given the right redox conditions and phosphorus concentrations in the water column may increase again. In view of the potential for the sediments to provide a source of iron and phosphorus, and the impact on the benthic populations, it would seem wise to prevent the build up of ferric floc on the sediments within the reservoir. This may be achieved by periodic removal of the sediment around the inlet, which has been carried out in the Norfolk Broads, although it is an expensive practice. Alternatively, the inflowing water and floc should pass through a settlement lagoon before it enters the reservoir to remove the floc, so that precipitated material does not collect on the reservoir floor. O these two options, it would then be much cheaper and simpler to remove accumulated sediment from a shallow lagoon.

6.7 Evaluation

6.7.1 Efficiency of ferric dosing

Ferric sulphate dosing has been one of the tools employed in management of cyanobacterial blooms in Anglian Water Services reservoirs since 1990. As a consequence of this addition plus features such as jetted inflows, helixors and bubble curtains, and reduced pumping regimes, the eutrophic status of some of the regions reservoirs is believed to be slowly decreasing (P. Daldorph, pers. comm.). At Foxcote reservoir, a small storage reservoir in Buckinghamshire, ferric dosing has been carried out since 1983. Since that time, macrophytes have replaced phytoplankton, and the diversity of macrophyte species has increased (Young *et al.,* 1988; Daldorph & Price, 1994). In most of the other reservoirs in the region, cyanobacterial blooms have not been eliminated, despite several years of intensive ferric dosing, although declines in chlorophyll have occurred in Rutland and Ardleigh Waters (Daldorph & Price, 1994).

6.7.2 Is Rutland Water typical?

The experience of the failure of phosphorus removal to control cyanobacterial blooms in Rutland Water, exemplifies the failure of the OECD models (Vollenweider & Kerekes, 1982) to describe the controlling forces of eutrophication in this waterbody. The OECD models assume strong 'bottom - up' dependence on identifiable elements such as phosphorus, but an international investigation determined that eutrophication management by nutrient reduction was insufficient in the majority of cases (Sas, 1989). The failure of 'bottom-up' control to reduce the incidence of cyanobacterial blooms in Rutland Water and many other reservoirs, suggests that 'top-down' effects, such as predation, have an important role to play in the management of eutrophication. Studies of fish predation in particular may lead to a better understanding of the trends in cyanobacteria population in a reservoir.

6.7.3 Fish predation as an explanation for the reduction in size of *Daphnia*

Rutland Water is an internationally renowned trout fishery. It is maintained on a 'put and take' basis (Moore, pers. comm.). Although AWS has substantial records on the number of rainbow and brown trout, with which the reservoir is stocked, and catch returns supply some information as to the sizes which the fish attain, very little information is available about the coarse fish population. AWS has analysed the gut contents of trout, and established that their main diet is Diptera larvae, and that the trout are not major foragers of zooplankton (T. Fanshawe, pers. comm.). As a result, the coarse fish population is considered to be the major predatory force on zooplankton in the reservoir.

When the original decision was taken to establish Rutland Water as a trout fishery, steps were taken to remove the coarse fish population. A coarse fishery was not considered viable in the reservoir, due to the lack of spawning grounds (Moore, 1982). Rotenone was added to the inflowing river Gwash, during the filling of the reservoir, resulting in widespread removal of coarse fish. Metal grills were fixed to the river inflow points to stop fish entering the reservoir by this route, although it was likely that fry would be able to pass through unhindered (Moore, 1982). Whilst sampling during 1992-1993, the author observed the presence of many thousands of fry in the shallow waters, such as those round pontoons and boats in the summer, together with many adult roach and other coarse fish dead on the shoreline showing signs of spawning stress. This suggests that spawning does occur in the reservoir, although this has never been verified.

When examining the historical *Daphnia* data for Rutland it was considered reasonable to assume that during 1979-1980, when the reservoir was newly filled, the predation pressure by coarse fish was low following Rotenone dosing; during 1990-1993 coarse fish predation pressure was high; and during 1985 predation pressure was in a medium state, given that any fish surviving in the reservoir since its filling was complete would have been breeding, thereby increasing their numbers since filling occurred.

Fish predation is thought to be the cause of the decline of *Daphnia pulex* in Rutland and the dominance of a smaller species *Daphnia galeata* (Harper & Ferguson, 1982; Smith, 1988). This idea is supported by studies in the London reservoirs. In Queen Elizabeth II reservoir, which serves London, the annual mean zooplankton biomass accounted for 20% of the total particulate carbon of the seston during 1970-1972 (Duncan, 1975a & b). Three species of *Daphnia* made up the dominant fraction of this. In 1970 the dominant daphnid was *Daphnia hyalina*, which became subdominant to *D. pulex* in 1971 and to the largest species, *D. magna* in 1972. Coincident with this change in dominant species was a fourfold increase in the mean and maximal zooplankton biomass, and a decline in algal crops. This change in dominance to a larger species was considered to be due to the collapse of the pike-perch population and an associated reduction in predation pressure in the reservoir. More recent studies by Sed'a and Duncan (1994) have determined that in the absence of large numbers of planktivorous fish, large-bodied *Daphnia* persist, contributing to the reduction of algal crops.

Daphnia longispina is one of the smallest daphnid species (Hrbacek, 1987), and has been dominant in Rutland Water since 1975, coexisting with the smaller cladoceran *Bosmina longirostris*. O.F. Müller (Harper & Ferguson, 1982; Smith, 1988). Since 1990, however, *Bosmina* has become rare in the reservoir (Sanderson, pers. comm.). This does not support the hypothesis of fish predation causing increased dominance of smaller and smaller species. The size of *Bosmina* (0.36-0.62mm), is within the smallest size class of *Daphnia longispina* (<1mm), which is the dominant size class throughout the year in Rutland. It is likely that *Daphnia longispina* has outcompeted *Bosmina longirostris* in the reservoir, due to the dominance of smaller *Daphnia* individuals below the 1mm threshold above which are commonly preyed upon by fish.

The reduction of the mean size of daphnids of the same species as a result of fish predation has also been well documented. Lammens *et al.* (1985) found that when young planktivorous fish were abundant the *Daphnia hyalina* population was dominated by small individuals. When recruitment of planktivorous fish was poor *Daphnia hyalina* was larger. Hrbacek and Hrbackov'a-Esslov'a (1960) determined that dwarf species, or strains with a diminished average length in adult instars of *Daphnia longispina* develop under fish predation pressure. Similar conclusions were reached by Galbraith (1967) who found that the number of daphnids above 1.3mm decreased, although the actual numbers of daphnids did not decline. Gliwicz and Rykowska (1992) found that body size declined, and so did the age at first reproduction. This strategy ensured that the numbers were kept constant, despite predation pressure.

It is likely that the coarse fish explain the decline in the number of daphnids reaching >1.6mm length. The increasing coarse fish population may also explain the apparent decline in size of gravid females since 1985, which has occurred without any apparent loss in actual numbers of daphnids.

6.7.4 Is ferric too dangerous to allow massive release into the environment?

The evidence of this investigation suggests that ferric sulphate should not exceed 1.69mg Fe l^{-1}. At 0.5mg Fe l^{-1}, behavioural adaptations that reduce the exposure of *Daphnia* to iron and ensure survival. Continued exposure to low concentrations apparently leads to morphological adaptation of the filtering apparatus, which also ensures continued survival and maintained growth. The consequence of a reduction in the daphnid population growth rate, or in a reduction in the feeding rate might be an increase in the biomass of algae, and continued occurrence of cyanobacterial blooms.

The addition of ferric sulphate to Rutland Water has had some success in the reduction of phosphorus in the reservoir, and it remains a useful tool in nutrient reduction. However, the evidence of this investigation, and the studies of the NRA and Environment Agency on the deleterious effects of ferric on the benthic populations in the dosed area of the reservoir, suggest that ferric floc should not be allowed to enter the reservoir. Phosphorus should be removed from the water prior to entry into the reservoir to protect the benthic environment and to ensure that no deleterious effects will occur to the daphnid population that might itself increase the occurrence of cyanobacterial blooms (through reduced grazing).

6.7.5 Alternative management techniques that may be used to replace ferric dosing

The evidence from Rutland Water suggests that in deep reservoirs, ferric dosing is not a wholly successful management tool for controlling cyanobacterial blooms. In this case, cyanobacterial blooms have continued, despite a reduction in phosphorus concentration, although the average chlorophyll *a* concentration has declined year on year.

Alternative techniques to ferric dosing which may be employed to control cyanobaterial blooms include mixing, flushing, collapsing gas vesicles, inoculation with bacteria and viruses, mechanical removal, addition of carbon dioxide, addition of copper sulphate, and biomanipulation. Most artificial reservoirs are built with features to ensure the water column is well mixed. This reduces phytoplankton abundance by increasing the time spent by photosynthesising cells below the compensation depth (Steel, 1975; Reynolds, 1984; Oskam, 1994), and prevention of anoxia in the hypolimnion inhibits nutrient release from anaerobic sediments (Burns, 1981; Klapper, 1991; Verner, 1994). Mixing has limited success for a number of reasons. Cyanobacteria are not always diminished by continuous mixing, due to their ability to adapt to low light irradiance (Walsby, 1992). Cyclical periods of mixing has had some success, although *Microcystis* is able to adapt to changing light regimes and float to the surface at the onset of calm conditions (Walsby & McAllister, 1987). Additionally, during bloom conditions *Microcystis* has proved difficult to mix into the lower water column, because of the high buoyancy of the colonies (Visser *et al.*, 1994).

Flushing water through reservoirs, over short periods (10-30 days; Reynolds, 1992) apparently prevent the dominance of slow-growing, large, inedible cyanobacteria such as *Aphanizomenon*. However, in drought prone eastern England retention times are much longer than this - Covenham reservoir has a retention time of 8 months, and Rutland Water two years. Ultrasonic radiation has been shown to be successful in bursting cyanobacterial gas vesicles in laboratory experiments, and could be implemented on a large scale (Walsby, 1992). Circulating water through a pipe to crush gas vesicles, originally designed for application at sewage treatment works, has possiblilities on the small scale (Clarke & Walsby, 1988, Walsby, 1992).

The use of bacteria and viruses to control cyanobacteria is attractive, due to the specificity of the treatment, but this practice has not been attempted on a large scale (Parr & Clarke, 1992; Cooke *et al.*, 1993). Preliminary investigations suggest that innoculation with cyanophages or bacteria will only control the biomass of existing blooms, and cannot prevent the appearance of new blooms, since the inoculi rely on the blooms for their own existence (Fraleigh & Burnham, 1988; Parr & Clarke, 1992, Cooke *et al.*, 1993). Natural toxins have been found, although not identified, in decomposing barley straw and similar materials (Ridge *et al.,* 1994; Newman & Barrett, 1993), which has had some success in small water bodies (Ridge *et al.*, 1994).

Mechanical removal of massive cyanobacterial scums with rakes and booms dragged behind a boat is only a short term clean up technique, and does not prevent further development of scum. Carbon dioxide injection has been employed in the US and Germany for several decades. Hypolimnetic water rich in CO_2 is pumped into the epilimnion within the same lake which has been observed to cause the collapse of *Microcystis* (Shapiro, 1990). This technique is not legal in the UK. Another technique not legal in the UK, is the addition of trace concentrations of copper sulphate, to which some planktonic cyanobacteria are more sensitive than green algae (Gohlke, 1972). Copper interferes with their growth and nitrogen fixation (Horne, 1979). However, field tests have been unsuccessful. In the Biesboch reservoir in the Netherlands, additions of copper sulphate were ineffective on the cyanobacteria population, despite the elimination of the entire benthic population (Oskam & van Breemen, 1992).

Biomanipulation, the enhancement of the biomass of larger zooplankton, has received considerable attention as a management tool in recent years. Maintenance of large-bodied zooplankton species leads to suppression of phytoplankton through grazing, reducing algal and cyanobacterial biomass, improving lake transparency.

In shallow lakes macrophyte beds have great value as refuges and alternative food sources for zooplankton (Moss, 1990; Irvine *et al.,* 1990; Phillips & Moss, 1994). In the absence of macrophyte refuges, zooplankton biomass and diversity may be maintained by reduction of spawning by cyprinids (eg. Roach) through netting regimes, or removal of cyprinids by the introduction of a piscivorous predator (McQueen & Post, 1984; Faafeng & Braband, 1990; Leventer & Teltsch, 1990; McQueen, 1990). The success of biomanipulation in eutrophic lakes and reservoirs, depends upon the threshold of phosphorus loading (Benndorf, 1987), and has generally been applied after or coincident with nutrient control techniques (Lyche, 1989; Benndorf, 1987; Hrbacek, 1994), or with management of hydraulic parameters (Moss, 1992; Phillips & Moss, 1994).

The key to successful biomanipulation is control of the fish population. Hosper *et al* (1992) indicated that 70% of the total number of bream, roach and carp, should be removed to achieve long-term effects, although large perch, eel and small pike should be returned. Difficulties in capturing fish as the number of fish in the reservoir decreased led to instabilities in the fish population in the Rimov (Czech Republic) and Bautzen (Germany) reservoirs , although strategic lowering of the water level to reduce the area of suitable spawning areas combined with continued intensive fishing had more success (Sed'a & Kubecka, 1995). The manipulation of fish stocks by the introduction of predators requires a massive stocking of adult fish, into often unfavourable conditions. The cost-effectiveness of this practice is doubtful since the results are not assured, although some successes have been reported (Hosper *et al.*, 1992; Schultz *et al.*, 1992; Mehner *et al.*, 1994).

The success of biomanipulation in Rutland Water would require an understanding of the fluxes in fish populations present, their sources and knowledge of the spawing grounds, followed by strict control of the fish population. Further research is required to establish whether a lake biomanipulation is possible in the presence of a valuable trout fishery. A recent study (Harper *et al.*, 1995) suggested that part of the reservoir (one of the bays) should be separated with respect to fish movement, and the water quality and zooplankton biomass within be extensively studied.

APPENDICES

Appendix I - Technical appendix

Appendix II - Data appendix

I Technical Appendices

I (a) The dominant daphnid species in Rutland Water

I (b) Analysis of iron in water samples

I (c) Analysis of chlorophyll *a* in water samples

I (d) Spatial variation of daphnids, chlorophyll *a* and iron in Rutland Water

I (e) The difference between daphnid numbers collected with a 10 litre Patalas from 0, 2, 4, 8, 12, 16, and 24m depth on 1/9/93

I (f) Variability of samples

I (g) A comparison of *Daphnia* egg counts using different methods of preservation

I (h) A sub-sampling technique for counting *Daphnia*

I (i) Comparison of 'projected filtering area' and 'estimated filtering area' of daphnids

I (j) Algal culture medium

I (k) Algal culture monitoring

I (l) Random sampling error for *Chlorella* counts

I (m) Typical composition of ferric sulphate W grade

I (n) The effect of sodium hydroxide on the growth of *Chlorella vulgaris*

I (p) Laboratory culture of *Daphnia*

I (q) Dunnett's Test

I (r) Paper submitted to 'Ecological management of shallow lakes and reservoirs' at Leicester, March 1996

I (a) The dominant daphnid species in Rutland Water

After the initial filling of Rutland Water, the dominant daphnid species present was *Daphnia pulex*, which was replaced in late 1975 by *Daphnia hyalina* (Harper & Ferguson, 1982).

Smith (1988) carried out extensive studies on the zooplankton assemblage of the reservoir and found this latter dominant form to be *Daphnia hyalina* var. *lacustris* (Sars) based on the description of this form by Scourfield and Harding (1976).

During this study, assistance was sought from Professors Hrbacek and Korinek in the Czech Republic, and Professor Green in the UK with the identification of specimens collected from Rutland Water during 1975 and 1992, together with laboratory specimens that had been cultured for a few months.

All three regarded unhelmeted forms to be *Daphnia longispina* O.F. Müller, and helmeted forms to be *Daphnia galeata* Sars. They were in agreement that the specimens were not *D. hyalina* based on the views of this species of Christie (1983) and Flössner and Kraus (1986).

Christie (1983) described *Daphnia hyalina* var. *lacustris* as a form of *Daphnia longispina* O.F. Müller. Flössner and Kraus (1986) included *D. hyalina* var. *lacustris* within *D. Galeata* Sars on morphological bases. For example, forms with high rounded helmets were incorporated as *D. galeata forma gracilis.*

Specimens bred in the laboratory for several months from individuals collected from the reservoir were more informative. They were found to show diagnostic head features of *Daphnia longispina*, such as high but rounded helmets and high antennule mounds.

It is on the basis of these features of cultured specimens the species was described as *Daphnia longispina* O.F. Müller, and this species was assumed to have been present since 1975.

I (b) Analysis of iron in water samples

Method No. 216, Section C of the Chemistry Laboratory Procedures Manual (NRA, 1991) was used.

Filtering

A Whatman® cellulose nitrate membrane (0.45µm) was placed on the filter platform of a suction Buchner funnel and the top replaced and tightened taking care not to damage the membrane. 250 ± 1ml of the well mixed sample was poured into the reservoir and filtered until the filter membrane appeared dry. The filter membrane was removed using non-metal forceps and placed in a clean dry Sterilin® petri-dish until ready to digest. The filtrate was kept for determination of the dissolved iron content.

Digestion

For digestion of particulate iron samples, the filter membrane was placed in a 100ml conical flask, with 50 ± 0.5ml 10% nitric acid (prepared by adding 5 ± 0.05ml 'PrimaR' grade nitric acid to 45 ± 0.5ml of deionised water) and a few anti-bumping granules. A blank using a clean filter membrane and 50ml 10% nitric acid was also prepared. For digestion of the dissolved fraction, 50 ± 0.5ml of the filtrate was poured into a 100ml conical flask and 5 ± 0.05ml 'PrimaR' grade nitric acid added. The samples were then digested on a hot plate, at approximately 170°C, for at least 30 minutes. The volume was never allowed to fall below about 15ml, and so additional deionised water was added as necessary. The samples were then allowed to cool to room temperature and 2.5 ± 0.1 ml 'AAS' grade hydrogen peroxide was added and warmed gently until the samples effervesced. As the effervescence subsided, the heat was increased and digestion continued for 10-15 minutes, again the volume was not allowed to fall below 15ml. The samples were then cooled to room temperature, prior to filtration through Whatman® No. 541 hardened ashless filter paper. This removed the anti-bumping granules and the filter membrane from the digested sample before it was transferred to a 50ml volumetric flask, and the volume made up to 50 ± 0.05ml with deionised water.

Analysis

Determination of iron was carried out by atomic absorption spectrophotometry, using a Varian Techtron (Type AA-6) at University of Leicester. The lower limit of detection was 0.001 mMolar Fe.

Standard solutions were made up from commercially available solutions as detailed in Table I (i).

After igniting the flame, the blank solution (1% nitric acid for low range and 10% nitric acid for high range determinations) was aspirated until equilibrium conditions were established. The top standard (0.2, 0.5, 1.0, 1.5, and 2.0 mg/l for low range and 2.0, 4.0, 10.0, 20.0 and 50mg/l for high range) was aspirated and the burner position adjusted to achieve maximum sensitivity.

The samples were then individually aspirated and a recording made of each measure given. The value was given in mMoles and was converted to mg/l for the purpose of this study, by multiplying the reading given by the atomic weight of iron (approximately 56g). Where the concentration of iron in a sample exceeded the concentration of the top standard the sample was diluted and re-analysed, maintaining the same concentration of nitric acid in the original sample.

Table I (i) Standard solutions for iron determination by AAS

a) Low Range (dilutions made using 1% v/v nitric acid 'Primar' grade)			
Standard	Volume taken	Final volume	Intermediate standard conc.
Fe, Mn: 1000mg l^{-1}	10ml	100ml	100ml
Intermediate standard	Volume taken	Final volume	Working standard
Fe, Mn: 1000mg l^{-1}	2	1000ml	0.2mg l^{-1}
	5	1000ml	0.5mg l^{-1}
	10	1000ml	1.0mg l^{-1}
	15	1000ml	1.5mg l^{-1}
	20	1000ml	2.0mg l^{-1}

b) High range metal standards (dilutions made using 10% v/v nitric acid)

Metal standard	Volume taken(ml)	Final volume	Working standard
Fe, Mn: 1000mg l^{-1}	50	1000ml	50mg l^{-1}
	20	1000ml	20mg l^{-1}
	10	1000ml	10mg l^{-1}
	4	1000ml	4mg l^{-1}
	2	1000ml	2mg l^{-1}

I (c) Analysis of chlorophyll *a* in water samples

The method used was based on that described by Talling and Driver (1963) with the modifications given in WRc (1973).

Filtering
A Whatman® glass microfibre GF/C membrane (1.2µm), of 4.7cm diameter, was placed on the filter platform of a suction Buchner funnel and the top replaced and tightened taking care not to damage the membrane. 1 ± 0.001 litres of the well mixed sample was poured into the reservoir and filtered under vacuum until the filter membrane appeared dry. The filter membrane was removed using forceps and placed in a clean dry graduated boiling tube.

Chlorophyll *a* extraction
Chlorophyll *a* was extracted from the filters using boiling methanol as a solvent (Talling & Driver, 1963). This procedure was carried out in a fume cupboard. A 1 litre beaker of water, with a few anti-bumping granules added, was heated to 70-90°C and the heat turned off. 14.5ml of 93% aqueous methanol ('Analar' grade) was added to a graduated boiling tube containing the filter membrane and the total volume of the contents recorded. The boiling tubes were covered with foil lids and placed upright in the heated water and allowed to boil for 1 - 1.5 minutes. The samples were then removed, stoppered, and placed in a rack to cool to room temperature in the dark.

Once cool 100% methanol was added to restore the contents to the original volume before boiling. The tube was then shaken, to disperse the pigment, and the extract poured into a centrifuge tube (10ml volume). The sample was centrifuged for 5 minutes at a speed of 3000 - 4000 revs / minute in a Denley BS400 centrifuge.

Analysis
The clear supernatant resulting from centrifugation was transferred to a spectrophotometric cuvette of path length 4cm. A matched cuvette was used to measure a blank of 90% methanol. The absorbance of the extract was measured at 665nm and 750nm using a Cecil 2020 spectrophotometer with a limit of detection of 0.001, corresponding to a chlorophyll *a* value of 0.05µg l^{-1}.

The concentration of chlorophyll *a* was calculated from the following equation:

$$\text{Chl } a = \text{Ve} \cdot \text{E} \cdot \frac{(OD_{665} - OD_{750})}{\text{VF} \cdot l}$$

Where:
Chl *a* = chlorophyll *a* concentration in µg l^{-1}
Ve = volume of extract
E = extinction coefficient of chlorophyll *a* in 90% methanol = 13.9 (from Talling & Driver (1963))
$(OD_{665} - OD_{750})$ = absorbance of extract at 665nm less absorbance of extract at 750nm
VF = volume of water filtered in litres
l = path length of cuvette in cm

I (d)Spatial variation of daphnids, chlorophyll *a* and iron in Rutland Water

Two different types of spatial survey were carried out a) to determine the differences in the distribution of *Daphnia*, chlorophyll *a* and iron throughout the reservoir and b) to determine the variation in the distribution of *Daphnia* within the south arm and c) to decide on regular sampling points, a spatial survey was carried out in this arm.

Method: a) Whole reservoir - On a map, the reservoir was divided into the north arm, south arm and eastern basin, which were reported in Smith (1988) to behave as distinct areas with separate circulations). A grid was placed over the map of the reservoir and a random number table provided co-ordinates for 30 random points, 10 within each section of the reservoir (See figure I(i)). At each sampling point, samples were collected for daphnid numbers, chlorophyll *a* concentration (as a measure of algal biomass) and iron concentration, from 1m depth using a 10 litre Patalas (method of use described in chapter 4) and a 2 litre Friedinger water sampler[1]. One sample was taken at each site. These surveys were carried out during July and November 1993. For methods of analysis, see Appendix I (a & b)

b) South arm - A grid was placed over a map of the south arm of the reservoir. A random number table provided co-ordinates for 30 random points within the arm (See figure I(ii)). At each sampling point a 140μm plankton net (used as described in Smith, 1988) was lowered to 3m depth to collect samples for daphnid abundance. Samples were collected between 0-3m since many of the survey sites were shallow (<5m), lowering the net to 3m depth ensured that there was no sediment disturbance. One replicate was taken at each site. This survey was carried out during May 1992.

Results

<u>Daphnids</u>

The results from the two spatial surveys carried out over the whole reservoir are displayed in table I(i). Chi-squared values are also given.

A Chi-squared test was performed on the data which showed that the *Daphnia* were non-randomly distributed. The three areas of the reservoir - north arm, south arm, and eastern basin showed similar variation in daphnid distribution, and did not behave as separate parts.

The results from the spatial survey in the south arm carried out in May 1992 are displayed in table I(ii).

---

[1] The Friedinger Water sampler was cylindrical and opaque, with a volume of 2 litres. It had lids at the top and bottom which were opened prior to lowering the sampler into the water. Once it had been lowered to the required depth the lids were caused to close by passage of a brass messenger down the rope to trigger the lids. It was then drawn up and the contents emptied into a 10litre bucket.

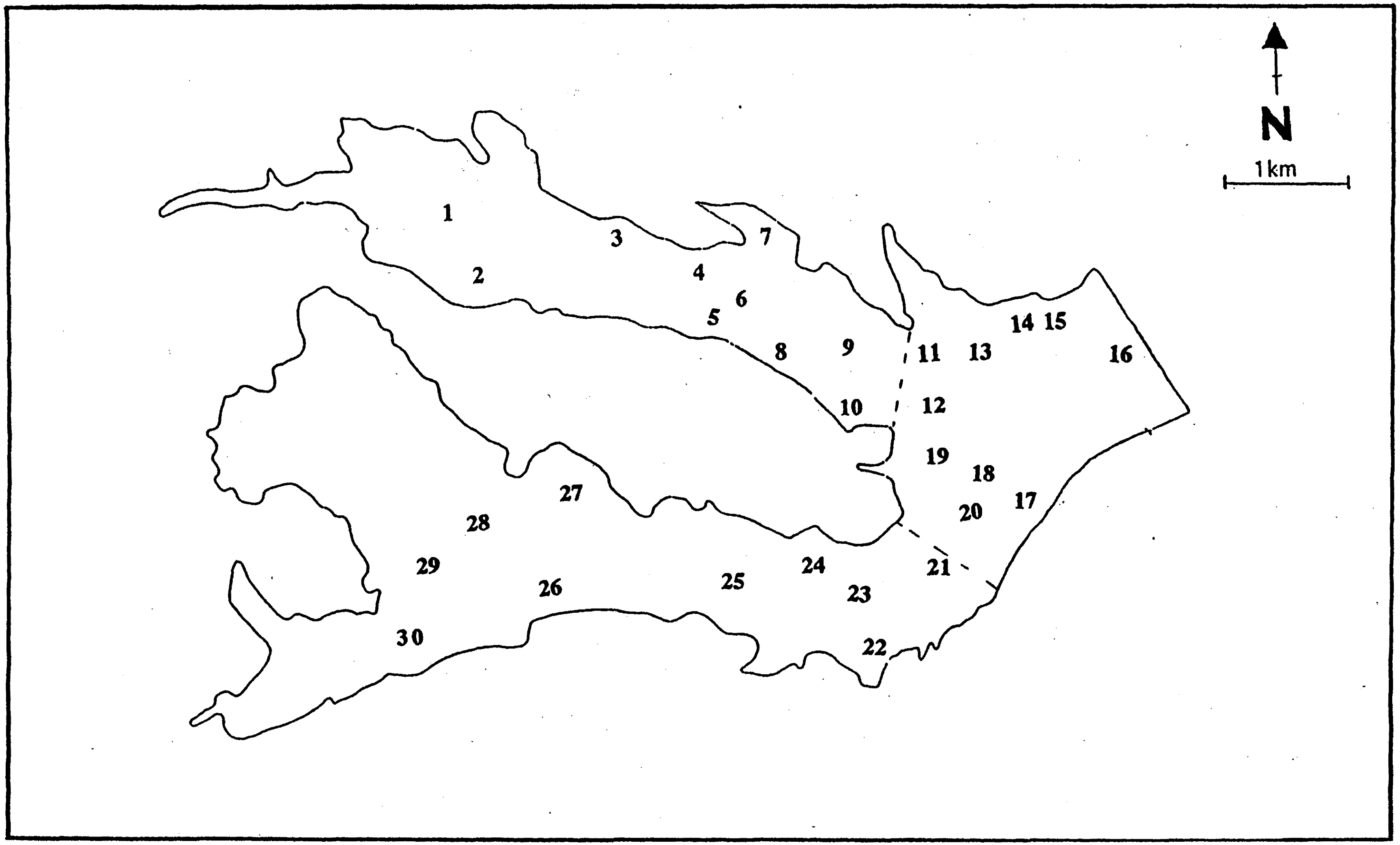


Figure I (i) Whole reservoir - 30 random sites

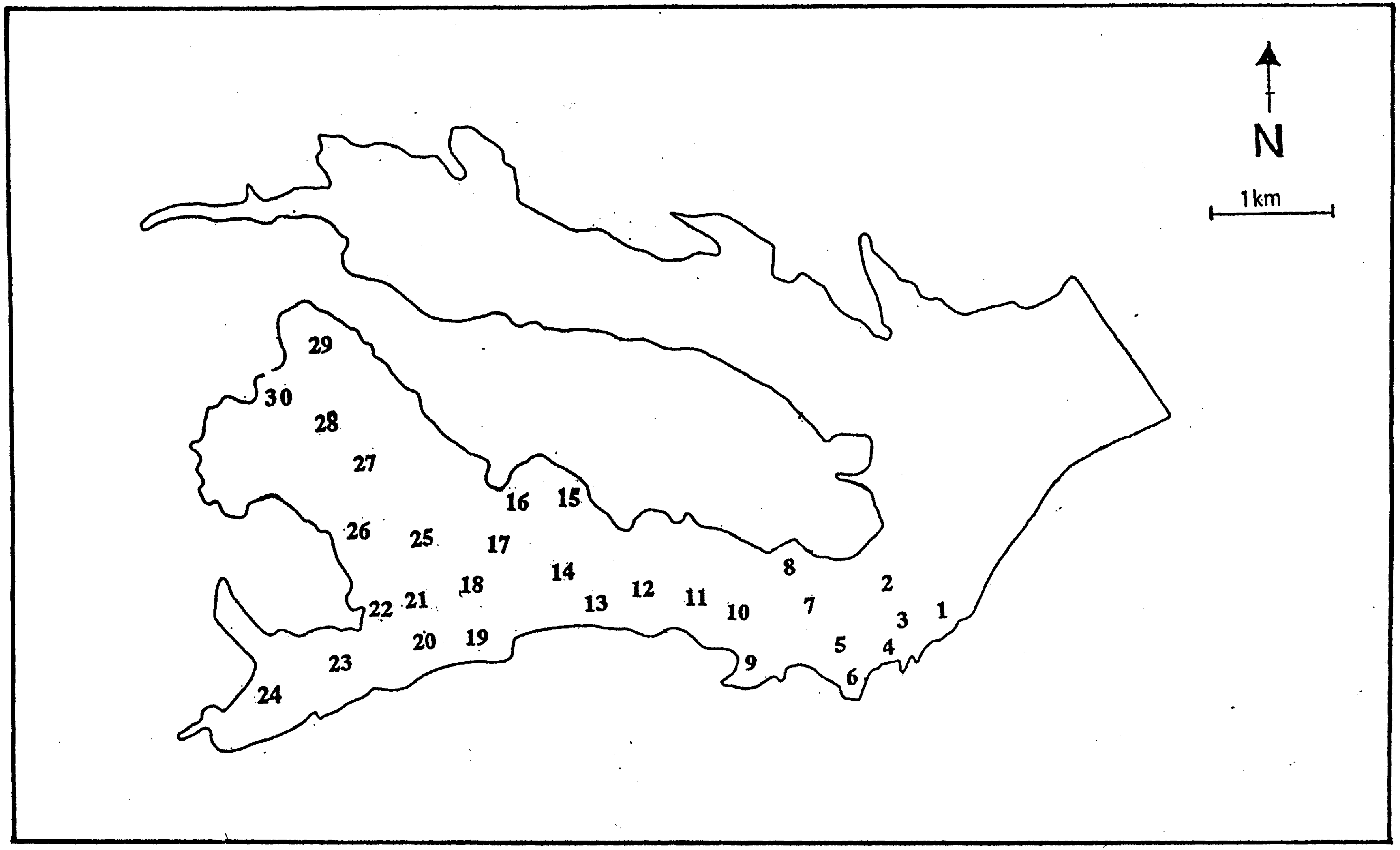


Figure I (ii) South arm - 30 random sites

Table I(i) Daphnid distribution in whole reservoir

July		November	
(Sites 1-10 = north arm; sites 11-20 = eastern basin; sites 21-30 = south arm)			
Site	Daphnids	Site	Daphnids
2	122	2	444
3	125	3	424
4	71	4	122
5	514	5	1144
6	353	6	230
7	56	7	113
8	54	8	376
9	226	9	294
10	726	10	1024
11	128	11	84
12	456	12	240
13	175	13	96
14	225	14	94
15	148	15	87
16	352	16	70
17	185	17	300
18	218	18	176
19	229	19	133
20	321	20	364
21	123	21	696
22	257	22	380
23	307	23	356
24	247	24	412
25	222	25	300
26	290	26	1624
27	299	27	248
28	295	28	1144
29	267	29	164
30	263	30	444
Mean	246.5		396.9
Variance	20030.5		139136.5
Chi-squared	2356.5		10166.2

A Chi-squared test showed significant differences between the sites, that is the daphnids were non-randomly distributed. The numbers of *Daphnia* found in the vicinity of the nature reserve, where it is shallow (sites 23-30), were fewer than in deeper parts of the south arm. Perhaps due to the presence of large numbers of fish, especially fry in the nature reserve region.

The number of samples that would be required to give a representative count of the number of daphnids in the reservoir was calculated using the following equation (Cassie, 1971):

$$n = \left(\frac{\text{Students } t \times S}{L}\right)^2 \qquad \text{(Equation x)}$$

Where Students' t for 30 samples in the survey was 2.04; S = standard deviation; L = 20% of the mean value i.e. 20% error acceptable.

Table I(ii) Distribution of daphnids in south arm of reservoir

Site	Daphnids	Count/10litre
1	1500	62.2
2	5290	215.9
3	2380	97.1
4	580	23.6
5	3110	126.9
6	2040	83.1
7	1000	40.8
8	3170	129.3
9	2200	89.8
10	1880	76.7
11	1500	61.2
12	1980	80.8
13	1890	77.1
14	2210	90.2
15	2270	92.6
16	7280	297.1
17	17220	70.28
18	7060	288
19	4110	167.7
20	510	20.8
21	520	21.2
22	350	13.1
23	50	2
24	90	3.6
25	60	2.4
26	60	2.4
27	45	1.8
28	5	0.2
29	1	0.04
30	2	0.08
Mean		74.56
Variance		6454.03
Chi-squared		2510.28

For the spatial survey conducted in July 1993 34 samples were required. For the spatial survey conducted in November 1993, *n* was 92 samples. For the spatial survey conducted in May 1992 in the south arm *n* was equal to 121 samples.

Chlorophyll

The chlorophyll *a* concentrations resulting from the spatial surveys conducted during 1993 are shown in table I(iii), in which chi-squared values are given.

In both surveys there were significant differences between the amounts of chlorophyll *a* recorded at each site. In July higher chlorophyll *a* concentrations were recorded in the main basin. During November, the south arm and main basin sites gave greater chlorophyll *a* concentrations.

Table I(iii) Chlorophyll *a* distribution in Rutland Water

(Sites 1-10 = north arm; sites 11-20 = eastern basin; sites 21-30 = south arm)

July Site	July Chlorophyll *a* µg/l	November Site	November Chlorophyll *a* µg/l
1	20.64	1	2.18
1	20.64	1	2.18
2	24.08	2	0.89
3	30.23	3	0.57
4	47.64	4	0.73
5	40.65	5	0.47
6	45.03	6	0.95
7	57.13	7	0.73
8	47.95	8	0.62
9	69.22	9	0.63
10	43.78	10	2.24
11	72.14	11	0.94
12	70.47	12	0.52
13	71.72	13	1.61
14	87.15	14	0.94
15	95.91	15	1.78
16	115.92	16	2.19
17	188.48	17	1.35
18	90.07	18	1.88
19	79.64	19	1.73
20	75.06	20	2.41
21	48.05	21	1.51
22	47.54	22	1.35
23	48.37	23	0.84
24	57.33	24	2.42
25	53.58	25	3.41
26	39.72	26	2.65
27	37.74	27	2.09
28	38.47	28	3.59
29	33.67	29	0.42
30	38.26	30	1.15
Mean	60.5		1.49
Variance	1088.36		0.75
Chi-squared	521.52		14.63

The number of sample sites required to give a representative measure of chlorophyll *a* were calculated using equation x. In July, 31 samples would be required to be taken to be representative, accepting 20% error, whilst for November 37 samples would be required.

<u>Total Iron</u>

The total iron concentrations from the spatial surveys carried out during 1993 are presented in table I(iv). Chi-squared values are given.

Table I(iv) Total iron distribution in the reservoir

July		November	
(Sites 1-10 = north arm; sites 11-20 = eastern basin; sites 21-30 = south arm)			
Site	mg/l Fe	Site	mg/l
1	0.07	1	0.112
2	0.06	2	
3	0.04	3	0.168
4	0.06	4	
5	0.07	5	0.224
6	0.09	6	
7	0.06	7	lost
8	0.06	8	
9	0.05	9	0.224
10	0.05	10	
11	0.02	11	0.224
12	0.04	12	
13	0.08	13	0.168
14	0.08	14	
15	0.04	15	0.224
16	0.08	16	
17	0.16	17	0.28
18	0.09	18	
19	0.14	19	0.28
20	0.13	20	
21	0.14	21	0.336
22	0.08	22	
23	0.07	23	0.728
24	0.07	24	
25	0.05	25	0.504
26	0.07	26	
27	0.08	27	0.336
28	0.08	28	
29	0.06	29	0.336
30	0.04	30	
Mean	0.07		0.316
Variance	0.001		0.023
Chi-squared	0.438		1.038

The chi-squared test showed that iron was randomly distributed within the reservoir. However, calculations with equation x, determined that in July 40 samples would ensure a representative sample and in November 27 samples would be required, accepting 20% error.

I (e) The difference between daphnid numbers collected with a 10 litre Patalas from 0, 2,4, 8, 12, 16, and 24m depth on 1/9/93

Throughout this study samples were taken from multiple depths to obtain an integrated value of *Daphnia* numbers for each site. One-way analysis of variance was carried out on data collected over a 16 hour period on September 1st 1993 from the Limnological Tower (see figure I(iii)) to decide whether to include 0m depth samples, since at the surface phytoplankton biomass tends to be reduced (Moss, 1988; NRA, pers. comm.) and hence daphnid biomass would be expected to be reduced also compared with the rest of the nominal water column. In addition the Patalas lids were not found to close easily at the surface often resulting in an incomplete sample. The results are presented in Table I(v).

Table I(v) Daphnid counts (individuals per litre) at the Limnological Tower on 1/9/93

	Depth						
Time	0m	2m	4m	6m	12m	16m	24m
0900	189	180	132	132	113	46	29
1100	199	215	94	63	64	38	104
1300	344	115	102	79	57	67	18
1500	277	184	86	287	67	77	54
1700	260	184	116	280	61	60	67
1900	449	386	248	171	78	22	17
2000	209	261	161	103	51	32	20
2100	150	176	120	116	149	65	17
2300	37	146	171	126	95	68	49
2400	63	165	177	107	81	150	29
0100	48	146	97	124	42	69	125

One-way Analysis of Variance gave a significant difference (<0.01) between the depths. Statistical comparison of the counts from each depth was carried out using Fisher's protected least significant difference (PLSD):

$$ta \cdot \sqrt{\frac{ms_r}{r}}$$

where ms_r is the between group mean square; *ta* is the two tailed *t* value at 99% significance level at the within groups degrees of freedom; $r = (1/N_a + 1/N_b)$ where N_a is the count of group *a* and Nb is the count of group *b*.

Fisher's PLSD was calculate to be 78.266 and was significant for the following comparisons:
0m with 12m, 16m and 24m; 2m with 24m; 4m with 24m; and 8m with 24m.

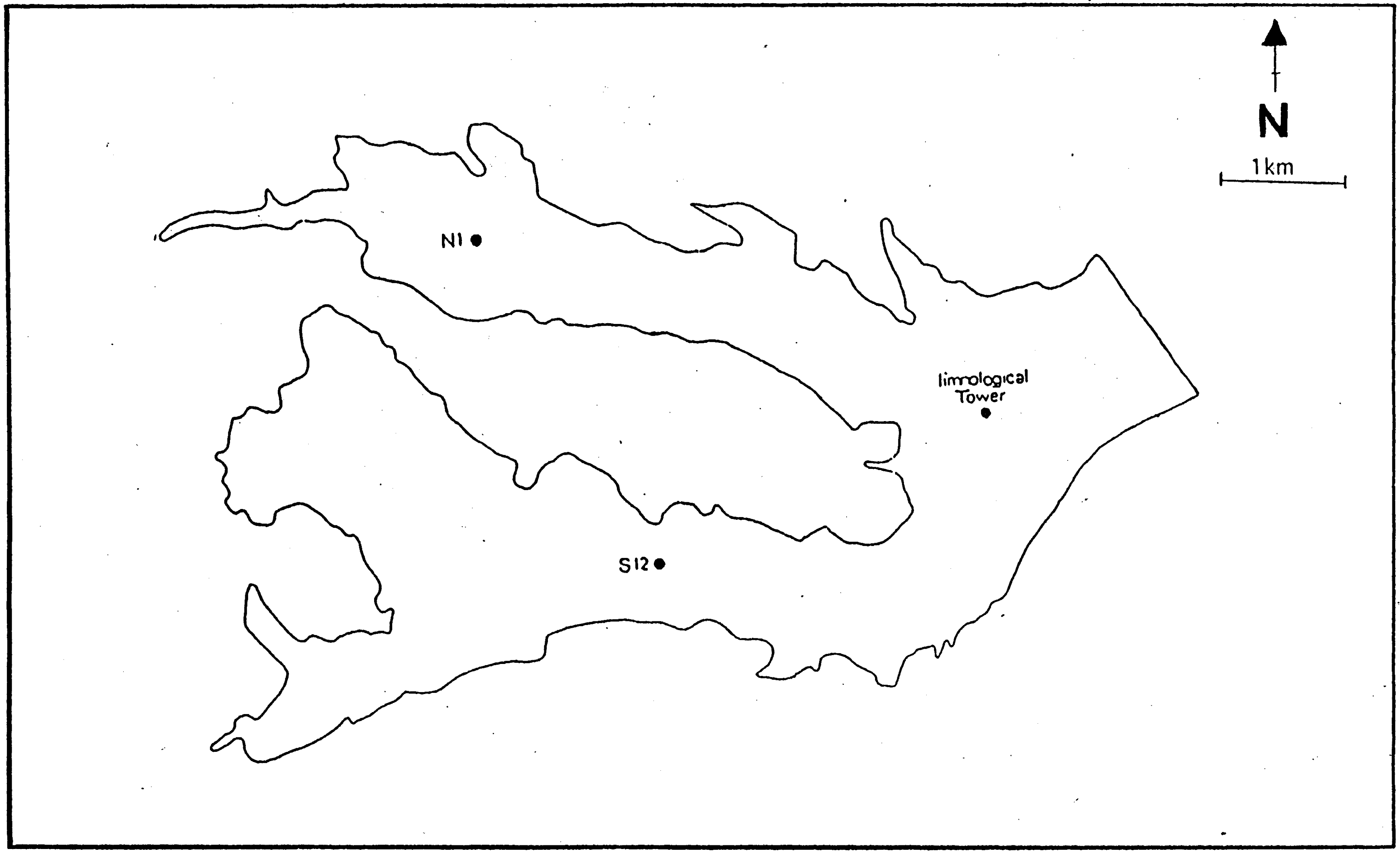


Figure I (iii) Location of sites LT (Limnological Tower), N1 and S12

I (f) Variability of samples

Replicate samples were taken and analysed to examine the reliability of taking one sample at each depth or site. The number of field samples required to give a statistically representative estimate of the daphnid population, and chlorophyll *a* and iron contents of each site or depth were calculated.

Method

Daphnid samples were collected, using a 10 litre Patalas, from two sites, known as North buoy 1 and South buoy 12 (see figure I(iii)) from 5m depth. Ten replicates were collected from each site. Ten replicate samples for chlorophyll *a* and iron analysis were obtained using a rigid 5m long tube, from the Limnological Tower. Methods of collection and analysis of these parameters are described in chapter three.

Results

Table I(vi) shows the *Daphnia* counts from sites N1 and S12. Chi-squared values are also given.

Table I(vi) Daphnid counts from replicate Patalas hauls at sites N1 and S12

a) N1		b) S12	
Replicates	Daphnid/litre	Replicates	Daphnids/litre
1	48.6	1	53.8
2	62.8	2	63.8
3	10.0	3	71.5
4	61.0	4	60.6
5	48.7	5	67.6
6	40.5	6	69.4
7	66.7	7	53.0
8	52.8	8	72.0
9	39.2	9	65.3
10	58.0	10	55.4
Mean	48.83		63.24
Variance	2702.69		520.98
Chi-squared	49.81		7.41

Chi-squared values were calculated for ten replicates from each site. The daphnids were contagiously distributed at any one site, as indicated by the significance of the chi-squared value ($p<0.001$).

Allowing for 20% error, the number of replicates that would be required to give a representative sample at each site was found using equation x:

14 Patalas samples would give a representative sample at site N1, whilst at the S12 site 2 Patalas samples would give a representative count allowing for 20% error.

Table I(vii) shows the chlorophyll *a* concentrations from two surveys carried out in July and November 1993. In July the survey was carried out during a bloom of the Cyanobacteria *Aphanizomenon flos aquae* (NRA, pers. comm.). The number of replicates that would be required to be taken to achieve 20% error was calculated as above, using equation x.

During the bloom of *Aphanizomenon* in July 12 samples for chlorophyll *a* would be required; during November 7 samples would provide a representative sample.

The chi-squared values for the July survey suggested that chlorophyll was non-randomly distributed. Clumps were observed in the samples. The chi-squared value for the November survey is very small indicating a random chlorophyll distribution. The results indicate that the amount of error associated with taking only one sample increases as the biomass of algae increases.

Table I(vii) Chlorophyll *a* at Limnological Tower

During July Sample	μg/l chl *a*	During November Sample	μg/l chl *a*
1	77.97	1	0.89
2	251.45	2	1.62
3	277.72	3	0.94
4	232.26	4	0.88
5	337.35	5	0.92
6	256.03	6	0.99
7	190.15	7	1.24
8	236.02	8	1.21
9	179.31	9	0.85
10	294.81	10	0.93
Mean	233.31		1.05
Variance	5141.01		0.06
Chi-squared	437.43		0.5

Table I(viii) shows the total iron concentrations for ten replicates collected from the Limnological Tower.

Table I(viii) Total Iron at the Limnological Tower

Sample	Iron mg/l
1	0.17
2	0.18
3	0.21
4	0.19
5	0.21
6	0.2
7	0.19
8	0.18
9	0.18
10	0.19
Mean	0.19
Variance	0.00017
Chi-squared	0.08

There were no significant differences between the replicates. One sample provided an accurate estimate of the concentration of iron present in the top 0-5m of the water column on that particular occasion.

I (g) A comparison of *Daphnia* egg counts using different methods of preservation

The number of eggs counted within a sample of the *Daphnia* population is used to estimate the instantaneous birth and death rates, and hence study the dynamics of a population. Therefore an accurate count is of great importance. Four methods of preservation of *Daphnia* samples collected from the field were examined to determine any differences in the estimate of an egg count within a population. These methods included two which killed the specimens quickly and two that involved slow death and possible distortion ('ballooning') of the daphnids and associated egg loss. These were compared with a control in which live daphnids were preserved individually and any egg loss included in the count.

Methods

Four replicate net hauls were taken between 0-5m from the Limnological Tower in March 1994 (figure I(iii)) and amalgamated in a bucket. The combined sample was then filtered through a 140µm mesh and preserved in one of the following ways:

a) 70% industrial methylated spirits with glycerol added (Hall, 1964: de Bernardi, 1974)
b) Sugar formalin (40gl^{-1} sucrose with 4% Formaldehyde (Haney and Hall, 1973))
c) 4% formaldehyde
d) 40% formaldehyde (net immersed in 40% formaldehyde for 30 seconds and then transported dry to laboratory (Sed'a, 1989))

Five replicates (each made up from 4 net hauls) were taken for each form of preservation. Ten additional net hauls were collected from 0-5m and transported live to the laboratory in a cool box. These ten live samples were used as a control and preserved in the laboratory in 70% IMS and glycerol - each daphnid being placed in an individual container in order that any egg loss could be recorded.

For the control samples, the number of daphnids and the number of eggs borne by 100 females, including those lost due to preservation (those outside the carapace), were counted in the individual containers. For the samples preserved in IMS, sugar formalin and 4% formaldehyde in the field, the number of daphnids and the number of eggs borne by 100 females was counted using a Bogorov trough. For the samples retained on the mesh after initial immersion in 40% formaldehyde, 100 gravid (egg-bearing) females were removed and the eggs counted.

Results and analyses

The raw counts are displayed in Table I(ix).

The number of daphnids in the sample was not determined during counting for the 40% formaldehyde method, so a mean value was estimated using the ratio of gravid females to whole count in the control sample. This gave a mean figure of 458 daphnids. The number of eggs that would be expected to be present in a population of 1000 daphnids was calculated for all methods and the controls. The numbers were rounded to the nearest integer for ease of calculation. These standardised egg numbers are presented in Table I(x).

Table I(ix). Daphnid egg counts

Treatment	Daphnids Counted	Gravid Females	Eggs	No. Females with eggs lost
CONTROL	409	100	465	4
	508	100	500	2
	506	100	403	2
	486	100	489	1
	473	100	449	0
	506	121	626	5
	485	107	670	2
	515	114	615	4
	492	118	531	0
	483	105	603	1
IMS	524	105	525	
	511	111	643	
	508	106	514	
	503	102	603	
	514	109	612	
SUGAR F	531	103	409	
	522	101	394	
	514	106	396	
	503	111	407	
	499	107	399	
4% F	348	100	481	
	658	100	434	
	481	100	510	
	566	100	507	
	521	100	494	
40%		100	580	
		100	665	
		100	661	
		100	681	
		100	652	

Table I(x) Egg Count per 1000 daphnids

Control	IMS	Sugar F	4% F	40% F
1137	1002	770	1382	1266
984	1258	755	659	1451
796	1012	770	1060	1442
1006	1199	809	896	1486
949	1190	799	948	1423
1237				
1381				
1194				
1079				
1248				

The mean egg count per 1000 daphnids and standard errors for each method and the control are displayed in figure I(iv).

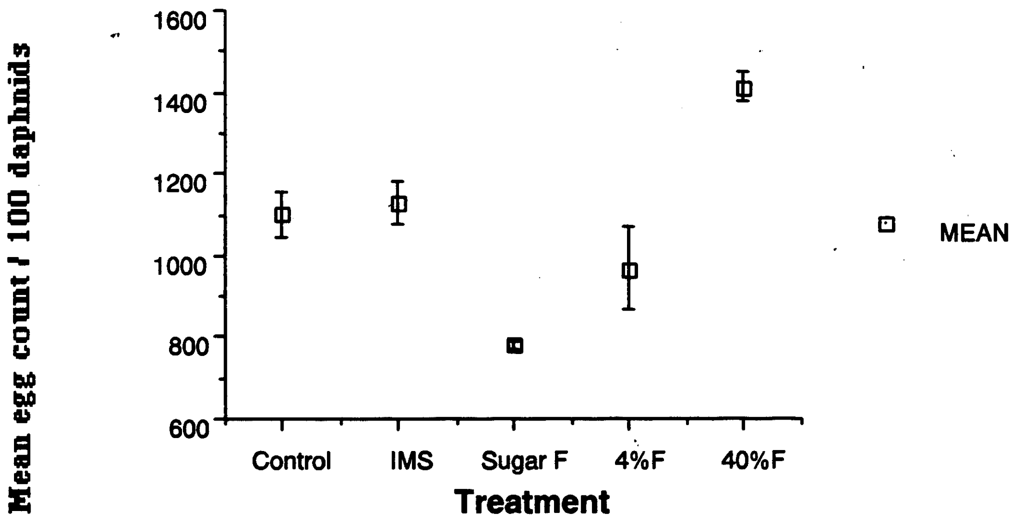


Figure I(iv) Comparison of mean egg counts using four methods of preservation with standard error bars (A)

The mean counts for the controls and the IMS field method were not significantly different ($p>0.05$). The mean egg count per 100 daphnids in sugar formalin was low compared to the other treatments and was significantly different ($p<0.01$). High egg loss had been noted during counting. Mean egg counts per 100 daphnids from the 4% formaldehyde field method had the greatest variation but with limits within that of the control and did not differ significantly ($p>0.05$).

The mean egg counts from samples preserved in 40% formaldehyde and held dry on the mesh had the highest mean and this was well above that of the control. Analysis of Variance comparison between this method and the control gave a Fisher PLSD value of 169.19 which was significant at 95%. This suggested that either the population sampled for this method carried a higher number of eggs per female (unlikely since the same site was used for all samples), or the method of removing the gravid females from the mesh gave a skewed result. Mixing was carried out before counting the control and other treatments to ensure random distribution of the gravid females, that is so that a range of clutch sizes would be counted. This could not be achieved in samples preserved in 40% formaldehyde. Those females carrying more eggs would appear more obvious under the microscope than those containing only one or two eggs, and there was probably a bias towards them, so that the range of clutch sizes was not accounted for in the resulting counts.

To attempt to include this variation in the number of eggs borne per female, a second determination of a mean estimate for the whole count was made using the ratio of eggs to daphnids from the control count. This gave a daphnid count estimate of 589. The resulting estimates of eggs per 1000 daphnids were as follows: 985, 1129, 1123, 1157, 1107

The means and standard errors using these values are displayed in figure I(v).

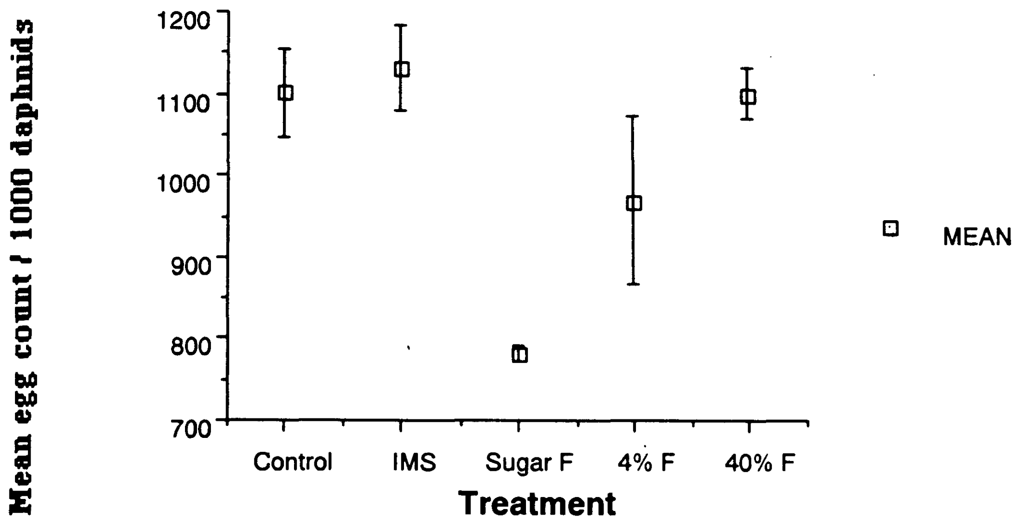


Figure I(v). Comparison of mean egg counts from four methods of preservation and their standard errors (B)

This calculation brought the 40% formaldehyde count to well within the control range which would be the expected result. Analysis of Variance was carried out to determine the statistical differences within and between the control and preserved treatments. The results are displayed in table I(XI). (Significant results P<0.01) are indicated by an *)

Table I(xi) Analysis of Variance statistics for four methods of daphnid preservation and a control

Comparison	Mean Diff.	Fisher PLSD
Control vs. IMS	-31.1	169.19
Control vs. SF	320.5	169.19*
Control vs. 4%F	132.1	169.19
Control vs. 40%F	0.9	117.87
IMS vs. SF	351.6	195.36*
IMS vs. 4%F	163.2	195.36
IMS vs. 40%	32	205.39
SF vs. 4%F	-188.4	195.36*
SF vs. 40%	-319.6	205.39*
4%F vs. 40%F	-111.2	205.39

Analysis of Variance showed that there were statistical differences between the preservation treatments. Sugar formalin was significantly different (p<0.01) from the other methods of treatment. There was no significant difference between the estimates using the other methods of preservation although samples preserved in 4% formalin had a wide range of error. Methods of preservation that kill the animals quickly (i.e. within seconds) would be expected to give reasonable estimates of the egg count within a population, since it is whilst the animal is dying that distortion of the carapace of daphnids such as *Daphnia* and *Bosmina* occurs resulting in the loss of eggs from the brood chamber (de Bernardi, 1984). This includes both the IMS method used in this study and the method of Sed'a (1989) using 40% formaldehyde. The addition of sucrose to 4% formaldehyde has been found to prevent carapace distortion and associated egg loss (Haney and Hall, 1973).

Sugar formalin was found to result in high egg loss, an observation also made by Prepas (1978) who suggested concentrating the samples on a nylon filter and treating them with a solution of 60g l^{-1} sucrose and 2% formaldehyde buffered with sodium borate and maintained at low temperature (6°C).

The effects of 4% formaldehyde of slow death resulting in ballooning of the carapace and loss of eggs and embryos observed by de Bernardi (1984) were not significant. However, the large error range of the counts suggests that samples preserved in this way should be used with care when estimating population dynamics from egg counts.

Samples preserved in alcohol (IMS) gave a good estimate of the egg count compared with the control, and this method is easily and safely applied in the field. The percentage of gravid females that had lost their eggs during preservation was calculated using the control figures was found to be 1.97%. It may then be assumed that there is likely to be some egg loss with this method, but a loss of 2% is not important where comparisons are being made between sites and seasons.

Samples immersed in 40% formaldehyde and then transported to the laboratory outside the medium (Sed'a, 1989) also gave a good estimate of the egg count compared with the control, but the dangers of using formaldehyde in the field and the cumbersome method of counting in the laboratory made this method difficult to use, especially if a large number of samples were being collected.

I (h) A sub-sampling technique for counting *Daphnia*

During periods when *Daphnia* densities are high (>25 l^{-1}) the 10 litre Patalas sample required sub-sampling to maximise counting effort. Smith (1988) investigated several methods of sub-sampling and found that the method described below provided the most accurate sub-sample. This method was investigated to determine the statistical viability of using a single sub-sample to provide a representative count of the whole sample.

Method

After suspension in tap water, the sample was poured quickly between two 200ml beakers 6-8 times and a known volume promptly drawn off using an Eppendorf® fixed volume pipette. If the sample was suspended in 100ml, a 1/10 subsample was taken by drawing off 10ml of the mixed sample; a 1/20 subsample by drawing off 5ml; a 1/40 subsample by drawing off 2.5ml etc. Each subsample was diluted with tap water making it up to 25 ml for counting.

Results

The counts are displayed in table I(xii) with calculated chi-squared values. A chi-squared test was used to analyse the variation between the sub-samples. Different samples were used in a, b and c.

Table I(xii) Number of daphnid per litre in ten replicate sub-samples

	No. Daphnids per litre									
a) 1/10 sub-sample										
Daphnids	155	165	167	161	151	144	137	134	146	151
Mean = 151.1		Variance = 125.21				Chi-squared = 11.14 (n.s. p>0.05)				
b) 1/20 sub-sample										
Daphnids	269	274	262	267	276	272	275	263	270	278
Mean = 270.6		Variance = 29.37			Chi-squared = 0.97 (n.s. p>0.05)					
c) 1/40 sub-sample										
Daphnids	59	65	67	71	63	69	57	62	64	61
Mean = 63.8		Variance = 19.06			Chi-squared = 2.68 (n.s. p>0.05)					

The differences between the counts were not significant at the p >0.05 level. The daphnids were randomly distributed within 100ml volume prior to removal of each sub-sample. Therefore, only one sub-sample needed to be taken from each sample to estimate, with accuracy within 20% the number of daphnids in the whole sample.

Sub-sampling was checked regularly in this way throughout the study.

I (i) Comparison of 'projected filtering area' and 'estimated filtering area' of daphnids

Methods

50 animals were taken from stock cultures. The standard length of each daphnid was measured (figure I (vi)) using a Nikon SM-ZU dissecting microscope at 70 times magnification. The individual was then placed on its right side on a microscope slide and the third thoracic limb (figure I (vii)) dissected out. The 'projected filtering area' was measured by projecting the magnified filtering comb onto paper, drawing round the image and calculating the area using a digitising area line planimeter (Tamaya Planix 5000) as described by Korinek & Machacek (1979), Koza & Korinek (1985), and Korinek *et al.* (1986). In addition five setae from the centre of the filtering comb were measured at 140 times magnification using a Zeiss (standard 16) phase contrast stage microscope. It was assumed that the findings of Pop (1991) were true in *Daphnia longispina*, and the following equation used to estimate the filtering area (Egloff & Palmer, 1971; Crittenden, 1981):

$$Y = 1.879 \; . \; x^{1.996}$$

where y = estimated filtering area of one comb (mm^2); and x = mean seta length from 5 measured setae (SL) (mm).

Results

The 'projected' and 'estimated' filtering areas (PFA) for 50 animals from stock cultures are shown in table I (xiii).

As the length of the daphnid increased so too did the projected filtering area. The measured and calculated PFA's were not significantly different from one another using Analysis of Variance on log (1 + x) transformed data ($p>0.5$). Hence the equation of Egloff and Palmer (1971) and Crittenden (1981) gave an accurate estimation of the PFA from setae length measurement, removing the necessity to draw each filtering comb and measure with a planimeter.

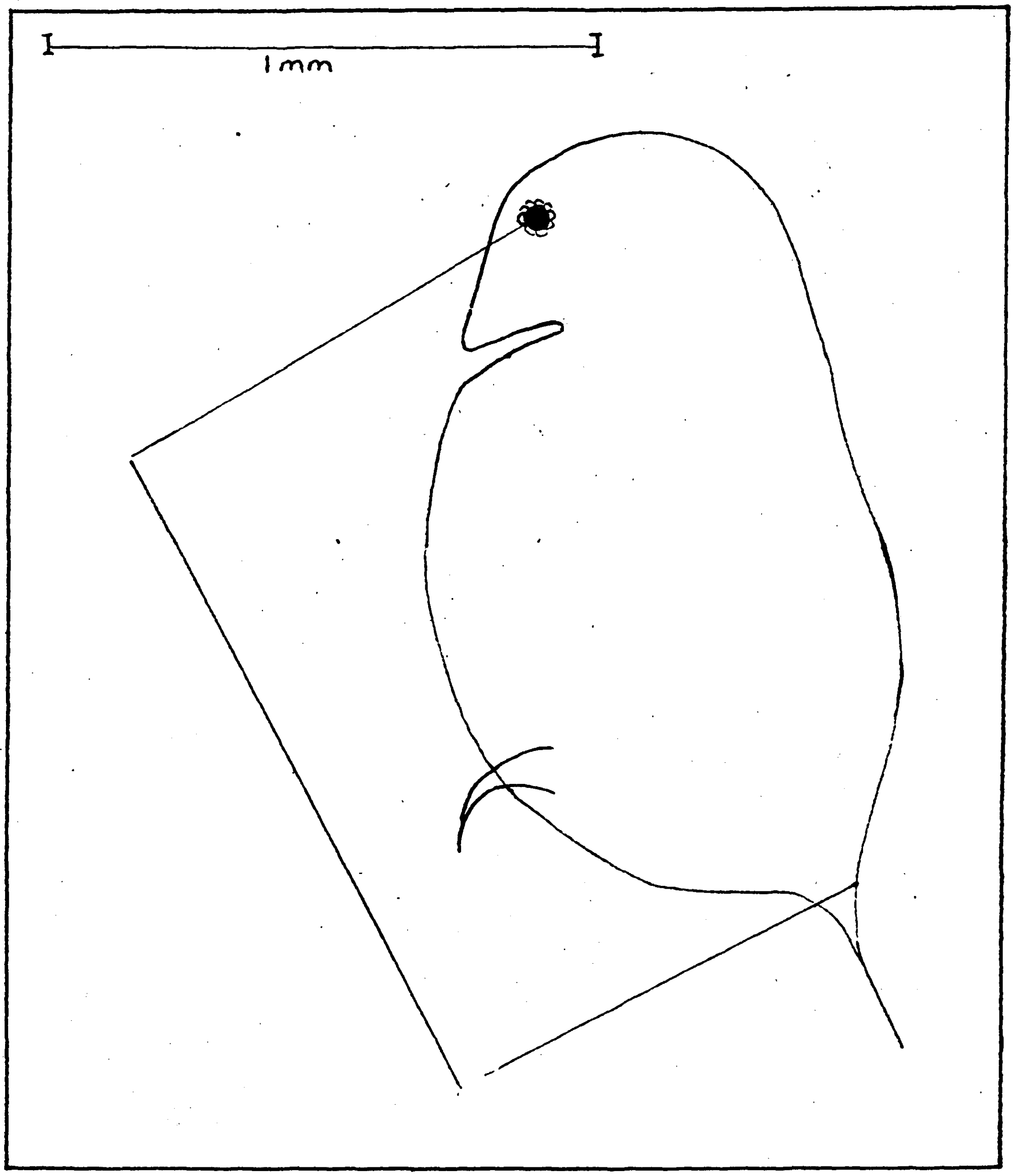


Figure I (vi) Measurement of standard body length

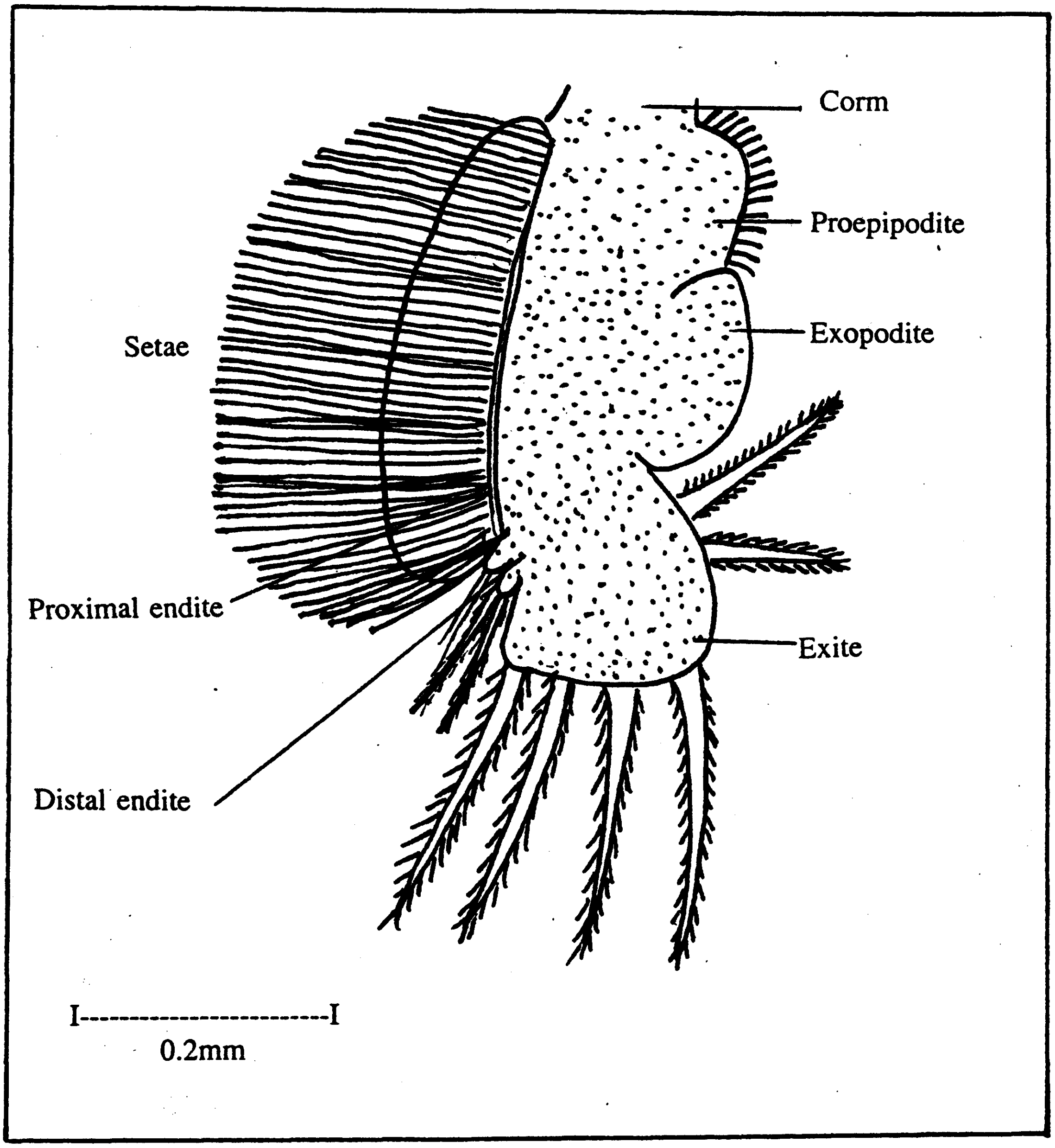


Figure I (vii) Schematic representation of daphnid third thoracic limb

Table I(xiii) Measured and calculated projected filtering area (PFA) of 50 stock daphnids

Standard length (mm)	Mean setae length (mm)	Measured PFA (mm)	Calculated PFA (mm)
0.64	0.123	0.031	0.028
0.66	0.128	0.030	0.031
0.7	0.129	0.034	0.031
0.7	0.139	0.033	0.036
0.72	0.124	0.036	0.029
0.73	0.149	0.042	0.042
0.74	0.124	0.028	0.029
0.74	0.135	0.039	0.034
0.76	0.147	0.04	0.041
0.78	0.125	0.031	0.029
0.78	0.134	0.032	0.034
0.8	0.139	0.036	0.036
0.8	0.149	0.044	0.042
0.82	0.134	0.032	0.034
0.84	0.144	0.042	0.039
0.85	0.15	0.044	0.042
0.85	0.14	0.038	0.037
0.9	0.154	0.044	0.044
0.94	0.154	0.056	0.054
0.96	0.163	0.054	0.05
1.0	0.164	0.049	0.051
1.02	0.168	0.053	0.053
1.06	0.17	0.052	0.054
1.10	0.181	0.06	0.062
1.14	0.178	0.062	0.06
1.16	0.18	0.064	0.061
1.2	0.18	0.066	0.061
1.2	0.19	0.07	0.068
1.26	0.189	0.064	0.067
1.26	0.199	0.073	0.074
1.3	0.195	0.073	0.072
1.31	0.180	0.064	0.061
1.34	0.195	0.074	0.072
1.34	0.205	0.07	0.069
1.38	0.189	0.069	0.067
1.4	0.195	0.074	0.072
1.4	0.205	0.078	0.079
1.47	0.203	0.078	0.078
1.5	0.209	0.084	0.082
1.54	0.204	0.076	0.078
1.56	0.210	0.084	0.083
1.6	0.215	0.09	0.087
1.62	0.220	0.093	0.091
1.65	0.214	0.089	0.09
1.69	0.209	0.084	0.086
1.7	0.227	0.106	0.102
1.73	0.214	0.085	0.09
1.78	0.225	0.105	0.1
1.8	0.225	0.1	0.1
1.84	0.225	0.103	0.108

I (j) Algal culture medium

Two types of media were used to maintain the alga. To stimulate slow growth, agar plates were used. For exponential growth prior to use in growth inhibition experiments and as food for *Daphnia*, Jaworski's medium was used.

Agar plates
Chlorella were maintained on agar plates in the dark at 4°C. The agar preparation contained the following nutrients dissolved in 1 litre of deionised water (the concentration of each nutrient is in parentheses):

> Agar (10g l^{-1}), proteose peptone (1g l^{-1}), potassium nitrate (200mg l^{-1}), potassium dihydrogen orthophosphate (20mg l^{-1}), manganese sulphate (20mg l^{-1}).

The agar was prepared in an autoclave at University of Leicester, and the plates poured in semi-sterile conditions. Each plate was inoculated by streaking with algae taken from a culture in Jaworski's medium in semi-sterile conditions, and then refrigerated at 4°C. When the alga was required for zooplankton feeding or for growth inhibition experiments, plates were placed in an environmental cabinet (BDH Ltd., PO Box 8, Dagenham, Essex; Model no. 3) at 20°C for growth to develop for two or three days. Algae were then washed off into Jaworski's medium.

Jaworski's medium
Nine stock solutions were prepared in deionised water, and the working medium made up from stock as required (final concentration in culture is in parentheses):

Stock solution 1 20g l^{-1} Calcium nitrate (0.02mg l^{-1})
Stock solution 2 12.4g l^{-1} Potassium dihydrogenorthophosphate(0.012mg l^{-1})
Stock solution 3 50g l^{-1} Magnesium sulphate (0.05mg l^{-1})
Stock solution 4 15.9g l^{-1} Sodium hydrogen carbonate (0.016mg l^{-1})
Stock solution 5 2.25g l^{-1} EDTA ferric and sodium ion (2.25 x10^{-3} mg l^{-1});
2.25g l^{-1} EDTA disodium ion (2.25 x 10^{-3}mg l^{-1})
Stock solution 6 2.48g l^{-1} Orthoboric acid (2.48 x 10^{-3}mg l^{-1})
1.39g l^{-1} Manganese chloride (1.8 x 10^{-3}mg l^{-1})
1g l^{-1} Ammonium molybdate (1 x 10^{-3}mg l^{-1})
Stock solution 7 0.04g l^{-1} Cyanocobalamin (Vitamin B12) (4 x 10^{-4}mg l^{-1})
0.04g l^{-1} Thiamine (Vitamin B1) (4 x 10^{-4}mg l^{-1})
0.04g l^{-1} Biotin (4 x 10^{-4}mg l^{-1})
Stock solution 8 80g l^{-1} Sodium nitrate (0.08mg l^{-1})
Stock solution 9 36g l^{-1} Sodium orthophosphate (0.036mg l^{-1})

One ml of each stock solution was withdrawn using a calibrated Eppendorf micropipette and placed in a volumetric flask which was then made up to 1 litre with deionised water. Before use it was equilibrated overnight in contact with air. After equilibration the pH was measured using a Kent (EIL 7045/46) pH meter, and adjusted to pH 6.5 - 8.5 as necessary using either 1M hydrochloric acid or 1M sodium hydroxide solution. The hardness of this medium was between 150-180mg l^{-1} as calcium carbonate.

I (k) Algal culture monitoring

Progress of cultures was monitored three times weekly by counting with a Lund Cell using a Zeiss (standard 16) phase contrast stage microscope at 160 times magnification. 5 $\pm$ 0.05 ml of the culture was removed from the medium, a single subsample counted and then discarded.

The density as cells per ml was calculated as described by Lund *et al.* (1958):

The following precautions and assumptions described by Lund *et al.* (1958) and Lund (1958) were used:

* The chamber was filled by continuous flow from the pipette.

$$\text{Cells per ml} = \frac{\text{no. organisms counted}}{\text{no. fields scanned}} \times \frac{\dfrac{\text{(Area of chamber)}}{\text{(Area of field)}}}{\begin{array}{c}\text{(Volume of chamber)}\\ \text{(ml)}\end{array}}$$

* 100-200 cells of the algal species were counted. This gave variation small enough to ensure that changes in the population equivalent to half a division were detected. That is, that a count of 100 cells was within $\pm$ 20 cells of the true figure and the likelihood of a single count being outside these figures was extremely small.

* The very ends of the chamber were not counted since a small amount of evaporation occurs there.

* Personal counting error and the cells per colony error was relatively unimportant. The random sampling error comprised by far the largest part of the total standard error.

I (l) Random sampling error for *Chlorella* counts

An investigation was carried out into random sampling error for estimating the number of cells ml^{-1} in order to determine how many replicates would be required to give a good estimate.

Ten replicate 5.0$\pm$0.01ml samples were taken from the same culture and a subsample of each replicate counted using a Lund Cell chamber. Ten fields were counted for each replicate. The resulting counts are displayed below (table I(xiv)). A value in cells per ml was calculated using the equation:

$$\text{Cells per ml} = \frac{\text{no. organisms counted}}{\text{no. fields scanned}} \times \frac{\dfrac{\text{(Area of chamber)}}{\text{(Area of field)}}}{\text{(Volume of chamber) (ml)}}$$

Table I (xiv) Replicate counts of a *Chlorella* sample

	Replicates									
Fields	1	2	3	4	5	6	7	8	9	10
1	724	690	601	642	659	607	624	698	759	598
2	782	741	591	584	741	624	646	603	702	587
3	697	941	629	621	721	591	671	604	693	751
4	685	757	620	757	698	587	687	597	641	604
5	629	604	636	796	607	756	752	671	598	653
6	598	609	614	542	598	704	591	603	604	672
7	592	612	692	624	547	729	586	720	678	599
8	584	684	756	609	682	684	604	741	651	652
9	587	696	784	608	625	692	612	651	643	741
10	741	604	592	641	714	657	714	659	613	721
	1.49	1.49	1.46	1.44	1.48	1.49	1.46	1.47	1.48	1.48 $x10^7$ cm l^{-1}

Standard error between the estimates of cells per ml from ten replicates was 5.2 $x10^4$ cells ml^{-1}, an error of 0.35%. This suggested that one replicate per culture or test would suffice to estimate the number of algal cells present within acceptable limits of 20% error.

I (m) Typical composition of ferric sulphate W grade (Data supplied by E & A West)

Metal	ppm w/w (Commercial supplier)	Estimated loading to Rutland Water (Kg)
Fe^{3+}	11.36%	4722.3
Fe^{2+}	0.16%	66.51
Ni	12.0	498.8
Cr	3.0	124.7
Cu	0.5	20.8
Pb	5.0	207.9
Mn	700.0	29099.0
Zn	80.0	3325.6
Cd	2.0	83.14
Co	18.0	748.3
Ti	600.0	24942.0
As	<1.0	-
Hg	<0.05	-

Much of the composition of Fisons 'technical grade' ferric sulphate, used throughout this study is unknown. Fisons estimate the copper and lead contamination to be 0.005% and zinc contamination to be 0.05%.

I (n) The effect of sodium hydroxide on the growth of *Chlorella vulgaris*

Method

A 2 litre volume of Jaworski's medium was made up as described in 5 Appendix I(j) and divided into two 1 litre fractions - one was the control medium, the other the test medium with 3ml 1 Molar sodium hydroxide added. This was judged to be twice the maximum amount added to the medium when ferric sulphate was added. The pH was 9.8. The test was set up as follows:

a) 1 control vessel containing 200ml Jaworski's medium and an inoculum of 4.35×10^4 cells *Chlorella* ml^{-1}

b) 4 replicate test vessels containing 200ml Jaworski's medium and sodium hydroxide as above, and an inoculum of 4.35×10^4 cells *Chlorella* ml^{-1}

These vessels were maintained in an environmental cabinet, for 7 days. At the end of the test the number of cells *Chlorella* ml^{-1} in each vessel were counted using a Lund Cell, as described in Appendix I (k).

Results

Table I(xv) Lund Cell counts for *Chlorella* in sodium hydroxide

Replicate	Control	Replicates			
Lund cell		1	2	3	4
1	316	268	278	284	296
2	265	274	275	275	275
3	317	259	265	283	268
4	308	276	284	275	272
5	296	289	293	274	275
6	268	284	276	283	269
7	297	276	271	269	274
8	264	275	272	276	281
9	278	284	276	277	277
10	269	291	275	278	276
Mean	287.8	277.6	276.5	277.4	276.3
Cell/ml	3.3×10^6	3.2×10^6	3.2×10^6	3.2×10^6	3.2×10^6

Growth rate μ was calculated as in Appendix I(k). In the control vessel *Chlorella* grew at a rate of 0.62μ d^{-1}, and in sodium hydroxide at a rate of 0.61μ d^{-1}. These results indicate that the effect of sodium hydroxide on the growth of *Chlorella vulgaris* is insignificant.

I (p) Laboratory culture of *Daphnia*

Source of animals and genetic integrity
Daphnia longispina O.F. Müller, was collected from Rutland Water and cultured in the manner described below.

Female daphnids cyclically reproduce by diploid parthenogenesis, producing individuals genetically identical to themselves. In natural populations in unfavourable conditions male daphnids develop and they reproduce sexually to increase the genetic variability of the population (Carvalho & Hughes, 1983). In a lake population there are many different clones, each of which differs in their genetic suitability to seasonal changes in their environment, such as temperature, chlorophyll *a* concentration, population density, and pH (Carvalho & Crisp, 1987). It was therefore assumed that genetically different clones could show variation in their tolerance to toxins.

At the commencement of this study 20 daphnids were taken from a Rutland Water sample and clones allowed to develop. The brood size, day to first brood and time between broods were monitored. The clone that showed the most consistent demographic pattern was used throughout the study. This technique eliminated the possibility that the responses observed in ferric toxicity tests would be responses to the culturing techniques rather than the ferric.

Type and size of vessel
Vessels are commonly made of chemically resistant glass such as pyrex or plastic such as Teflon, polyethylene and Plexiglas. PVC and nylon are avoided since they are toxic. Vijverberg (1989) advised that pipe connections and valves should also be made from pyrex or pure plastics.

The larger the vessel the less the container effects, such as zooplankton sticking to the sides. The shape of the vessel is important too - circular containers avoid aggregation of animals in certain areas in response to light conditions and water movements. A small surface to volume ratio decreases the chance that animals may become trapped by the surface tension of the medium. A low surface/volume ratio also reduces browsing or bottom feeding (Vijverberg, 1989).

Throughout this study the daphnids were cultured in 1 litre pyrex beakers filled to 800ml. The beakers were covered with a foil lid to prevent evaporation. Suspended at the surface of the medium was a sheet of 53μm mesh. This prevented the daphnids becoming trapped at the surface layer.

Medium
Milbrink and Bengtsson (1991) stated that cultures maintained in water from the natural habitat, which had been membrane filtered, and fed algae, generally gave good results. When artificial media and food (such as trout chow) were used, growth and fecundity were poor and mortality high (Vijverberg, 1989). Artificial media have been improved with the addition of essential components such as selenium and vitamin B12 as well as artificial chelators, the latter which improves food availability (Cowgill, 1987; Tevlin, 1978).

Throughout this study an artificial medium was used containing 0.35g l^{-1} magnesium sulphate, 0.54g l^{-1} sodium hydrogen carbonate, 0.01g l^{-1} potassium chloride, and 0.21g l^{-1} calcium sulphate in deionised water, which had a hardness of between 150 - 180 mg l^{-1} as calcium carbonate. The medium was adjusted as necessary to between pH 6.5 - 8.5 using either 1m hydrochloric acid or 1M sodium hydroxide.

Temperature
Cultures were maintained in an environmental cabinet (BDH model 6) at 20 $\pm$ 2°C. Laboratory studies have shown that mean mortality rates are low between 10-18°C, suggesting that this is the optimal temperature range for the majority of British freshwater zooplankton (Vijverberg, 1989). There is a direct relationship between growth rate and temperature, although it varies with species (Vijverberg, 1980). At 20°C *Daphnia* have an 8-week lifespan (Ten Berge, 1978); *Daphnia longispina* matures in 6 days at 13°C; *Daphnia pulex* matures in 9 days at 16°C in natural populations (Langeland *et al.*, 1985). However, the majority of toxicity investigations have been conducted at 20 $\pm$ 2°C (Enserink *et al.*, 1990; Milbrink & Bengtsson, 1991; Jones *et al.*, 1991), since this was usually close to the summer temperatures

experienced in the natural environment, and is the common ambient temperature in laboratories.

Light

Light was supplied in the environmental cabinet from white fluorescent tubes. In the literature a variety of photoperiods have been used: Milbrink and Bengtsson (1991) 20hr light: 4hr dark; Jones *et al.* (1991), 14hr light: 10hr dark; Vijverberg (1989) 8hr light: 8hr dark. OECD standards stipulate 16hr light: 8hr dark photoperiods for ecotoxicology tests (OECD, 1981). This latter regime was used throughout this study since the longer day period minimised the chances of the induction of sexual reproduction in *Daphnia* (Vijverberg, 1989).

Oxygen concentration

The medium was aerated to saturation prior to use, which took approximately 4 hours, and the oxygen content was measured using a Clandon (YSI model 58) dissolved oxygen meter.

Adema (1978) found the oxygen consumption of 25 adult egg-bearing daphnids was about 850μg oxygen per day. The 150 young they produce on average in 24 hours consumed an additional 600mg oxygen per day. Consequently 10 daphnids were kept in 1 litre of medium which was replaced on alternate days to maintain an appropriate oxygen concentration.

Food

Post-embryonic development is highly dependent on food quality and quantity (Langeland *et al.*, 1985). The past food quality and feeding history of a population play an important part in the egg production rates in response to changing food conditions (Donaghay, 1985). A single algal species may adequately sustain a zooplankton species all through its development from new-born to adult, although moderate densities of bacteria in algal cultures enhances food quality (Vijverberg, 1989).

The levels of food used in previous studies vary enormously. For example, Enserink *et al.* (1990) suggested 1 x 10^8 cells l^{-1} food, but Milbrink and Bengtsson (1991) added 6ml algae three times a week (approx. 5.0 x 10^6 cells ml^{-1}). Ten Berge (1978) stated that 25 new-born *Daphnia* require 10^8 cells daily. 25 adults needed 10-15 times more. Too much food gave increased reproduction with many tiny young born per female ('cheap' neonates). Other symptoms such as oxygen deficiency in the dark and a turbid culture also occurred. Too little food gave a reduced number of offspring, small clutches of large neonates, an increased number of males, production of ephippia, and a clear culture (Vijverberg, 1989).

The *Chlorella* cultures, on which *Daphnia* were maintained throughout this study, were not sterile, although care had been taken to avoid contamination by solvents and detergents. Protozoans and heterotrophic flagellates as well as small quantities of bacteria were known to be present, which added to the value of the food. Yeast extract (microbiological grade) was added at 20ppm as an organic supplement. Algae were added with the new medium, at a concentration of 1.25 x 10^6 cells ml^{-1}.

Culture procedure

Strategy

Eight individually numbered cultures were maintained in 800ml of medium with 1.25 x 10^6 ml^{-1} algal additive and 20ppm yeast extract in 1 litre glass beakers. Each cultures was reset when 24 days old by discarding the adults and replacing them with 20 neonates (young daphnids, less than 24 hours old) taken from any culture containing neonates. If there were no neonates released on the day when the oldest culture reached 24 days old, they were kept for one additional day and then reset. When each culture was about 5 days old (i.e. when some of the adults were gravid) the number per culture was reduced to 10. The cultures were staggered so that at any one moment there were four groups of 2 cultures differing in age by 6 days. This strategy ensured an adequate supply of neonates for toxicity testing requirements and the continual maintenance of the cultures.

Culture maintenance

All neonates were removed daily and discarded unless required for testing or resetting cultures. Adult daphnids were transferred with a wide-bore polyethylene tube (approx. 6mm diameter). Neonates were transferred this way too, or by slowly pouring the medium through a fine net partially immersed in another beaker containing fresh medium. The net was then inverted to release the neonates.

Feeding

All cultures were fed daily with the alga *Chlorella vulgaris*. The algae were harvested by centrifuging appropriate aliquots at 4000rpm for 10 minutes, discarding the supernatant and resuspending the algae in 100ml of the *Daphnia* culture medium. A 1ml aliquot of the suspension was diluted to 50ml with the medium and the absorbance of the dilution measured at 440nm using a spectrophotometer (Cecil 2020). Cell density was calculated using the following equation (Unilever, 1985):

$$\text{Cell no. x } 10^7 = 0.002 + (1.753 \text{ x Abs}) + (\text{Abs}^2) \text{ x dilution factor}$$

Each daphnid culture was given the calculated volume of algal feed to give a minimum of 1.25×10^6 cells ml^{-1}, once daily. If the culture appeared green with algae after 24 hours it was not necessary to feed it. Yeast extract was added at 20ppm when the medium was renewed.

Culture monitoring

Some observations made by Cowgill (1987) have been useful for determining the health of the culture. Sudden high temperatures or a maintenance temperature that exceeded the usual for an acclimated population led to decreased oxygen concentrations. Overcrowding and dirty living conditions due to infrequent habitat renewal, accumulation of discarded carapaces and dead daphnids, and the accumulation of faecal material led to infection by aquatic fungae. Good culture health was shown by the absence of ephippial eggs, consistent demographic results over time, such as a mean brood size of 2-12 (dependent on the species), consistent day of first brood, a similar number of broods per lifespan, constant number of broods per female and a regular brood interval.

I (q) Dunnett's Test

Dunnett's test compares the mean results of a series of treatments, where one of the means is a control and the others are treatment means.

Dunnett's test is used to compare each treatment mean X_i, where *i* goes from 2 to *k* , and *k* is the total number of treatments, with the control mean X_c:

$$t = \frac{X_c - X_i}{\sqrt{S^{-2}\left(\frac{1}{n_c} + \frac{1}{n_i}\right)}}$$

Where S^{-2} is the overall average variance (or mean square (error)) and n_c and n_i are the number of observations in the control and treatment groups respectively. These *t* values are compared to a suitably modified *t* table with 2 values; the degrees of freedom for the average variance:

$$\sum_{i=1}^{k} n_i - k$$

where n_i is the number of observations in the ith treatment; and the total number of treatments including the control.

I (r) Poster paper presented at Leicester conference on Lake Management

THE EFFECTS OF FERRIC DOSING FOR PHOSPHORUS CONTROL ON *DAPHNIA LONGISPINA* O.F. MULLER (CLADOCERAN)

Selena Randall[1], Bill Brierley[1] & David Harper[2]
[1] Environment Agency, Anglian Region, Kingfisher House, Orton Goldhay, Peterborough PE2 5ZR
[2] Ecology Unit, Department of Zoology, University of Leicester, Leicester LE1 7RH

Introduction
Eutrophication, recognised as a problem in freshwaters since the 1940's results principally from modern farming practices, which use fertilisers rich in nitrates and ammonia, and the discharge of phosphate-loaded domestic and industrial sewage effluent to rivers. In reservoirs the effects of eutrophication, such as enhanced phytoplankton growth, shading out of macrophytic plants, oxygen depletion, and excessive development of cyanobacterial blooms, led to problems at water treatment works and in public water supply systems. Techniques to minimise the effects of eutrophication, such as destratification and biomanipulation have become widely used.

Eutrophication control by removal of nutrients, in particular, phosphorus, has had some success over the past 15 years. Once such technique, using iron salts precipitates available phosphates from the water column to the sediments and prevents internal loading by maintenance of a layer of iron over the sediment, to precipitate any phosphates entering the interstitial waters. Anglian Water Services began dosing their water supply reservoirs with ferric sulphate in the 1980's. After success in reducing cyanobacterial blooms at Foxcote and following the closure of Rutland Water due to their presence in 1989, ferric dosing began in Rutland in 1990.

The environmental impact of ferric compounds has been little researched. The effects on filter-feeders were considered of particular importance due to their central role in reservoir food chains (Galbraith, 1967; McQueen & Post, 1984; McQueen & Post, 1986; Vague & Pace, 1992). Direct toxicity of ferric sulphate, or the smothering effect of the floc may lead to changes in the population dynamics with consequences on the algal community. *Daphnia* has an important role in the food chain, and there are established methods for its use in toxicity tests. The species used was *Daphnia longispina* O.F. Müller, the dominant daphnid in Rutland Water. As filter-feeders daphnids take up iron through ingestion. The feeding morphology and behaviour is complex and has received a great deal of study (Lampert, 1974; Fott et al., 1974; Korinek & Machacek, 1979; Korinek et al., 1985; Rigler, 1961; Lampert & Schober, 1980; Philipova & Postnov, 1988; Urabe, 1991). The quality of ferric precipitate as food was small and the presence of ferric with algal food diluted the suitable food present. Affects on feeding morphology and feeding behaviour were expected below the concentration of iron at which population effects were observed.

Study Site
Rutland water is situated approximately midway between Leicester & Peterborough at 50°40'N, 0°37'W. Its construction began in 1971 and was completed by February 1975. Filling was completed by spring 1977 (Smith, 1988). Raw water is pumped through a submerged inlet pipe, located at the eastern end of the south arm. This inlet is inclined at 22° to the horizontal to aid mixing of the river and reservoir water. Ferric sulphate is added to the river water as it is pumped through the inlet.

Direct Toxixity - Laboratory studies

Methods
The Cladoceran *Daphnia longispina* was collected from the reservoir and cultured in the laboratory in an artificial media containing $0.35gl^{-1}$ magnesium sulphate, $0.54gl^{-1}$ sodium hydrogen carbonate, $0.01gl^{-1}$ potassium chloride and $0.21gl^{-1}$ calcium sulphate. The cultures were kept at $20 \pm 2°C$ (Enserink et al., 1990, Milbrink & Bengtsson, 1991; Jones et al., 1991), under a light regime of 16 hours light : 8 hours dark (OECD, 1981; Vijverberg, 1989) in an environmental cabinet. The cultures were fed the alga Chlorella at a concentration of 1.25×10^6 cells per ml with yeast extract as an organic additive (Vijverberg, 1989). Acute toxicity tests were carried out over 48 hours, and chronic tests over 21 days, on *Daphnia longispina* in ferric sulphate and china clay (an inert particulate substance which acted as a control). Appropriate china

clay concentrations were derived from the dry weight of ferric sulphate in each test concentration to give equivalent amounts of particulate material.

Results

Acute tests in ferric

There were no significant mortalities ($p>0.5$) under dissolved iron exposure. Mortalities were below 20% in all iron concentrations. After 48 hours there was no significant difference between the dissolved iron in the samples, which was assumed to have come out of solution into particulate form (Figure 1). Percentage mortality increased significantly ($p<0.05$) with increasing concentration of particulate iron, suggesting that there was a detrimental effect (Figure 2). The mean effective dose (ED_{50}) was calculated using the method of Litchfield and Wilcoxen (1949), to be 11.48mgl^{-1} between confidence limits of 12.39 and 10.63mgl^{-1}.

Chronic tests in ferric

Mortalities increased significantly ($p<0.05$) with increasing concentration of particulate iron (Figure 3), and the number of broods and the mean clutch size coincidentally decreased. In addition the day of the first brood became later with increasing with increasing iron concentration. No neonates were born in 15.9mgl^{-1} particulate iron. An ED_{50} of 4.49mgl^{-1} iron precipitate was calculated as above, between 90% confidence limits of 6.51 and 3.09mgl^{-1}. The median effective doses from the acute and chronic tests were used to calculate safe limits of particulate iron of 1.69mgl^{-1} Fe, a concentration of particulate iron below which no harmful effects would be expected in Daphnia longispina (Sprague, 1971).

Acute tests in china clay

Mortality increased significantly ($p<0.01$) with increasing concentration of china clay (Figure 4). These mortalities could not be attributed to toxicity since china clay is inert, and the grade of the substance was pure, but were associated with the presence of suspended matter.

Chronic tests in china clay

The number of mortalities increased significantly as the amount of china clay increased (Figure 5) and the day to the first brood increased. Additionally the number of broods and the mean clutch size declined as china clay concentration increased.

Field investigations

Methods

Sampling using a 10L Patalas sampler (Patalas, 1954) from different depths between 2-10m, took place on Rutland Water fortnightly from 7 sites in a transect in the south arm during 1992-1993, following statistical evaluation of the sampling methods. Raw data from Smith (1988), collected from the reservoir during 1985 was used as a pre-ferric dosing comparison. The 'egg ratio' method (Paloheimo, 1974) was used to calculate the population birth rate, and corrected for shifts in the age of the population using Taylor and Slatkins model (Taylor & Slatkin, 1981). The instantaneous population growth rate (*r*) was calculated using the exponential growth equation (Edmondson, 1968), and death rate assumed from the difference between birth rate and *r* (Edmondson, 1968). Any changes in these population statistics would result from direct and indirect toxicity of ferric sulphate. The total iron (mg/l) in the reservoir was analyzed to investigate the hypothesis that the concentration would decrease spatially with distance from the inlet.

Results

Spatial comparisons between densities, fecundities and birth and death rates of *Daphnia longispina* found no effect within the south arm of the reservoir. Raw data collected by Smith (1988) in 1985 provided the most recent daphnid population information prior to ferric dosing, and was used for comparison. The 1992-1993 population dynamics of Daphnia were not significantly different from those of the 1985 population, suggesting that ferric dosing has not had an impact on the daphnids in Rutland to date. Total iron concentrations fluctuated throughout 1992 between 0-0.5mgl^{-1}, but through a narrower range in 1993 of 0-0.2mgl^{-1}. NRA data from 1990 onwards showed iron levels ranged between0.1-17.5 mgl-1, although values above 0.1mgl^{-1} were rarely detected, and did not vary significantly between sites in the reservoir. This suggested that iron is rapidly dispersed within the water column, despite the appearance of an orange plume at the inlet sites where dosing occurs.

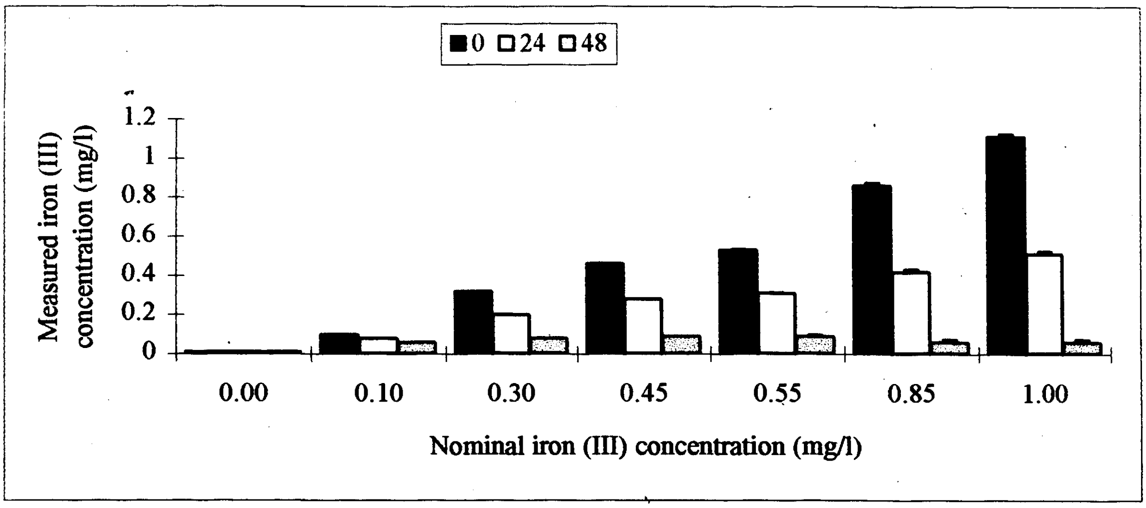


Figure 1 Dissolved iron concentration in acute tests over 48 hours (95% error bars)

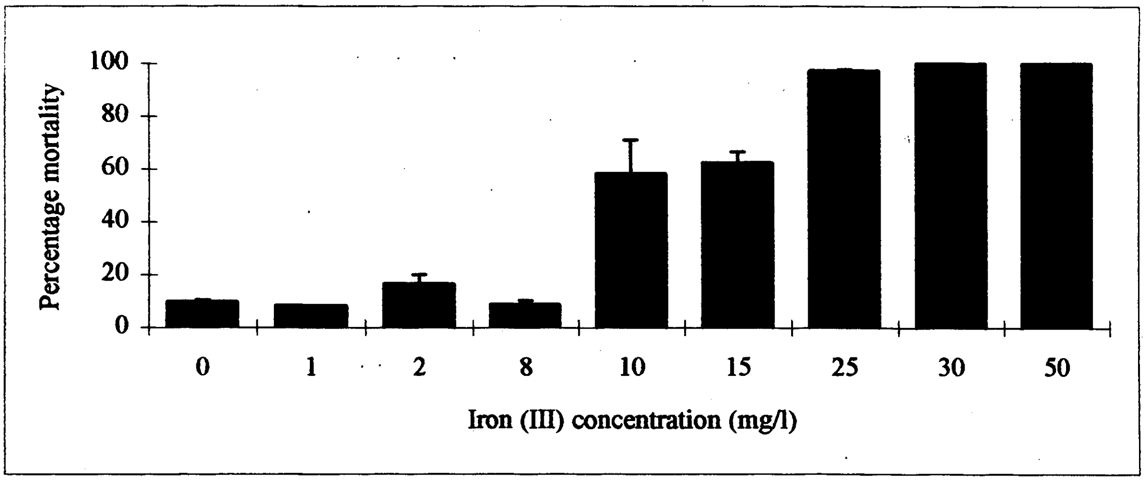


Figure 2 Percentage mortality in particulate iron (48 hours) (9%% error bars)

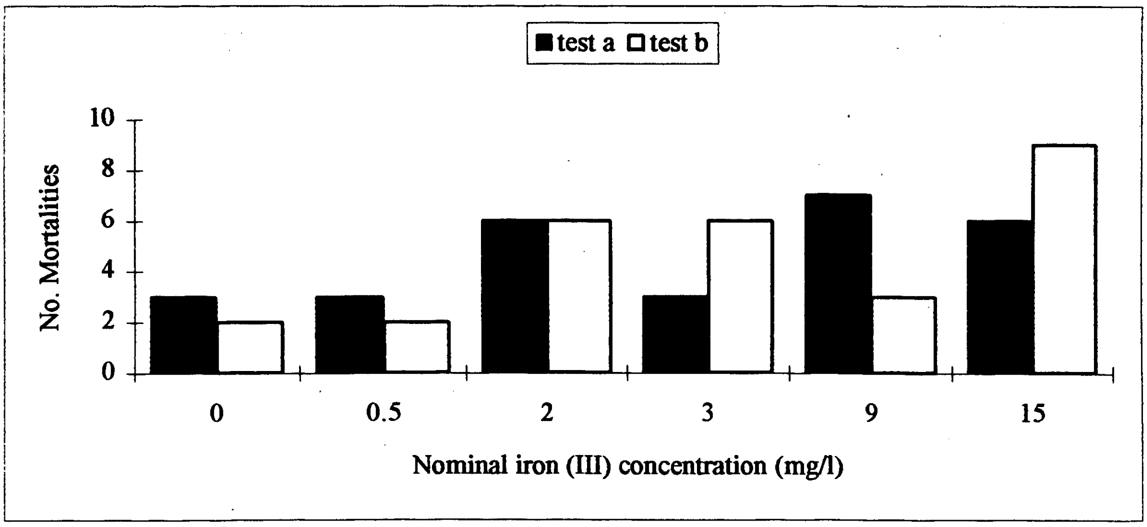


Figure 3 Daphnid mortalities in particulate iron (21 days)

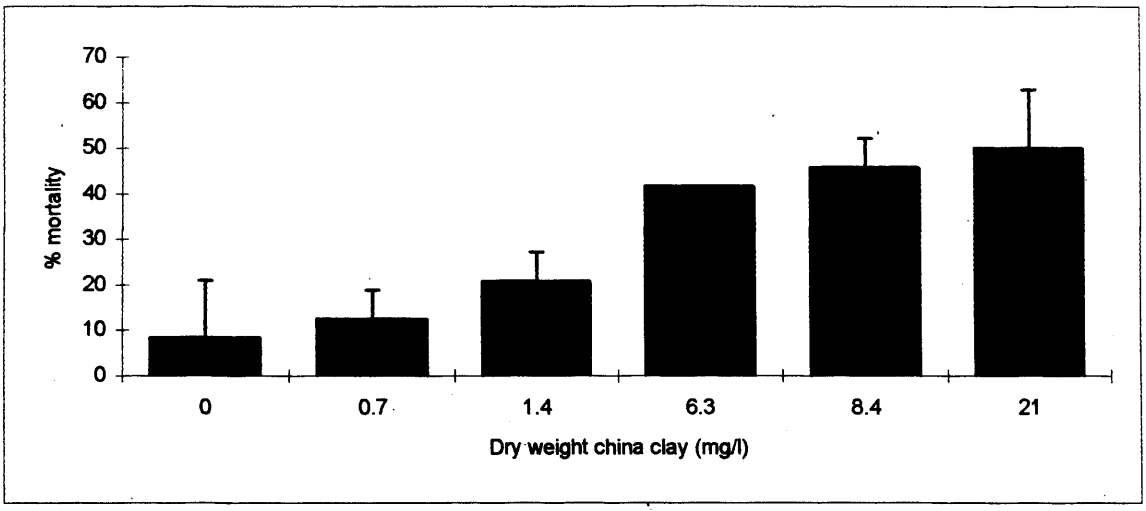


Figure 4 Percentage mortalities in china clay (48 hours) (95% error bars)

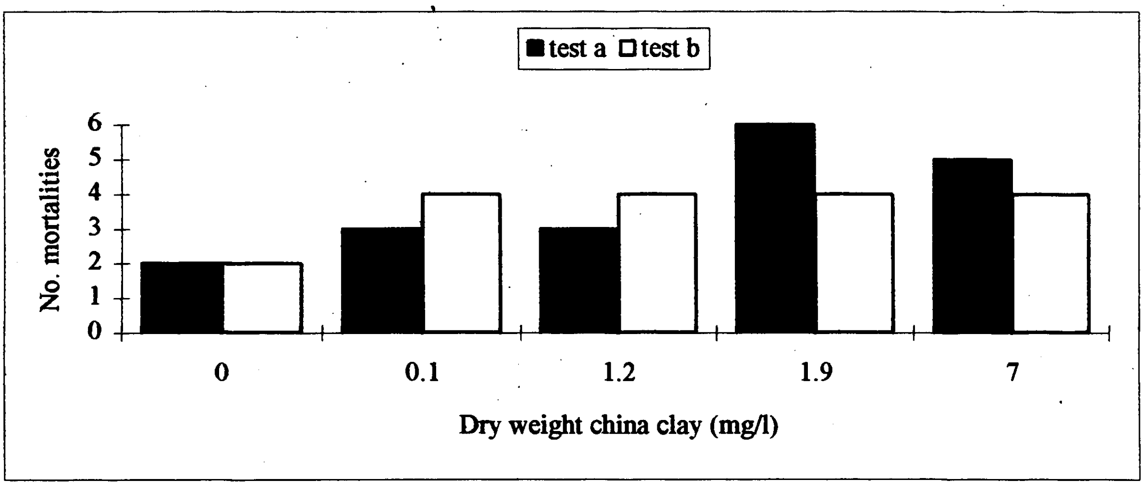


Figure 5 Daphnid mortalities in china clay (21 days) (95% error bars)

Indirect effects - Laboratory studies

Methods

Animals exposed to ferric sulphate or china clay in chronic toxicity tests were collected once mortality occurred or at the end of the test, and preserved in 4% formalin. The filtering area of the third thoracic limb (Figure 6) was calculated from setae length, using the equation:

$$y = 1.879 \cdot x^{1.966}$$

(Egloff & Palmer, 1971; Crittenden, 1981) where y = estimated the area of one comb (mm^2); and x = mean seta length from 5 measured setae (mm). The relationships between standard length (measured from the eye to the base of the tail) and filtering area was then compared to determine whether ferric sulphate precipitates had an impact on morphology of *Daphnia*. Thoracic appendage beat rate was directly observed to determine whether mechanical interference of feeding by the precipitate occurred. *Daphnia* were exposed to the suspended ferric sulphate in a hanging droplet (Figure 7). Video equipment recorded the thoracic appendage rate, and the number of times food was rejected from the food groove.

Results

Effects of ferric sulphate and china clay on filtering area

With increasing concentration of precipitated iron the slope of the data became steeper, suggesting that filtering area increased during the test (Figure 8). Above 1.2mm standard length there was a significant difference between filtering area in ferric of 9mgl-1 and above, compared with the control ($p<0.01$). In china clay as with ferric sulphate, there was an increase in steepness of the data suggesting that the filtering area increased during the test (Figure 9). Above 1.2mm standard length there was a significant difference between the filtering area in china clay concentrations of 7.0mgl-1 dry weight and above compared with a control ($p<0.001$).

Effects of ferric sulphate and china clay on feeding behaviour

The mean number of thoracic beats per minute declined as the concentration of iron precipitate increased (Figure 10). Post-abdominal rejection rate increased above 0.5mgl^{-1} (Figure 11). There was no significant reduction in thoracic beat rate in china clay compared with the control containing no suspended material ($p>0.1$). Cessation of the thoracic beat rate did not occur. The number of post- abdominal rejection rates increased significantly with increasing china clay.

Field investigations

Methods

The total body length (measured from top of head to base of tail) of daphnids within the south arm were expected to increase in size from sites 1-7 (with increasing distance from the inlet). Size distributions from samples collected during 1992-1993 were compared with those of 1979-1980 (Harper & Ferguson, 1982), 1985 (Smith, 1988) and 1990-1991 (Sanderson, pers comm.). Each daphnid was assigned to a size class as used by Thompson et al. (1982), for different instars of Daphnia hyalina (which is the same size as D. longispina, (Hrbacek, 1987)). These were:I = <1.0mm; II = 1.0-1.29mm; III = 1.3-1.59mm; IV = 1.6-1.89mm; V = >1.9mm.The filtering area of the third thoracic limb was measured as in laboratory studies for daphnidscollected from the reservoir over 1992-1993 to determine whether the presence of ferric sulphate precipitates in the reservoir had impacted on the morphology of the filtering apparatus.

Results

The distribution of daphnids within size classes I-V (Thompson et al., 1982) fluctuated over the season for both 1992-1993 as well as the 1985 data sets, although there were no significant trends. The number of daphnids in size classes IV and V decreased significantly between 1980 and 1985, but there were no further changes of significance between 1985 and 1993 (Figure 12). Above standard length 1.2mm there was a significant increase ($p<0.001$) in the filtering area of animals in the south arm compared with animals elsewhere in the reservoir (Figure 13, 14, 15 & 16).

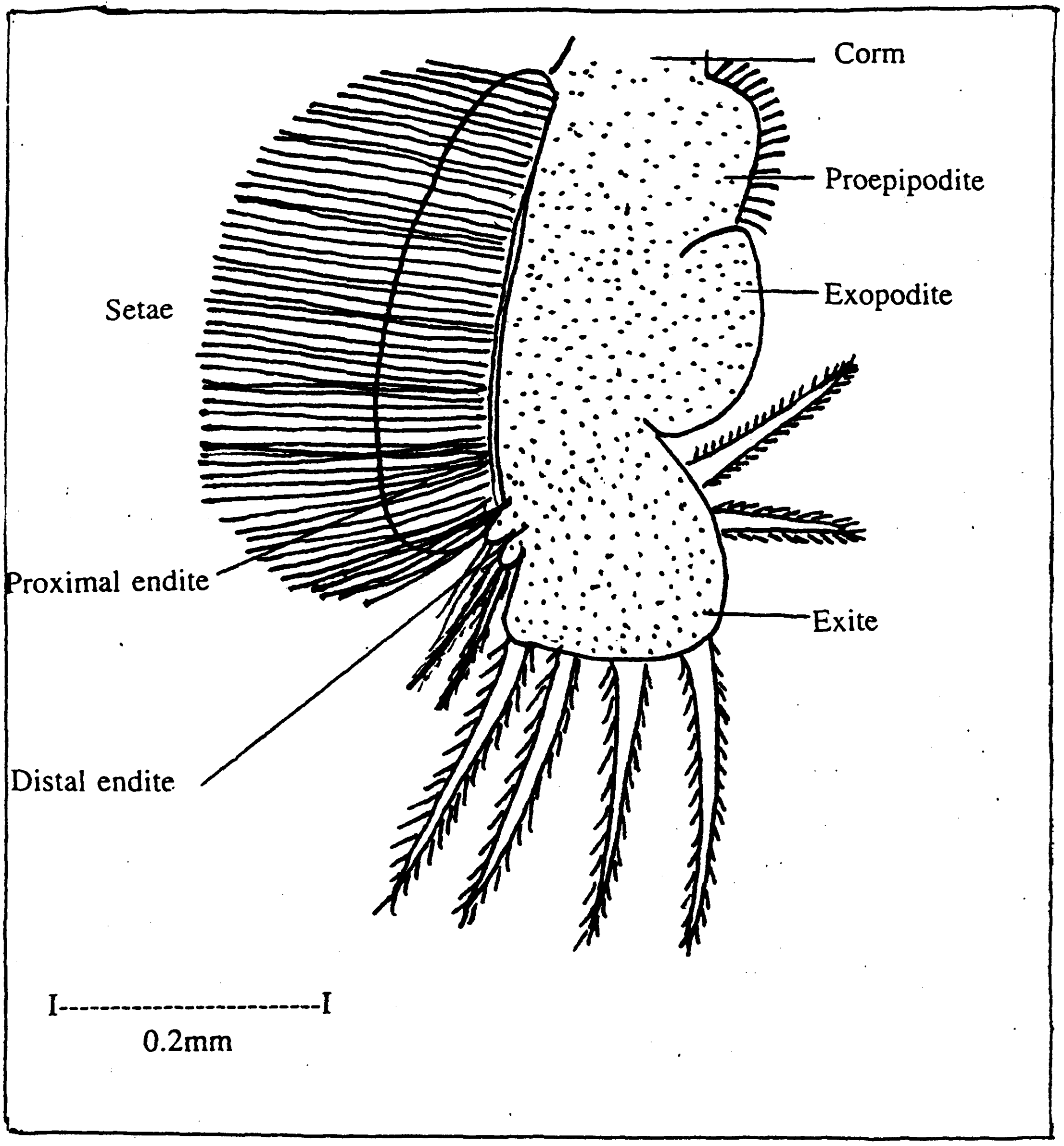


Figure 6 Schematic representation of daphnid third thoracic limb

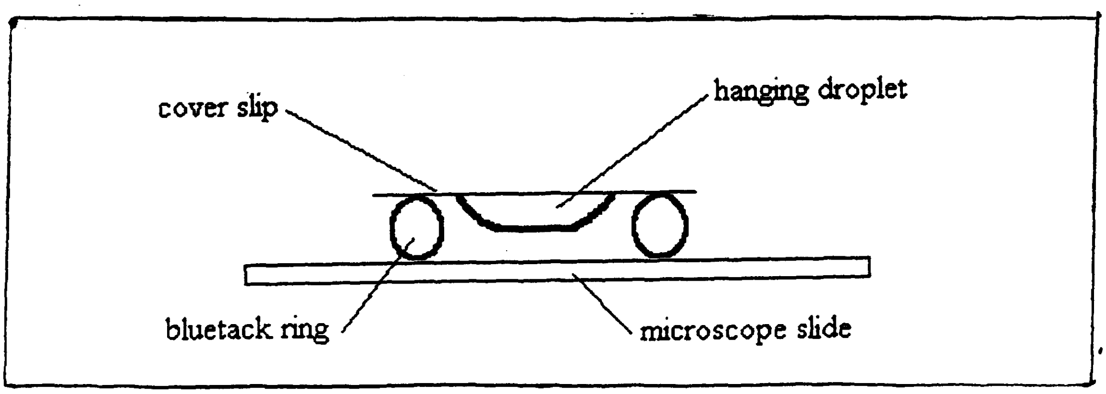


Figure 7 Cross section through hanging droplet

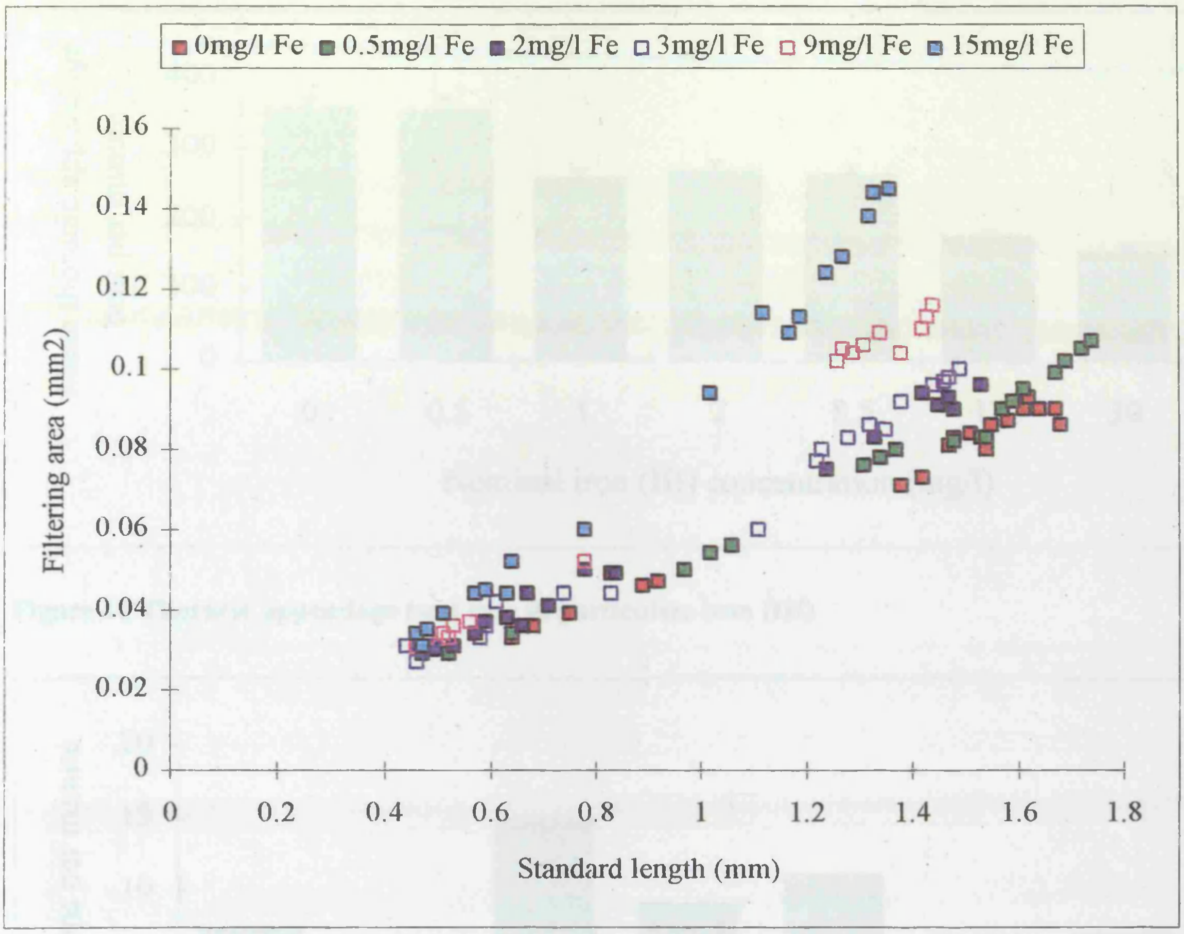


Figure 8 Relationship between standard length an filtering area in iron (III)

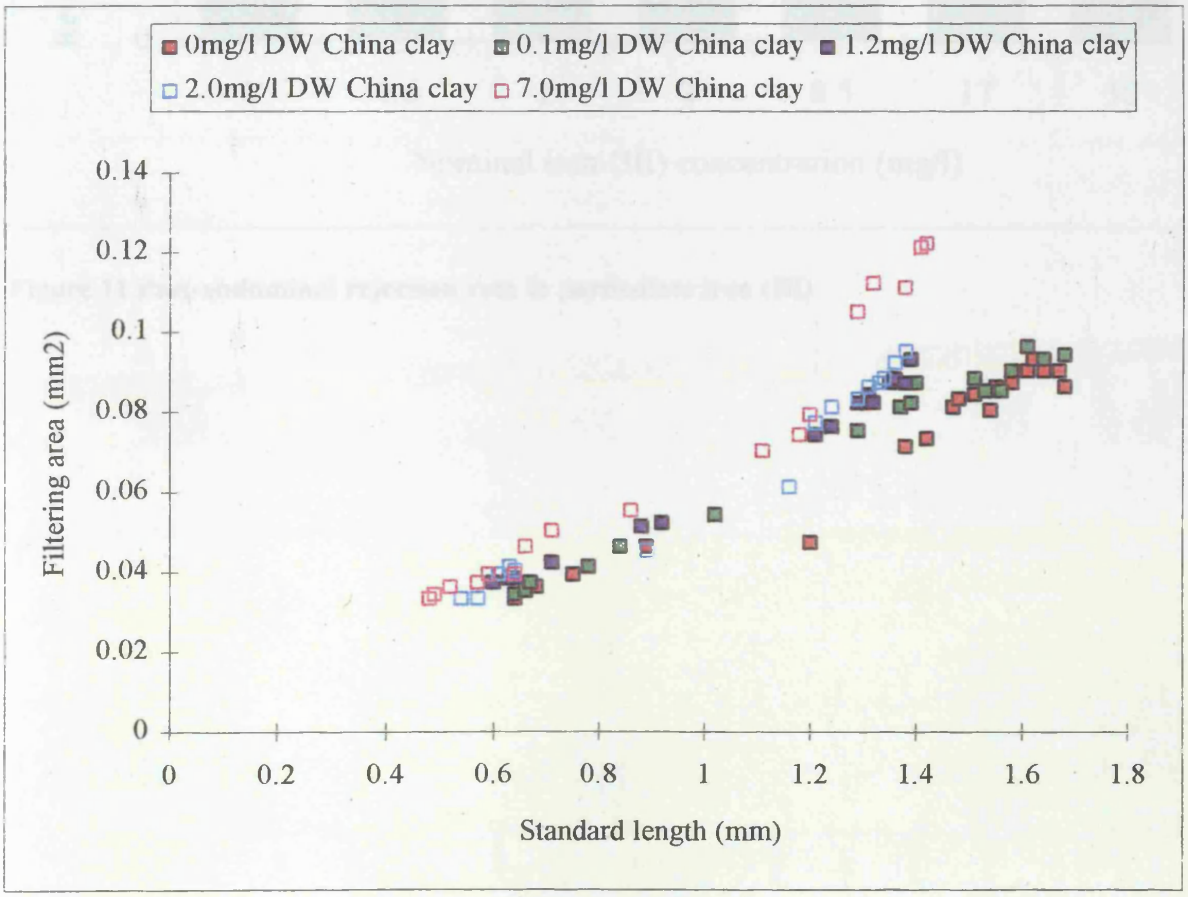


Figure 9 Relationship between standard length and filtering area in china clay

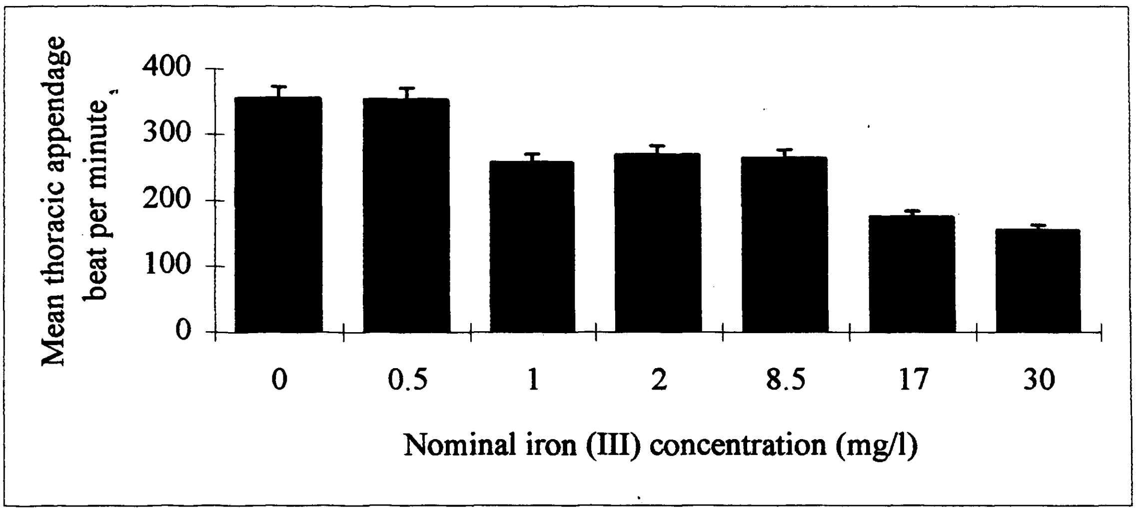


Figure 10 Thoracic appendage beat rate in particulate iron (III)

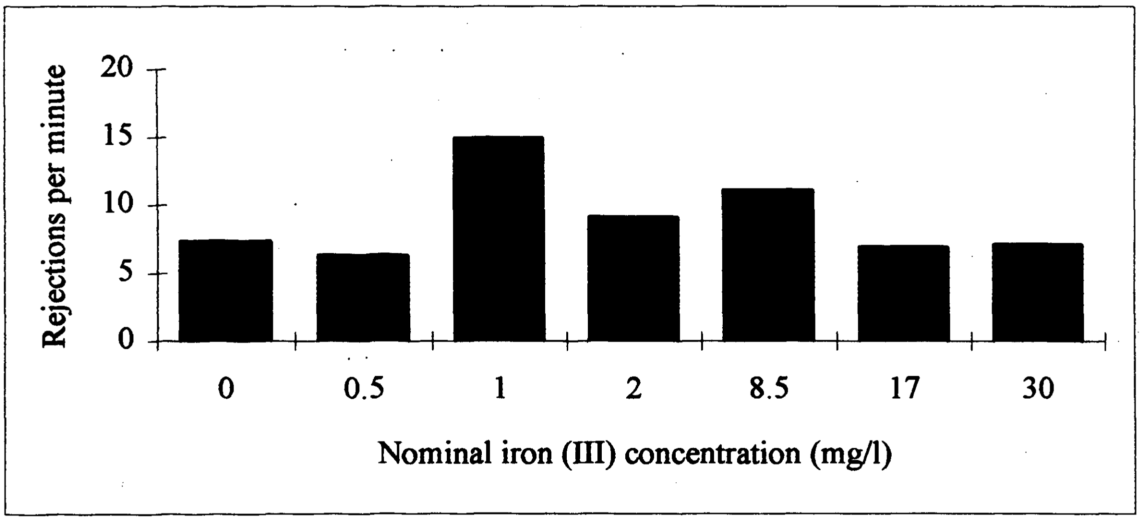


Figure 11 Post-abdominal rejection rate in particulate iron (III)

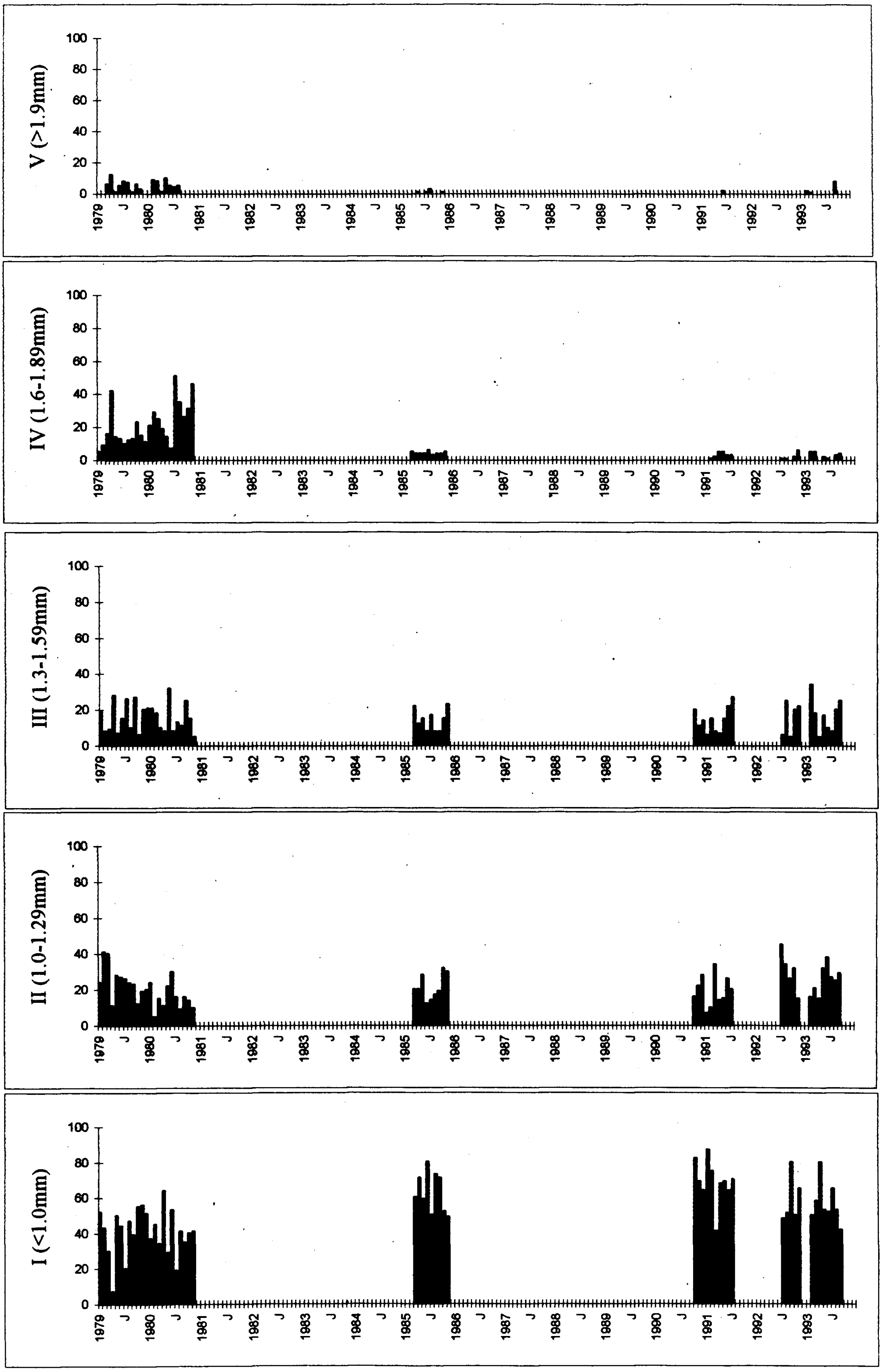


Figure 12 Percentage size distribution of daphnids in Rutland Water 1979-1993

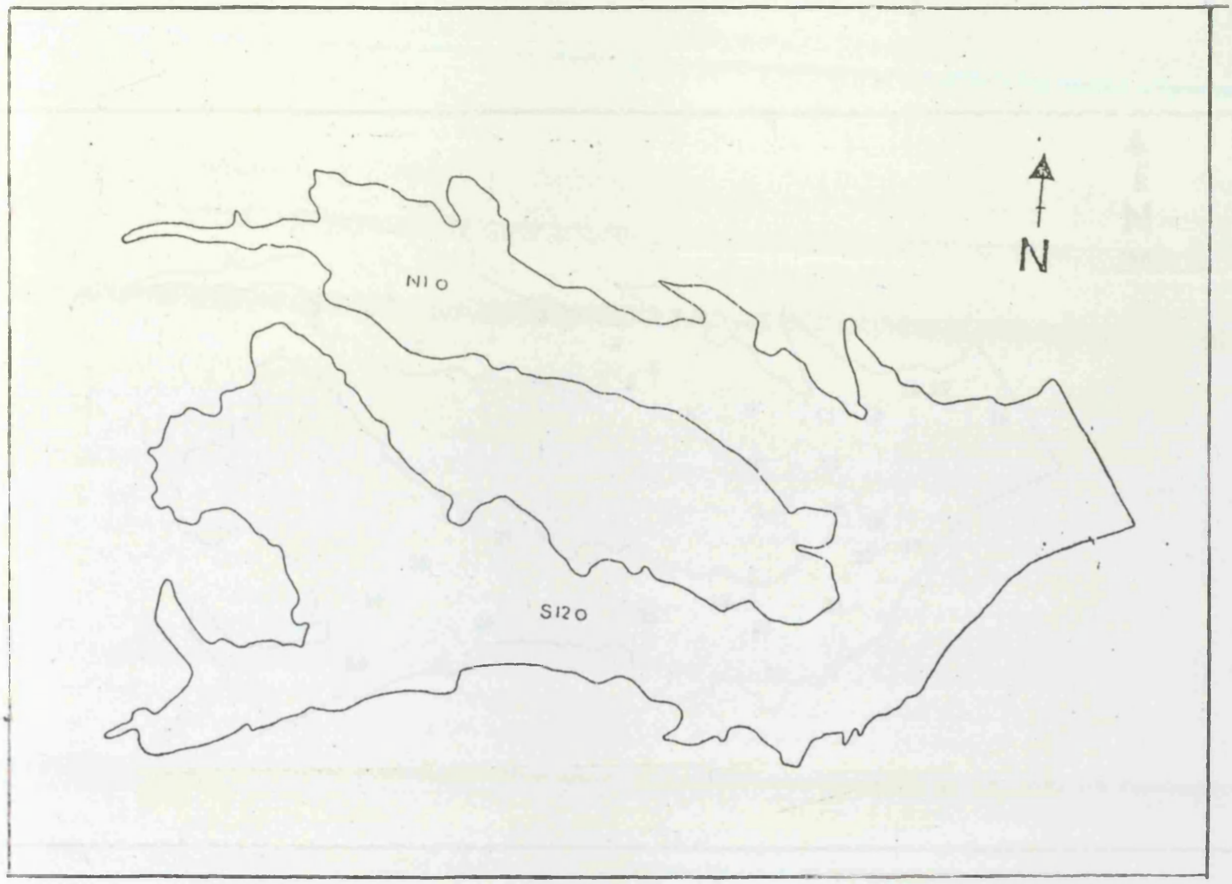


Figure 13 Location of sites N1 and S12

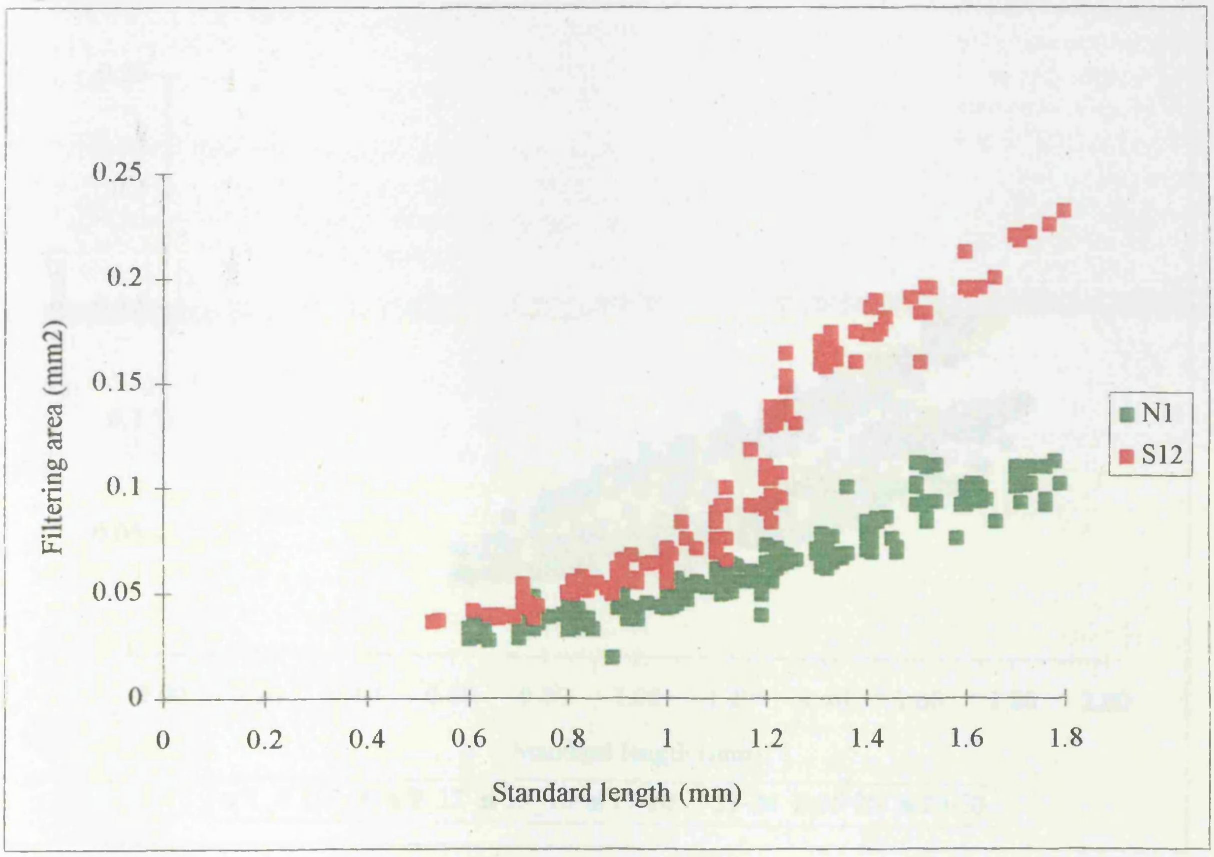


Figure 14 Filtering area of third thoracic limb in Daphnids collected from sites N1 and S12

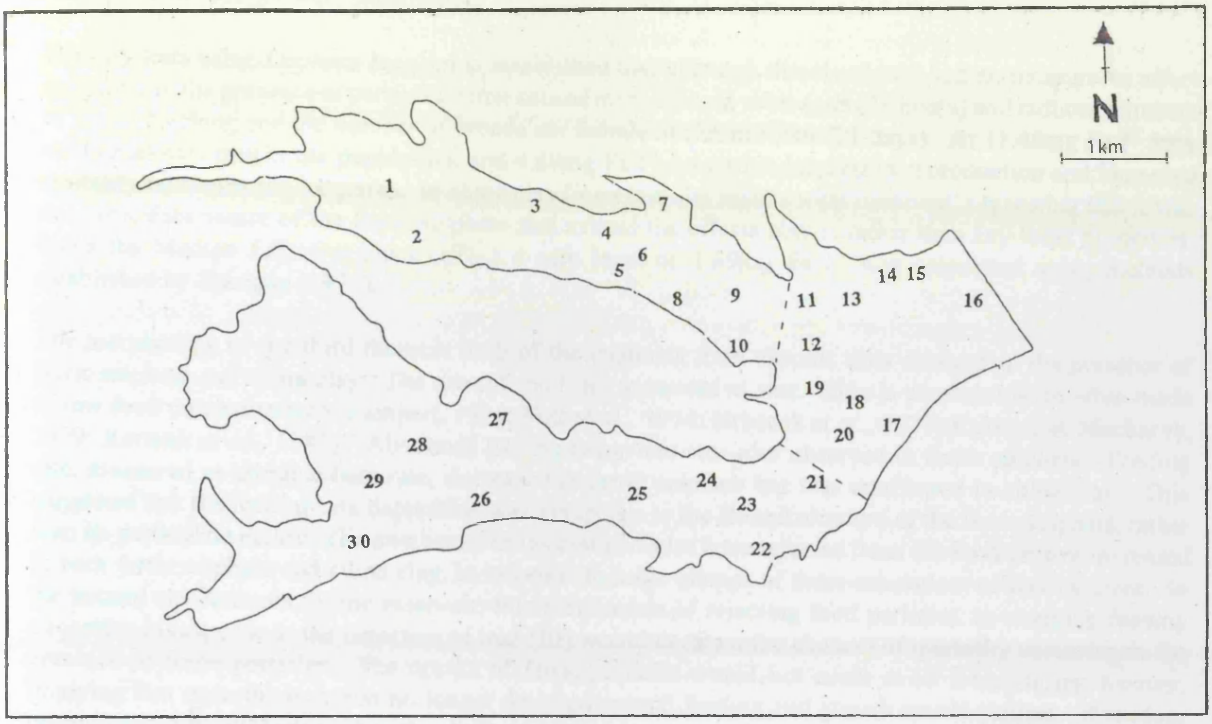


Figure 15 Location of random sampling points

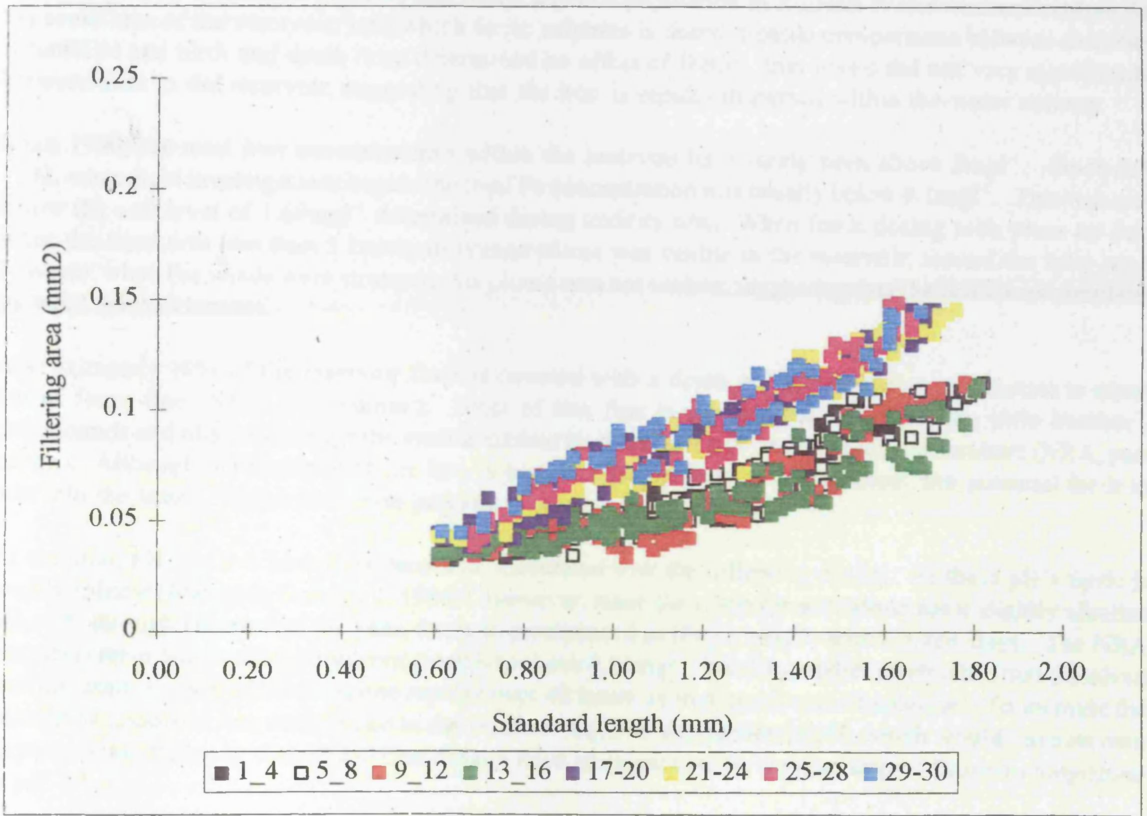


Figure 16 Filter area of third thoracic limbs in Daphnids collected from 30 random sites

Discussion

Through laboratory and field studies, some of the effects of ferric sulphate on the Cladoceran *Daphnia longispina* OF Müller were determined.

Toxicity tests using *Daphnia longispina* established that although dissolved iron had no measurable effect on *Daphnia*, the presence of particulate iron caused mortalities in acute tests (48 hours) and reduced numbers of young hatching and the number of broods per female in chronic tests (21 days). At 11.48mg Fe l^{-1} 50% mortalities occurred in the population, and 4.49mg Fe l^{-1} caused reductions in reproduction and increased mortality rates over the longterm. In china clay (inert) similar results were observed, suggesting that it was the particulate nature of the ferric sulphate that caused the effects above, rather than any toxic properties. From the Median Effective Dose (ED_{50}) a safe level of 1.69mg Fe l^{-1} was calculated using methods established by Sprague (1971).

The morphology of the third thoracic limb of the daphnids from chronic tests changed in the presence of ferric sulphate and china clay. The area of the filter increased in size. This is an observation often made in low food concentrations (Lampert, 1974; Fott et al., 1974; Hrbacek *et al.*, 1979; Korinek & Machacek, 1979; Korinek *et al.*, 1985). Abnormal feeding behaviour was also observed in ferric sulphate. Feeding rate, measured as thoracic beat rate, decreased in ferric sulphate but was unaffected in china clay. This suggested that the feeding rate depression was a response to the chemical nature of the ferric sulphate, rather than its particulate nature. The number of times that particles were rejected from the food groove increased in both ferric sulphate and china clay, in response to large clumps of these substances collecting there. In the natural environment ie. the reservoir, this mechanism of rejecting food particles, or stopping feeding altogether in response to the detection of iron (III) would decrease the chances of mortality occurring in the presence of ferric particles. The uptake of ferric particles would not occur at all times during feeding, implying that once the iron was no longer detected normal feeding and growth would resume. If feeding behaviour ceases altogether, then the daphnid is at risk not only of not taking in enough food to survive, but also of becoming oxygen starved (Lampert, 1987).

Field investigations carried out in Rutland Water found no evidence of deleterious effects by ferric sulphate on the daphnid population. Field studies of the daphnid population in Rutland Water were concentrated in the south arm of the reservoir, into which ferric sulphate is dosed. Spatial comparisons between densities, fecundities and birth and death rates determined no effect of ferric. Iron levels did not vary significantly between sites in the reservoir, suggesting that the iron is rapidly dispersed within the water column.

Since 1990, the total iron concentrations within the reservoir have rarely been above 5mgl^{-1}. Since July 1992, when field investigations began, the total Fe concentration was usually below 0.1mgl^{-1}. This was well below the safe level of 1.69mgl^{-1} determined during toxicity tests. When ferric dosing took place on days when the wind was less than 5 knots, an orange plume was visible in the reservoir, around the inlet zone. however, when the winds were stronger, this plume was not visible, suggesting that the ferric was circulated by wind driven currents.

Approximately 10% of the reservoir floor is covered with a depth of between a few centimetres to about 1m of ferric floc (NRA, pers comm.). Most of this floc is unconsolidated, supporting little benthos - chironomids and oligochaetes are the most abundant invertebrates and occur in reduced numbers (NRA, pers comm). Although the majority of the iron is bound to phosphorus in the sediment, the potential for it to mix into the water column is forever present.

At the inlet, pH's of 2-3 have been recorded, associated with the inflowing dosant. At these pH's ferric is readily soluble (Mance & Campbell, 1988). However, since the reservoir as a whole has a slightly alkaline pH of 8, throughout most of the year, ferric is precipitated as ($Fe_2O_3.nH_2O$) within a few days. The NRA has rarely recorded dissolved iron concentrations above 0.01mgl^{-1}. Toxicity studies established that dissolved iron concentrations at pH 7-8 decline rapidly over 48 hours as iron comes out of solution. To increase the amount of dissolved iron maintained in the medium required a reduction in pH, which would have its own impact on the daphnids. Dissolved iron did not have an impact on the survivorship of *Daphnia longispina* at pH 7-8.

The bottom waters of Rutland are generally oxidised (NRA, pers comm.). Under these conditions, insoluble ferric species are stabilised in colloidal form by the adsorption of natural compounds such as humic and tannic acids, and by inorganic anions such as phosphates and silicates. Dissolved iron occurs principally as Fe(III) as hydrous ferric oxides ($Fe_2O_3.nH_2O$). If the water becomes anoxic, iron is reduced to Fe(II) and exists as aquated species (Martin, 1991). Anoxic conditions are often present in the interstitial waters of the sediment. From these waters dissolved iron species may diffuse into the oxic layer where it is oxidised to iron (III) and is precipitated. As a result, in the absence of stratification, there is no net release of iron to overlying water (Davison & Tipping, 1984).

Raw data from 1985 provided the most recent daphnid population information prior to ferric dosing, and was used for comparison. The current population dynamics and parameters of the daphnid population were not found to differ significantly from those of the 1985 population, suggesting that ferric dosing has not had a significant impact on the daphnid population in Rutland to date. There has been a decline in the size of daphnids in the reservoir since 1980. This is likely to be due to an increase in the biomass of coarse fish in the reservoir, although this factor has not been investigated since the reservoir was constructed.

The filtering area of daphnid populations within the south arm of the reservoir increased in size compared with the filtering area of daphnids in the north arm. This response was observed in ferric sulphate in laboratory as described above. Further analyses are required to determine to what degree ferric was responsible for this morphological change and how much was due to inflowing river water and suspended particles.

Many organisms actively take up iron into their tissues. This uptake has been well studied in *Daphnia* (Smaridge, 1956; Perkins, 1985; Tazima et al., 1975; Hoshi & Kobayashi, 1972), and has been noted to occur at accelerated rates in neutral waters (Yan & Mackie, 1989). Any iron that is taken up by daphnids will be recycled in the food chain. Invertebrate and vertebrate predators that ingest iron with the daphnids, as they feed, and bacteria and protozoans will recycle the iron as daphnids and algal cells decompose. Fish and chironomids are also known to store iron in their tissues (Wong, 1982). *Daphnia* have regulatory structures to process and excrete iron from their bodies, which would limit any damage that elevated levels of this metal might cause (Hoshi & Kobayashi, 1972). It is not known whether fish and other invertebrates have an iron regulatory system. Iron that is ingested will be changed in form by chemical processes in the body, and once excreted and released into the water column may be in a form more easily taken up by algae, and may promote growth. The concentrations recycled in this way are, however, likely to be small.

Conclusions

- Acute toxicity tests (48 hours) on the Cladoceran *Daphnia longispina* established that dissolved iron is not toxic, whereas particulate iron caused 50% mortality above 11.5mg Fe l^{-1}.
- Chronic toxicity tests (21 days) found that long-term exposure led to 50% mortalities in 4.45mg Fe l^{-1}, and reduced the number of young born per clutch, the number of broods per female and increased the time between broods.
- A safe exposure concentration of 1.69mg Fe l-1 was determined, 15% lower than the figure of 2mg Fe l^{-1} established by WRc in 1981.
- Toxicity tests on *Daphnia longispina* conducted using inert, but insoluble china clay, determined similar results to those in ferric sulphate suggesting the particulate nature of ferric caused the mortalities.
- The filtering area of the 3rd thoracic limb increased on exposure to both ferric sulphate and china clay, an adaptation observed in low food concentrations.
- In ferric sulphate, the feeding rate of *Daphnia longispina* decreased, and the number of times that particles were rejected from the food groove increased. Increased rejectionary movements also occurred in china clay, but feeding rate was not suppressed.
- *Daphnia longispina* showed no pattern of distribution within the reservoir between July 1992 and September 1993, that might be associated with ferric dosing at the inlet.

- Population statistics determined during this period were compared with those calculated for the 1985 daphnid population, and found no change in these parameters that could be attributed to the commencement of ferric dosing in 1990.

- Measurement of the third thoracic limb showed an increase in filtering area occurred in *Daphnia* exposed to ferric precipitates in the reservoir during 1992 and 1993.

- There was no evidence to suggest that *Daphnia* in Rutland Water were exposed to levels of iron above the concentrations causing direct toxicity in laboratory investigations - the buffering nature of the reservoir meant that iron was rarely recorded above $0.1 mgl^{-1}$. However, an increase in size of the filtering area suggested prolonged exposure to sublethal concentrations occurred.

References

CRITTENDEN, R.N. (1981). Morphological characteristics and dimensions of the filter structures from three species of *Daphnia* (Cladocera). Crustaceana, 41, 233-248.

DAVISON, W., & TIPPING, E. (1984). Treading in Mortimers footsteps: the geochemical cycling of iron and manganese in Esthwaite Water. 52nd Annual Report Freshwater Biological Associaion, 91-101.

EDMONDSON, W.T. (1968). A graphical model for evaluating the use of the egg ratio for measuring birth and death rates. Oecologia, 1, 1-37.

EGLOFF, D.A., & PALMER, D.S. (1971). Size relations of the filtering areas of two *Daphnia* species. Limnology and Oceanography, 16, 900-905.

ENSERINK, L., LUTTMER, W., & MAAS-DIEPVEEN, H. (1990). Reproductive strategy of *Daphnia magna* affects the sensitivity of its progeny in acute toxicity tests. Aquatic Toxicology, 17, 15-26.

FOTT, J., KORINEK,V., PRAZAKOV'A, M., VODRUS, B., & FOREJT, K. (1974). Seasonal development of phytoplankton in fish ponds. Internationale Revue gesamten Hydrobiologie, 59, 629-664.

GALBRAITH, M.G. (1967). Size-selective predation on *Daphnia* by rainbow trout and yellow perch. Transactions of American Fisheries Society, 96, 1-10.

HARPER, D.M., & FERGUSON, A.J.D. (1982). Zooplankton and their relationships with water quality and fisheries. Hydrobiologia, 88, 135-145.

HOSHI, T., & KOBAYASHI, K. (1972). Studies on physiology and ecology of plankton. XXVI Promotion of haemoglobin synthesis by iron in *Daphnia magna* cultured under low oxygen conditions. Scientific Report of Niigata University, Series D. (Biology), 9, 55-62.

HRBACEK, J. (1987). Systematics and biogeography of *Daphnia* species. Memorie Dell'istituto Italiano Di Idrobiologia, 45, 31-35.

HRBACEK, J., DESORTOV'A, B., & POPOVSKY, J. (1979). Influence of the fish state on the phosphorus - chlorophyll ratio. Verheft Internationale erein Limnologie, 20, 1624-1636.

JONES, M., FOLT, C., & GUARDA, S. (1991). Characterizing individual, population, and community effects of sublethal aquatic toxicants: An experimental case study using *Daphnia.* Freshwater Biology, 26, 35-41.

KORINEK, V., KREPLOVA-MACHACKOVA, B., & MACHACEK, J. (1985). Filtering structures of Cladocera and their ecological significance. II Relation between the concentration of the seston and their size of filtering combs in some species of *Daphnia* and *Ceriodaphnia.* Vestnik Ceskoslovenske Spolecnosti Zoologicke, 50, 244-258.

KORINEK, V., & MACHACEK, J. (1979). Filtering structures of Cladocera and their ecological significance I *Daphnia pulicaria*. Vestnik Ceskoslovenske Spolecnosti Zoologicke, 44, 213-218.

LAMPERT, W. (1974). A method for determining food selection by zooplankton. Limnology and Oceanography, 31, 478-490.

LAMPERT, W. (1987). Laboratory studies on zooplankton - cyanobacteria interactions. New Zealand Journal of Marine and Freshwater Research, 21, 283-490.

LAMPERT, W., & SCHOBER, U. (1980). The importance of 'threshold food concentrations'. In W.C. KERFOOT (Ed.), Evolution and Ecology of Zooplankton Communities (pp. 264-267). University Press, New England.

LITCHFIELD, J.T., & WILCOXEN, F. (1949). A simplified method for evaluating dose-effect experiments. Journal of Pharmacology and Experimental Theory, 96, 99-113.

MANCE, G., & CAMPBELL, J.A. (1988). Proposed Environmental Standards for List II Substances in Water. (Technical Report 258). Water Research Centre, Medmenham, Bucks.

McQUEEN, D.J., & POST, J.R. (1984). Effects of planktivorous fish on zooplankton, phytoplankton, and water chemistry. Proceedings of 4th Annual Conference of NALMS, 35-42.

McQUEEN, J., & POST, J.R. (1986). Trophic relationships in freshwater pelagic ecosystems. Canadian Journal of Fisheries and Aquatic Sciences, 43, 1571-1581.

MILBRINK, G., & BENGTSSON, J. (1991). The impact of size-selective predation on competition between two *Daphnia* species: A laboratory study. Journal of Animal Ecology, 60, 1009-1028.

OECD. (1981). OECD Guidelines for Testing Chemicals. OECD, Paris.

PALOHEIMO, J.E. (1974). Calculation of instantaneous birth rate. Limnology and Oceanography, 19, 692-694.

PATALAS, K. (1954). Comparative studies on a new type of self-acting water sampler for plankton and hydrochemical investigations. Ecologia Polska, 2, 231-242.

PERKINS, P.S. (1985). Iron crystals in the attachment organ of the Erythrophagous copepod *Cardiodectes medusaeus* (Pennellidae). Journal of the Water Pollution Control Federation, 48 (5), 591-605.

PHILLIPOVA, T.G., & POSTNOV, A.L. (1988). Effect of food quantity on feeding and metabolic expenditure in Cladocera. Internationale Revue gesamten Hydrobiologia, 73 (6), 601-615.

RIGLER, J. (1961). The relation between concentrations of food and feeding rate of *Daphnia magna* Straus. Canadian Journal of Zoology, 39, 857-868.

SMARIDGE, M.W. (1956). Distribution of iron in *Daphnia* in relation to haemoglobin synthesis and breakdown. Quarterly Journal of Microscopiacal Science, 97 (2), 205-214.

SMITH, C.D. (1988). Aspects of the Ecology of Crustacean Zooplankton in Rutland Water. PhD. Thesis, University of Leicester.

SPRAGUE, J.B. (1971). Measurement of pollutant toxicity to fish (II) Sublethal effects and 'safe concentrations'. Water Research, 5, 245-266.

TAYLOR, B.E., & SLATKIN, M. (1981). Estimating birth and death rates of zooplankton. Limnology and Oceanography, 26, 143-158.

TAZIMA, I., HOSHI, T., & INOUE, S. (1975). Histological distribution of ferruginous compounds in

Daphnia. Zoological Magazine, 84, 67-70.

THOMPSON, J.M., FERGUSON, A.J.D., & REYNOLDS, C.S. (1982). Natural filtration rates of zooplankton in a closed system: the derivation of a community grazing index. Journal of Plankton Research, 4, 545-560.

URABE, J. (1991). Effect of food concentration on growth, reproduction and survivorship of *Bosmina longirostris* (Cladocera): an experimental study. Freshwater Biology, 25 (1), 1-8.

VAQUE, D., & PACE, M.L. (1992). Grazing on bacteria by flagellates and cladocerans in lakes of contrasting food web structures. Journal of Plankton Research, 14 (2), 307-321.

VIJVERBERG, J. (1989). Culture techniques for studies on the growth, development and reproduction of copepods and cladocerans under laboratory and in situ conditions: a review. Freshwater Biology, 21, 317-373.

WONG, P.J.S., CHAN, Y.K., & PATEL, D. (1982). Physiological and biochemical responses of freshwater algae to a mixture of metals. Chemosphere, II (4), 367-376.

YAN, N.D., MACKIE, G.I., & BOOMER, D. (1989). Chemical and biological correlates of metal levels in crustacean zooplankton from Canadian Shield lakes: A multivariate analysis. The Science of the Total Environment, 87/88, 419-438.

II Data Appendices

II (a) Chemical data for Rutland Water 1980 - 1994

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL IRON	18/06/90	0.050	0.050	0.050		0.050
TOTAL IRON	25/06/90	0.060	0.070	0.070		0.070
TOTAL IRON	02/07/90	0.050	0.050	0.100		0.080
TOTAL IRON	09/07/90	0.050	0.070	0.050		0.050
TOTAL IRON	16/07/90	0.050	0.050	0.050		0.050
TOTAL IRON	23/07/90	0.046	0.069	0.052		0.029
TOTAL IRON	30/07/90	0.060	0.050	0.050		0.050
TOTAL IRON	06/08/90	0.053	0.066	0.055		0.180
TOTAL IRON	13/08/90	0.056	0.061	0.061		0.089
TOTAL IRON	20/08/90	0.065	0.057	0.077		0.057
TOTAL IRON	29/08/90	0.051	0.050	0.050		0.076
TOTAL IRON	03/09/90	0.073	0.088	0.091		0.057
TOTAL IRON	10/09/90	0.050	0.050	0.050		0.064
TOTAL IRON	10/09/90	0.054	0.050	0.054		0.093
TOTAL IRON	18/09/90	0.130	0:110	0.060		0.070
TOTAL IRON	24/09/90	0.100	0.100	0.120		0.100
TOTAL IRON	01/10/90	0.090	0.180	0.110		0.220
TOTAL IRON	08/10/90	0.100	0.090	0.100		0.100
TOTAL IRON	15/10/90	0.050	0.060	0.090		0.090
TOTAL IRON	22/10/90	0.183	0.106	0.114		0.074
TOTAL IRON	29/10/90	0.050	0.210	0.050		0.150
TOTAL IRON	05/11/90		0.106	0.118		0.074
TOTAL IRON	12/11/90	0.226	0.167	0.199		0.110
TOTAL IRON	19/11/90	0.175	0.121	5.060		0.146
TOTAL IRON	26/11/90	0.148	0.145	0.125		0.212
TOTAL IRON	03/12/90	0.110	0.180	0.160		0.130
TOTAL IRON	12/12/90	0.250	0.270			
TOTAL IRON	17/12/90	0.360	0.580	0.360		0.410
TOTAL IRON	07/01/91	0.050	0.050			0.050
TOTAL IRON	14/01/91	0.150	0.130	0.270		0.270
TOTAL IRON	21/01/91	0.180	0.140	0.290		0.170
TOTAL IRON	28/01/91	0.140	0.110	0.180		0.170
TOTAL IRON	04/02/91	0.130	0.090	0.140		0.110
TOTAL IRON	20/02/91	0.160	17.500	0.330		0.170
TOTAL IRON	25/02/91	0.220	0.160	0.200		0.230
TOTAL IRON	04/03/91	0.120	0.110	0.290		0.570
TOTAL IRON	11/03/91	0.130	0.090	0.090		0.110
TOTAL IRON	18/03/91	0.110	0.120	0.160		0.120
TOTAL IRON	26/03/91	0.120	0.100	0.160		0.150
TOTAL IRON	03/04/91	0.070	0.110			0.080
TOTAL IRON	08/04/91	0.060	0.070			0.080
TOTAL IRON	16/04/91	0.120	0.060	0.110		0.200
TOTAL IRON	22/04/91	0.070	0.070	0.100		0.100
TOTAL IRON	30/04/91	0.080	0.030	0.090		0.100
TOTAL IRON	07/05/91	0.070	0.070	0.080		0.130
TOTAL IRON	13/05/91	0.060	0.060	0.190		0.070
TOTAL IRON	20/05/91	0.070	0.050	0.150		0.050
TOTAL IRON	28/05/91	0.050	0.040	0.070		0.120
TOTAL IRON	03/06/91	0.070	0.080	0.320		0.030
TOTAL IRON	10/06/91	0.030	0.030	0.070		0.030
TOTAL IRON	17/06/91	0.080	0.040	0.220		0.060
TOTAL IRON	24/06/91	0.030	0.040	0.100		0.070
TOTAL IRON	01/07/91	0.030	0.040	0.210		0.130
TOTAL IRON	08/07/91	0.030	0.040	0.070		0.080
TOTAL IRON	15/07/91	0.030	0.030	0.050		0.030

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL IRON	22/07/91	0.070	0.070	0.040		0.030
TOTAL IRON	29/07/91	0.030	0.030	0.030		0.030
TOTAL IRON	05/08/91	0.030	0.030	0.030		0.030
TOTAL IRON	12/08/91	0.030	0.050	0.040		0.030
TOTAL IRON	20/08/91	0.050	0.030	0.040		0.030
TOTAL IRON	27/08/91	0.030	0.030	0.030		0.030
TOTAL IRON	02/09/91	0.040	0.040	0.040		0.040
TOTAL IRON	09/09/91	0.050	0.030	0.030		0.030
TOTAL IRON	16/09/91	0.030	0.030	0.030		0.030
TOTAL IRON	25/09/91	0.040	0.040			0.030
TOTAL IRON	02/10/91	0.060	0.090	0.180		0.120
TOTAL IRON	07/10/91	0.030	0.030	0.030		0.030
TOTAL IRON	14/10/91	0.030	0.050	0.040		0.030
TOTAL IRON	21/10/91	0.070	0.030	0.050		0.035
TOTAL IRON	28/10/91	0.030	0.030	0.030		0.030
TOTAL IRON	04/11/91	0.030	0.030	0.030		0.030
TOTAL IRON	11/11/91	0.100	0.110	0.290		0.110
TOTAL IRON	18/11/91	0.060	0.030	0.090		0.030
TOTAL IRON	25/11/91	0.040	0.050	0.070		0.040
TOTAL IRON	02/12/91	0.030	0.057	0.030		0.030
TOTAL IRON	10/12/91	0.140	0.100	0.070		0.130
TOTAL IRON	17/12/91	0.120	0.050	0.100		0.070
TOTAL IRON	30/12/91	0.090	0.090	0.240		0.100
TOTAL IRON	07/01/92	0.070	0.080	0.300		0.080
TOTAL IRON	13/01/92	0.150	0.110	0.180		0.060
TOTAL IRON	20/01/92	0.030	0.030	0.030		0.030
TOTAL IRON	27/01/92	0.069	0.038	0.150		0.069
TOTAL IRON	03/02/92	0.090	0.040	0.210		0.130
TOTAL IRON	10/02/92	0.071	0.030	0.324		0.097
TOTAL IRON	17/02/92	0.120	0.130	0.350		0.140
TOTAL IRON	24/02/92	0.056	0.065	0.249		0.144
TOTAL IRON	02/03/92	0.040	0.040	0.120		0.080
TOTAL IRON	09/03/92	0.030	0.030	0.110		0.060
TOTAL IRON	16/03/92	0.030	0.030	0.030		0.030
TOTAL IRON	23/03/92	0.051	0.045	0.082		0.049
TOTAL IRON	30/03/92	0.080	0.081	0.099		0.095
TOTAL IRON	06/04/92	0.081	0.054	0.096		0.058
TOTAL IRON	21/04/92	0.035	0.048	0.093		0.053
TOTAL IRON	29/04/92	0.065	0.073	0.220		0.119
TOTAL IRON	05/05/92	0.063	0.030	0.080	1.880	0.030
TOTAL IRON	11/05/92	0.053	0.040	0.139	0.819	0.041
TOTAL IRON	18/05/92	0.067	0.030	0.122	0.059	0.121
TOTAL IRON	26/05/92	0.035	0.030	0.030	0.030	0.030
TOTAL IRON	01/06/92	0.052	0.030	0.030	0.102	0.030
TOTAL IRON	09/06/92	0.055	0.039	0.032	2.120	0.080
TOTAL IRON	15/06/92	0.030	0.030	0.030		0.030
TOTAL IRON	22/06/92	1.740	0.032	0.030		0.030
TOTAL IRON	29/06/92	0.035	0.030	0.030		0.030
TOTAL IRON	06/07/92	0.030	0.031	0.050	4.330	0.066
TOTAL IRON	13/07/92	0.030	0.030	0.045	5.950	0.055
TOTAL IRON	20/07/92	0.030	0.030	0.069	1.680	0.030
TOTAL IRON	27/07/92	0.030	0.030	0.078	0.128	0.030
TOTAL IRON	03/08/92	0.030	0.044	0.060	0.079	0.048
TOTAL IRON	10/08/92	0.030	0.030	0.077	0.058	0.030
TOTAL IRON	17/08/92	0.030	0.051	0.084	0.274	0.046
TOTAL IRON	24/08/92	0.030	0.030	0.030	0.055	0.030

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL IRON	01/09/92	0.030	0.030	0.125	0.176	0.052
TOTAL IRON	07/09/92	0.030	0.030	0.066	3.030	0.030
TOTAL IRON	14/09/92	0.030	0.030	0.068	0.036	0.033
TOTAL IRON	21/09/92	0.030	0.030	0.030	0.916	0.030
TOTAL IRON	28/09/92		0.030	0.093	0.180	0.030
TOTAL IRON	05/10/92	0.099	0.048	0.079	0.422	0.084
TOTAL IRON	12/10/92	0.030	0.030	0.035	0.072	0.045
TOTAL IRON	19/10/92	0.030	0.043	0.061	0.042	0.056
TOTAL IRON	26/10/92	0.030	0.030	0.060	0.080	0.060
TOTAL IRON	03/11/92	0.030	0.030	0.094	0.120	0.072
TOTAL IRON	09/11/92	0.036	0.030	0.132	0.062	0.033
TOTAL IRON	16/11/92	0.064	0.108	0.068		
TOTAL IRON	23/11/92	0.030	0.030	0.030	0.030	0.030
TOTAL IRON	03/12/92	0.051	0.067	0.141		0.076
TOTAL IRON	07/12/92	0.034	0.030	0.077	0.053	0.030
TOTAL IRON	14/12/92	0.230	0.486	0.104	0.134	0.084
TOTAL IRON	04/01/93	0.037	0.030	0.034	0.065	0.040
TOTAL IRON	18/01/93	0.090	0.081	0.110	0.103	0.081
TOTAL IRON	25/01/93	0.063		0.176	0.103	0.104
TOTAL IRON	01/02/93	0.044	0.049	0.056	0.043	0.053
TOTAL IRON	08/02/93	0.047		0.065	0.112	0.042
TOTAL IRON	15/02/93	0.059		0.054	0.338	0.058
TOTAL IRON	22/02/93	0.030		0.043	0.051	0.030
TOTAL IRON	01/03/93	0.063		0.039	0.076	0.128
TOTAL IRON	08/03/93	0.030		0.031	0.030	0.030
TOTAL IRON	15/03/93	0.045		0.030	0.030	0.030
TOTAL IRON	22/03/93	0.030		0.030	0.030	0.030
TOTAL IRON	29/03/93	0.030		0.030	0.030	0.030
TOTAL IRON	05/04/93	0.030		0.037	0.065	0.031
TOTAL IRON	13/04/93	0.055		0.062	0.101	0.043
TOTAL IRON	19/04/93	0.030		0.050	0.071	0.030
TOTAL IRON	26/04/93	0.055		0.037	0.062	0.044
TOTAL IRON	04/05/93	0.030		0.066	2.100	0.030
TOTAL IRON	10/05/93	0.037		0.044	0.030	0.066
TOTAL IRON	17/05/93	0.030		0.030	0.030	0.030
TOTAL IRON	24/05/93	0.030		0.030	0.030	0.030
TOTAL IRON	01/06/93	0.032		0.039	1.900	0.040
TOTAL IRON	07/06/93	0.030		0.030	0.058	0.030
TOTAL IRON	14/06/93	0.031		0.050	0.120	0.034
TOTAL IRON	21/06/93	0.030		0.053	0.031	0.030
TOTAL IRON	28/06/93	0.036		0.030	0.030	0.030
TOTAL IRON	05/07/93	0.030		0.030	0.030	0.030
TOTAL IRON	12/07/93	0.030		0.030	0.030	0.030
TOTAL IRON	19/07/93	0.030		0.030	0.030	0.030
TOTAL IRON	26/07/93	0.045	0.030	0.056	0.057	0.030
TOTAL IRON	02/08/93	0.030	0.030	0.030	0.030	0.030
TOTAL IRON	09/08/93	0.066	0.159	0.041	0.060	0.030
TOTAL IRON	16/08/93	0.030	0.030	0.030	0.030	0.030
TOTAL IRON	23/08/93	0.081	0.043	0.057	0.140	0.051
TOTAL IRON	31/08/93	0.030	0.030	0.030	0.030	0.030
TOTAL IRON	06/09/93	0.030	0.030	0.030	0.042	0.030
TOTAL IRON	13/09/93	0.093	0.087	0.071	0.085	0.064
TOTAL IRON	20/09/93	0.048	0.048		0.070	0.074
TOTAL IRON	27/09/93	0.059		0.068		
TOTAL IRON	04/10/93	0.057	0.038	0.049	0.063	0.047
TOTAL IRON	11/10/93	0.030	0.030	0.037	0.030	0.030

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL IRON	19/10/93	0.043	0.084	0.049	0.064	0.047
TOTAL IRON	25/10/93	0.030	0.030	0.030	0.030	0.030
TOTAL IRON	01/11/93	0.030	0.036	0.035	0.129	0.032
TOTAL IRON	08/11/93	0.046	0.031	0.038	0.044	0.049
TOTAL IRON	15/11/93	0.099	0.099	0.146	0.396	0.071
TOTAL IRON	22/11/93	0.043	0.033	0.061	0.068	0.042
TOTAL IRON	29/11/93	0.098		0.066		0.037
TOTAL IRON	06/12/93	0.083	0.063	0.075	0.084	0.044
TOTAL IRON	13/12/93	0.085	0.077	0.123	0.513	0.076
TOTAL IRON	20/12/93	0.091	0.080	0.122	0.219	
TOTAL IRON	10/01/94	0.130	0.120	0.240	0.210	0.150
TOTAL IRON	17/01/94			0.120	0.120	0.090
TOTAL IRON	24/01/94		0.100	0.110	0.140	0.100
TOTAL IRON	07/02/94		0.140	0.210	0.840	0.110
TOTAL IRON	07/03/94		0.110	0.150	0.120	0.110
TOTAL IRON	15/03/94		0.030	0.190	0.250	0.180
TOTAL IRON	28/03/94	0.180	0.110	0.120	0.140	0.100
TOTAL IRON	05/04/94	0.120	0.080	0.100	0.060	0.100
TOTAL IRON	11/04/94	0.070	0.080	0.050	0.070	0.040
TOTAL IRON	18/04/94	0.090			0.400	
TOTAL IRON	25/04/94	0.070	0.040	0.070	0.030	0.190
TOTAL IRON	03/05/94	0.030		0.080		
TOTAL IRON	09/05/94	0.050	0.030	0.050	0.040	0.030
TOTAL IRON	16/05/94	0.060	0.060	0.060	0.120	0.050
TOTAL IRON	31/05/94	0.030	0.030	0.050	0.060	0.040
TOTAL IRON	06/06/94	0.060	0.040	0.060	0.300	0.130
TOTAL IRON	13/06/94	0.060	0.040	0.040	0.060	0.030
TOTAL IRON	20/06/94	0.030	0.040	0.040	0.040	0.390
TOTAL IRON	27/06/94	0.050	0.030	0.030	0.030	0.030
TOTAL IRON	04/07/94	0.060	0.060	0.040	0.040	0.060
TOTAL IRON	11/07/94	0.050	0.040	0.030	0.030	0.030
TOTAL IRON	18/07/94	0.070	0.050	0.050	0.070	0.090
TOTAL IRON	25/07/94	0.070	0.040	0.050	0.030	0.030
TOTAL IRON	01/08/94	0.040	0.030	0.030	0.030	0.030
TOTAL IRON	08/08/94	0.040	0.030	0.030	0.060	0.030
TOTAL IRON	15/08/94	0.030	0.030	0.060	0.060	0.060
TOTAL IRON	22/08/94	0.030	0.030	0.030	0.040	0.030
TOTAL IRON	05/09/94	0.500	0.500	0.500	0.500	0.500
TOTAL IRON	12/09/94	0.030	0.030	0.060	0.040	0.040
TOTAL IRON	19/09/94	0.030	0.040	0.060	0.050	0.060
TOTAL IRON	26/09/94	0.040	0.040	0.060	0.550	0.060
TOTAL IRON	03/10/94	0.050	0.050	0.080	0.150	0.050
TOTAL IRON	10/10/94	0.050	0.030	0.040	0.030	0.040
TOTAL IRON	17/10/94	0.090	0.060	0.060	0.390	0.090
TOTAL IRON	24/10/94	0.080	0.060	0.100	0.090	0.050
TOTAL IRON	31/10/94	0.060	0.040	0.090	0.100	0.060
TOTAL IRON	07/11/94	0.070	0.090	0.070	0.050	0.320
TOTAL IRON	14/11/94	0.150	0.090	0.150	0.200	0.080
TOTAL IRON	21/11/94	0.050	0.050	0.060	0.190	0.050
TOTAL IRON	28/11/94	0.070	0.050	0.080		0.060
TOTAL IRON	05/12/94	0.110	0.060	0.150	0.110	0.090
TOTAL IRON	12/12/94	0.130	0.190	0.200	0.210	0.130
TOTAL IRON	19/12/94	0.090	0.080	0.170	0.230	0.180
SULPHATE	13/04/93	168.000		172.000	169.000	172.000
SULPHATE	19/04/93	172.000		171.000	171.000	173.000
SULPHATE	26/04/93	172.000		169.000	170.000	170.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
SULPHATE	04/05/93	165.000		169.000	169.000	168.000
SULPHATE	10/05/93	171.000		170.000	175.000	171.000
SULPHATE	17/05/93	190.000		191.000	192.000	190.000
SULPHATE	24/05/93	174.000		173.000	173.000	177.000
SULPHATE	01/06/93	170.000		170.000	171.000	171.000
SULPHATE	07/06/93	181.000		182.000	171.000	171.000
SULPHATE	14/06/93	167.000		167.000	164.000	168.000
SULPHATE	21/06/93	165.000		162.000	163.000	166.000
SULPHATE	28/06/93	174.000		165.000	166.000	167.000
SULPHATE	05/07/93	162.000		165.000	167.000	165.000
SULPHATE	12/07/93	165.000		171.000	169.000	170.000
SULPHATE	19/07/93	179.000		165.000	175.000	175.000
SULPHATE	26/07/93	160.000	163.000	168.000	169.000	164.000
SULPHATE	02/08/93	158.000	158.000	159.000	159.000	159.000
SULPHATE	09/08/93	155.000	157.000	162.000	152.000	161.000
SULPHATE	16/08/93	159.000	161.000	162.000	163.000	161.000
SULPHATE	23/08/93	173.000	169.000	175.000	174.000	173.000
SULPHATE	31/08/93	159.000	160.000	150.000	158.000	162.000
SULPHATE	06/09/93	168.000	164.000	164.000	164.000	167.000
SULPHATE	13/09/93	162.000	162.000	163.000	162.000	163.000
SULPHATE	20/09/93	163.000	165.000		164.000	162.000
SULPHATE	27/09/93	164.000		164.000		
SULPHATE	04/10/93	161.000	163.000	162.000	164.000	164.000
SULPHATE	11/10/93	168.000	165.000	162.000	165.000	166.000
SULPHATE	19/10/93	166.000	165.000	164.000	164.000	166.000
SULPHATE	25/10/93	164.000	166.000	165.000	167.000	165.000
SULPHATE	01/11/93	163.000	163.000	162.000	155.000	165.000
SULPHATE	08/11/93	163.000	171.000	169.000	167.000	170.000
SULPHATE	15/11/93	165.000	163.000	163.000	154.000	159.000
SULPHATE	22/11/93	152.000	153.000	155.000	153.000	146.000
SULPHATE	29/11/93	158.000		157.000		159.000
SULPHATE	06/12/93	154.000	155.000	152.000	154.000	155.000
SULPHATE	13/12/93	154.000	154.000	152.000	148.000	155.000
SULPHATE	20/12/93	143.000	146.000	143.000	142.000	146.000
SULPHATE	10/01/94	163.000	164.000	161.000	155.000	156.000
SULPHATE	17/01/94	159.000		155.000	156.000	158.000
SULPHATE	24/01/94		163.000	162.000	165.000	160.000
SULPHATE	31/01/94		167.000	165.000	163.000	165.000
SULPHATE	07/02/94		161.000	159.000	157.000	160.000
SULPHATE	21/02/94		157.000	156.000	157.000	158.000
SULPHATE	01/03/94		153.000	153.000	156.000	155.000
SULPHATE	07/03/94		157.000	155.000	155.000	155.000
SULPHATE	21/03/94		154.000	155.000	151.000	154.000
SULPHATE	28/03/94	151.000	150.000	151.000	150.000	151.000
SULPHATE	05/04/94	160.000	160.000	160.000	159.000	160.000
SULPHATE	18/04/94	153.000	154.000	151.000	149.000	152.000
SULPHATE	25/04/94	153.000	154.000	152.000	400.000	409.000
SULPHATE	03/05/94	154.000	153.000	154.000	155.000	160.000
SULPHATE	09/05/94	159.000	160.000	157.000	160.000	
SULPHATE	16/05/94	148.000	150.000	150.000	153.000	148.000
SULPHATE	23/05/94	153.000	154.000	154.000	156.000	154.000
SULPHATE	31/05/94	153.000	152.000	152.000	151.000	153.000
SULPHATE	06/06/94	145.000	144.000	146.000	144.000	143.000
SULPHATE	13/06/94	146.000	146.000	147.000	147.000	146.000
SULPHATE	20/06/94	153.000	151.000	152.000	151.000	151.000
SULPHATE	27/06/94	154.000	149.000	154.000	151.000	152.000

DETERMINAND	DATE	N1	ST	S12	IN	LT
SULPHATE	04/07/94	148.000	147.000	148.000	146.000	142.000
SULPHATE	11/07/94	149.000	150.000	151.000	151.000	151.000
SULPHATE	18/07/94	162.000	164.000	163.000	166.000	18.000
SULPHATE	25/07/94	152.000	154.000	154.000	155.000	154.000
SULPHATE	01/08/94	156.000	156.000	156.000	155.000	157.000
SULPHATE	08/08/94	154.000	154.000	155.000	163.000	164.000
SULPHATE	15/08/94	152.000	147.000	153.000	153.000	151.000
SULPHATE	22/08/94	159.000	160.000	159.000	164.000	164.000
SULPHATE	30/08/94	164.000	163.000	168.000	163.000	165.000
SULPHATE	05/09/94	177.000	166.000	182.000	161.000	144.000
SULPHATE	12/09/94	163.000	159.000	161.000	162.000	159.000
SULPHATE	19/09/94	161.000	160.000	162.000	160.000	161.000
SULPHATE	26/09/94	154.000	154.000	154.000	151.000	153.000
SULPHATE	03/10/94	153.000	145.000	131.000	146.000	142.000
SULPHATE	10/10/94	152.000	152.000	152.000	154.000	154.000
SULPHATE	17/10/94	149.000	150.000	146.000	148.000	147.000
SULPHATE	24/10/94	164.000	164.000	164.000	165.000	163.000
SULPHATE	31/10/94	150.000	153.000	150.000	35.000	151.000
SULPHATE	07/11/94	163.000	148.000	149.000	158.000	147.000
SULPHATE	14/11/94	160.000	160.000	158.000	160.000	161.000
SULPHATE	21/11/94	150.000	155.000	152.000	154.000	153.000
SULPHATE	28/11/94	161.000	161.000	159.000	161.000	164.000
SULPHATE	05/12/94	172.000	179.000	177.000	173.000	176.000
SULPHATE	12/12/94	148.000	149.000	148.000	146.000	149.000
SULPHATE	19/12/94	146.000	145.000	142.000	144.000	146.000
pH	07/04/81	8.230	8.240			8.230
pH	13/04/81	8.300	8.320			8.310
pH	22/04/81	8.390	8.400			8.340
pH	06/05/81	8.360	8.360			8.360
pH	12/05/81	8.350	8.390			8.390
pH	19/05/81	8.580	8.590			8.540
pH	25/05/81	8.300	8.410			8.410
pH	02/06/81	8.270	8.330			8.360
pH	09/06/81	8.140	8.240			8.350
pH	23/06/81	8.330	8.400			8.420
pH	30/06/81	8.280	8.300			8.330
pH	07/07/81	8.410	8.350			8.390
pH	14/07/81	8.320	8.360			8.440
pH	21/07/81					8.320
pH	04/08/81	8.510	8.500			8.450
pH	11/08/81	8.140	8.170			8.260
pH	18/08/81	8.350	8.310			8.390
pH	25/08/81	8.240	8.240			8.290
pH	01/09/81	8.520	8.440			8.380
pH	08/09/81	8.410	8.330			8.400
pH	15/09/81	8.300	8.270			8.290
pH	23/09/81	8.220	8.220			8.190
pH	29/09/81	8.340	8.320			8.300
pH	06/10/81	8.300	8.320			8.210
pH	13/10/81	8.390	8.340			8.320
pH	20/10/81	8.220	8.170			8.120
pH	27/10/81	8.300	8.290			8.310
pH	10/11/81	8.230	8.160			8.250
pH	17/11/81	8.230	8.230			8.250
pH	25/11/81	8.220	8.210			8.190
pH	01/12/81	8.300	8.330			8.330

DETERMINAND	DATE	NI	ST	ST2	IN	LT
pH	09/12/81	8.230	8.180			8.230
pH	05/01/82					8.190
pH	02/02/82	8.150	8.180			8.190
pH	09/02/82	8.210	8.210			8.190
pH	16/02/82	8.250	8.230			8.200
pH	23/02/82	8.200	8.190			8.180
pH	10/03/82	8.220	8.270			8.240
pH	16/03/82	8.200	8.280			8.270
pH	23/03/82	8.300	8.290			8.300
pH	30/03/82	8.280	8.280			8.300
pH	06/04/82	8.340	8.410			8.390
pH	13/04/82	8.450	8.440			8.400
pH	21/04/82	8.560	8.610			8.530
pH	27/04/82	8.440	8.430			8.420
pH	04/05/82	8.270	8.360			8.390
pH	11/05/82	8.410				
pH	18/05/82	8.470	8.500			8.560
pH	02/06/82	8.470	8.530			8.590
pH	08/06/82	8.520	8.460			8.460
pH	16/06/82	8.400	8.420			8.330
pH	29/06/82	8.060	8.180			8.220
pH	06/07/82	8.470	8.430			8.240
pH	14/07/82	8.230	8.250			8.290
pH	20/07/82	8.480	8.420			8.310
pH	27/07/82	8.180	8.230			8.130
pH	03/08/82	8.460	8.530			8.380
pH	10/08/82	8.350	8.340			8.440
pH	17/08/82	8.540	8.480			8.430
pH	24/08/82	8.330	8.340			8.300
pH	31/08/82	8.370	8.330			8.270
pH	07/09/82	8.410	8.280			8.350
pH	14/09/82	8.360	8.330			8.320
pH	22/09/82					8.050
pH	28/09/82	8.400	8.400			8.370
pH	05/10/82	8.350	8.360			8.290
pH	12/10/82	8.310	8.310			8.270
pH	19/10/82	8.310	8.300			8.270
pH	26/10/82	8.310	8.320			8.240
pH	02/11/82	8.270	8.280			8.200
pH	09/11/82	8.240	8.230			8.240
pH	23/11/82	8.240	8.280			8.300
pH	30/11/82	8.290	8.310			8.270
pH	07/12/82	8.210	8.220			8.240
pH	14/12/82	8.180	8.210			8.210
pH	05/01/83	8.160	8.170			8.120
pH	25/01/83	8.490	8.290			8.260
pH	02/02/83	8.670	8.300			8.230
pH	01/03/83	8.540	8.390			8.540
pH	08/03/83	8.540	8.550			8.530
pH	16/03/83	8.480	8.500			8.500
pH	19/04/83	8.410	8.410			8.390
pH	26/04/83	8.290	8.350			8.280
pH	17/05/83	8.310	8.360			8.300
pH	31/05/83	8.210	8.250			8.300
pH	07/06/83	8.390	8.390			8.320
pH	22/06/83	8.430	8.420			8.300

DETERMINAND	DATE	NI	ST	ST2	IN	LT
pH	12/07/83	8.250	8.220			8.150
pH	02/08/83	7.910	7.760			7.780
pH	10/08/83	8.080	8.010			7.840
pH	31/08/83	8.100	8.000			7.980
pH	06/09/83	7.980	7.980			7.950
pH	13/09/83	8.010	7.980			7.960
pH	20/09/83	8.070	8.040			
pH	10/10/83	8.080	8.080			8.020
pH	24/10/83					7.970
pH	07/11/83	7.910	7.930			7.930
pH	21/11/83					7.870
pH	28/11/83	8.210	8.130			8.230
pH	09/01/84	8.200	8.200			8.140
pH	30/01/84					8.180
pH	06/02/84					8.250
pH	13/02/84	8.260	8.280			8.180
pH	20/02/84	8.250	8.290			8.200
pH	08/03/84	8.100				8.010
pH	12/03/84	8.140	8.130			8.150
pH	19/03/84					8.080
pH	02/04/84	8.020	8.030			7.870
pH	09/04/84	8.070	8.050			7.920
pH	16/04/84	8.230	8.210			8.220
pH	14/05/84	8.300	8.310			8.200
pH	21/05/84	8.300	8.270			8.230
pH	04/06/84	8.370	8.370			8.200
pH	11/06/84	8.360	8.380			8.230
pH	18/06/84					8.500
pH	11/07/84	8.370	8.420			8.320
pH	23/07/84	8.130	8.230			8.180
pH	30/07/84	8.150	8.160			8.230
pH	07/08/84	8.050	8.040			8.050
pH	05/09/84					8.240
pH	19/09/84					8.230
pH	08/10/84		8.350			8.230
pH	17/10/84					8.300
pH	30/10/84					8.330
pH	05/11/84	8.280	8.300			8.220
pH	13/11/84	8.210	8.240			8.160
pH	26/11/84	8.190	8.200			8.150
pH	18/12/84		8.300			8.040
pH	18/12/84		8.200			
pH	18/12/84		8.200			
pH	04/02/85					8.080
pH	12/02/85					8.100
pH	19/03/87		8.730			
pH	19/03/87		8.730			
pH	04/06/90		8.590	8.640		8.720
pH	11/06/90		8.650	8.270		8.600
pH	18/06/90	8.350	8.460	8.380		8.360
pH	25/06/90	8.260	8.270	8.130		8.310
pH	02/07/90	8.390	8.370	8.410		8.310
pH	09/07/90	8.210	8.110	8.150		8.190
pH	16/07/90	7.890	8.250	8.400		8.370
pH	23/07/90	8.160	8.220	8.160		8.260
pH	30/07/90	8.000	8.140	8.150		8.110

DETERMINAND	DATE	NI	ST	ST2	IN	LT
pH	25/09/91	8.280	8.280			8.250
pH	02/10/91	8.160	8.160	8.000		8.020
pH	07/10/91	7.960	8.020	8.000		8.000
pH	14/10/91	8.020	7.980	8.040		8.070
pH	21/10/91	8.050	8.040	7.650		7.920
pH	28/10/91	7.960	8.050	8.060		8.050
pH	04/11/91	8.070	8.110	8.140		8.130
pH	11/11/91	7.890	8.020	7.960		8.050
pH	18/11/91	8.240	8.160	8.090		8.070
pH	25/11/91	7.970	7.970	7.930		7.930
pH	02/12/91	8.030	8.090	8.110		8.060
pH	10/12/91	7.970	7.980	8.000		7.900
pH	17/12/91	7.760	7.910	7.920		7.990
pH	30/12/91	8.020	8.030	7.950		8.030
pH	07/01/92	8.110	8.110	7.980		8.110
pH	13/01/92	8.100	8.100	8.020		8.050
pH	20/01/92	8.110	8.100	8.090		8.110
pH	27/01/92	8.080	8.110	7.940		7.980
pH	03/02/92	7.920	7.900	7.840		7.910
pH	10/02/92	7.850	7.940	7.780		7.940
pH	17/02/92	8.080	8.070	7.970		8.010
pH	24/02/92	8.040	8.020	7.880		7.950
pH	02/03/92	8.030	8.050	7.980		7.980
pH	09/03/92	8.100	8.090	7.950		7.990
pH	16/03/92	8.190	8.180	8.050		8.140
pH	23/03/92	8.190	8.190	8.120		8.170
pH	30/03/92	8.160	8.170	8.090		7.910
pH	06/04/92	8.140	8.110	7.960		8.020
pH	21/04/92	8.160	8.200	8.230		8.130
pH	29/04/92	8.230	8.260	8.100		8.210
pH	05/05/92	8.170	8.210	8.100	7.930	8.100
pH	11/05/92	8.160	8.190	8.020	7.920	8.160
pH	18/05/92	8.440	8.410	8.480	8.170	8.090
pH	26/05/92	8.220	8.250	8.320	8.350	8.170
pH	01/06/92	8.160	8.200	8.230	8.200	8.170
pH	09/06/92	8.200	8.200	8.190	7.880	8.100
pH	15/06/92	8.250	8.220	8.280		8.360
pH	22/06/92	8.210	8.210	8.280		7.380
pH	29/06/92	8.350	8.220	8.370		8.220
pH	06/07/92	8.180	8.190	8.190	7.820	8.190
pH	13/07/92	8.250	8.290	8.180	7.750	8.250
pH	20/07/92	8.280	8.330	8.160	7.940	8.390
pH	27/07/92	8.280	8.340	8.220	8.130	8.280
pH	03/08/92	8.110	8.210	8.180	8.210	8.270
pH	10/08/92	8.250	8.250	8.250	8.180	8.110
pH	17/08/92	8.350	8.280	8.210	8.150	8.210
pH	24/08/92	8.060	8.210	8.180	8.180	8.180
pH	01/09/92	7.860	8.070	8.110	8.130	8.130
pH	07/09/92	8.280	8.260	8.220	7.930	8.190
pH	14/09/92	8.150	8.200	8.210	8.080	8.140
pH	21/09/92	8.050	8.120	8.130	7.940	8.110
pH	28/09/92	7.800	7.970	7.840	7.820	7.930
pH	05/10/92	8.020	8.040	7.940	7.900	7.920
pH	12/10/92	8.140	8.130	8.110	8.110	8.080
pH	19/10/92	8.090	8.080	8.110	8.070	8.060
pH	26/10/92	8.070	8.060	8.050	8.040	8.020

DETERMINAND	DATE	N1	S1	S12	IN	LT
pH	06/08/90	7.720	7.840	7.970		7.850
pH	13/08/90	7.880	7.990	8.150		8.010
pH	20/08/90	7.820	7.850	7.860		7.850
pH	29/08/90	7.920	7.950	7.840		7.940
pH	03/09/90	7.730	7.730	7.750		7.730
pH	10/09/90	7.870	7.950	7.940		7.890
pH	18/09/90	8.130	8.150	8.120		8.220
pH	24/09/90	8.100	8.170	8.310		8.160
pH	01/10/90	7.900	7.830	8.010		7.850
pH	08/10/90	8.030	8.210	8.170		8.200
pH	15/10/90	8.210	8.260	8.230		8.260
pH	22/10/90	8.160	8.170	8.170		8.160
pH	29/10/90	8.200	8.210	8.190		8.190
pH	05/11/90		8.200	8.200		8.220
pH	12/11/90	8.160	8.150	8.170		8.140
pH	19/11/90	8.140	8.150	8.170		8.160
pH	26/11/90	8.130	7.890	8.000		8.020
pH	03/12/90	8.200	8.190	8.140		8.140
pH	12/12/90	8.170	8.210			
pH	17/12/90	8.060	8.120	8.140		8.140
pH	07/01/91	8.160	8.160			8.170
pH	14/01/91	8.170	8.200	8.120		8.120
pH	21/01/91	7.960	8.030	7.850		7.810
pH	28/01/91	8.100	8.100	7.860		7.810
pH	04/02/91	8.070	8.070	8.010		7.960
pH	20/02/91	8.300	8.280	8.060		8.120
pH	25/02/91	8.200	8.290	8.260		8.190
pH	04/03/91	8.060	8.130	8.030		8.000
pH	11/03/91	7.940	8.020	8.000		7.920
pH	18/03/91	8.000	8.050	7.990		7.930
pH	26/03/91	8.140	8.140	8.080		7.980
pH	03/04/91	8.220	8.170			8.140
pH	08/04/91	8.210	8.190			8.130
pH	16/04/91	8.440	8.440	8.270		8.040
pH	22/04/91	8.260	8.300	8.250		8.130
pH	30/04/91	8.320	8.340	8.260		8.180
pH	07/05/91	8.290	8.300	8.150		8.150
pH	13/05/91	8.220	8.230	8.180		8.320
pH	20/05/91	8.200	8.200	8.120		8.220
pH	28/05/91	8.160	8.190	8.080		8.020
pH	03/06/91	7.980	8.040	7.880		7.930
pH	10/06/91	7.910	7.950	7.970		7.950
pH	17/06/91	8.190	8.160	8.020		8.090
pH	24/06/91	8.320	8.330	8.210		8.180
pH	01/07/91	8.150	8.180	8.060		8.220
pH	08/07/91	8.180	8.230	8.180		8.120
pH	15/07/91	7.490	8.130	8.020		8.110
pH	22/07/91	8.130	8.210	8.280		8.280
pH	29/07/91	8.300	8.360	8.370		8.410
pH	05/08/91	8.400	8.460	8.400		8.360
pH	12/08/91	8.140	8.230	8.090		8.000
pH	20/08/91	8.320	8.380	8.310		8.380
pH	27/08/91	8.260	8.300	8.460		8.440
pH	02/09/91	8.350	8.370	8.400		8.240
pH	09/09/91	8.250	8.280	8.340		8.200
pH	16/09/91	8.240	8.260	8.280		8.200

DETERMINAND	DATE	NI	ST	SI2	IN	LT
pH	03/11/92	8.180	8.190	8.190	8.160	8.160
pH	09/11/92	8.250	8.230	8.210	8.200	8.210
pH	16/11/92	8.190	8.190	8.200		
pH	23/11/92	8.150	8.190	8.190	8.190	8.180
pH	03/12/92	8.180	8.190	8.160		8.160
pH	07/12/92	8.290	8.210	8.250	8.280	8.260
pH	14/12/92	8.110	8.160	8.160	8.150	8.160
pH	04/01/93	8.110	8.110	8.120	8.120	8.120
pH	18/01/93	8.270	8.220	8.210	8.230	8.190
pH	25/01/93	8.180		8.180	8.180	8.190
pH	01/02/93	7.860	8.060	8.110	8.120	8.120
pH	08/02/93	8.180		8.200	8.190	8.180
pH	15/02/93	8.230		8.230	8.230	8.230
pH	22/02/93	8.280		8.290	8.220	8.290
pH	01/03/93	8.290		8.300	8.260	8.270
pH	08/03/93	8.350		8.340	8.320	8.330
pH	15/03/93	8.540		8.560	8.390	8.370
pH	22/03/93	8.400		8.520	8.470	8.480
pH	29/03/93	7.720		8.460	8.490	8.540
pH	05/04/93	8.410		8.550	8.370	8.520
pH	13/04/93	8.430		8.410	8.330	8.410
pH	19/04/93	8.300		8.370	8.360	8.360
pH	26/04/93	8.400		8.400	8.320	8.320
pH	04/05/93	8.390		8.390	8.190	8.330
pH	10/05/93	8.280		8.460	8.370	8.280
pH	17/05/93	8.300		8.410	8.300	8.360
pH	24/05/93	8.350		8.440	8.400	8.360
pH	01/06/93	8.230		8.300	8.130	8.220
pH	07/06/93	8.340		8.420	8.410	8.430
pH	14/06/93	8.250		8.250	8.180	8.260
pH	21/06/93	8.360		8.290	8.250	8.330
pH	28/06/93	8.370		8.430	8.440	8.470
pH	05/07/93	8.390		8.480	8.490	8.520
pH	12/07/93	8.290		8.680	8.550	8.660
pH	19/07/93	8.040		8.220	8.250	8.320
pH	26/07/93	8.070	8.090	8.070	8.080	8.150
pH	02/08/93	8.200	8.260	8.270	8.210	8.180
pH	09/08/93	7.940	8.080	8.160	8.200	8.180
pH	16/08/93	8.270	8.220	8.280	8.280	8.280
pH	23/08/93	8.050	8.150	7.720	8.370	8.140
pH	31/08/93	8.160	8.150	8.260	8.260	8.140
pH	06/09/93	8.070	8.070	8.190	8.130	8.060
pH	13/09/93	8.020	8.060	8.120	8.060	8.020
pH	20/09/93	8.190	8.140		8.070	8.080
pH	27/09/93	8.120		8.110		
pH	04/10/93	8.080	8.070	8.080	8.050	8.070
pH	11/10/93	8.020	8.050	7.880	8.010	7.990
pH	19/10/93	8.290	8.180	8.150	8.090	8.140
pH	25/10/93	8.090	8.090	8.090	8.070	8.070
pH	01/11/93	8.200	8.200	8.140	8.080	8.090
pH	08/11/93	8.070	8.060	8.070	8.040	8.020
pH	15/11/93	7.800	7.980	8.060	8.020	8.060
pH	22/11/93	8.050	8.090	8.080	8.060	8.110
pH	29/11/93	8.060		8.110		8.070
pH	06/12/93	8.040	8.110	8.090	8.060	8.090
pH	13/12/93	8.090	8.130	8.130	8.120	8.150

DETERMINAND	DATE	NI	ST	SI2	IN	LT
pH	20/12/93	7.970	8.110	7.840	8.090	8.020
pH	10/01/94	8.200	8.200	8.200	8.200	8.300
pH	17/01/94	8.100		8.100	8.100	8.100
pH	24/01/94		7.700	7.500	8.400	8.100
pH	31/01/94		8.200	8.210	8.100	8.220
pH	07/02/94		8.200	8.200	8.090	8.210
pH	21/02/94		6.800	8.100	8.100	8.100
pH	01/03/94		7.900	8.000	8.100	8.100
pH	07/03/94		8.000	8.000	8.100	8.000
pH	15/03/94		7.900	7.900	7.900	7.900
pH	21/03/94		8.290	8.300	8.200	8.280
pH	28/03/94	8.100	8.100	8.100	8.100	8.100
pH	05/04/94	8.310	8.320	8.340	8.300	8.320
pH	11/04/94	8.320	8.310	8.310	8.290	8.290
pH	18/04/94	8.400	8.400	8.400	8.400	8.300
pH	25/04/94	7.800	8.000	8.100	8.200	8.200
pH	03/05/94	8.200	8.200	8.200	8.200	
pH	09/05/94	8.400	8.400	8.400	8.300	8.300
pH	16/05/94	8.200	8.200	8.300	8.200	8.200
pH	23/05/94	8.200	8.200	8.200	8.100	8.200
pH	31/05/94	8.200	8.200	8.200	8.200	8.200
pH	06/06/94	8.200	8.200	8.300	8.200	8.300
pH	13/06/94	8.200	8.200	8.300	8.300	8.400
pH	20/06/94	8.300	8.300	8.300	8.300	8.400
pH	27/06/94	8.200	8.300	8.300	8.300	8.300
pH	04/07/94	8.300	8.400	8.400	8.000	8.400
pH	11/07/94	8.300	8.300	8.400	8.400	8.400
pH	18/07/94	8.300	8.300	8.300	8.300	8.300
pH	25/07/94	8.300	8.400	8.500	8.500	8.500
pH	01/08/94	8.300	8.300	8.400	8.300	8.300
pH	08/08/94	8.300	8.300	8.400	8.300	8.100
pH	15/08/94	8.200	8.200	8.200	8.200	8.200
pH	22/08/94	8.300	8.300	8.300	8.300	8.300
pH	30/08/94	8.200	8.300	8.300	8.300	8.300
pH	05/09/94	8.200	8.200	8.200	8.200	8.200
pH	12/09/94	8.200	8.200	8.200	8.200	8.200
pH	19/09/94	8.200	8.200	8.200	8.200	8.200
pH	26/09/94	8.300	8.300	8.200	8.100	8.200
pH	03/10/94	8.100	8.100	8.100	7.800	8.100
pH	10/10/94	8.200	8.200	8.200	8.200	8.200
pH	17/10/94	8.200	8.200	8.200	8.100	8.200
pH	24/10/94	8.200	8.200	8.200	8.200	8.200
pH	31/10/94	8.100	8.200	8.200	8.200	8.200
pH	07/11/94	8.100	8.200	8.200	8.200	8.100
pH	14/11/94	8.000	8.000	8.000	8.000	8.000
pH	21/11/94	8.100	8.200	8.200	8.100	8.200
pH	28/11/94	8.000	8.000	8.000	7.900	8.000
pH	05/12/94	8.000	8.000	8.100	8.000	8.000
pH	12/12/94	8.100	8.100	8.100	8.200	8.200
pH	19/12/94	8.200	8.100	8.1	8.200	8.100
ALKALINITY	04/06/90		178.000	181.000		186.000
ALKALINITY	11/06/90		170.000	174.000		167.000
ALKALINITY	18/06/90	176.000	168.000	168.000		172.000
ALKALINITY	25/06/90	173.000	172.000	172.000		176.000
ALKALINITY	02/07/90	171.000	166.000	156.000		156.000
ALKALINITY	09/07/90	162.000	166.000	163.000		157.000

DETERMINAND	DATE	NI	ST	ST2	IN	LT
ALKALINITY	16/07/90	169.000	165.000	173.000		173.000
ALKALINITY	23/07/90	138.000	149.000	144.000		165.000
ALKALINITY	30/07/90	140.000	170.000	140.000		220.000
ALKALINITY	06/08/90	135.000	130.000	125.000		120.000
ALKALINITY	13/08/90	130.000	135.000	130.000		130.000
ALKALINITY	20/08/90	135.000	130.000	135.000		135.000
ALKALINITY	29/08/90	135.000	135.000	150.000		140.000
ALKALINITY	03/09/90	150.000	140.000	140.000		150.000
ALKALINITY	10/09/90	145.000	145.000	150.000		140.000
ALKALINITY	18/09/90	130.000	120.000	130.000		125.000
ALKALINITY	24/09/90	120.000	130.000	120.000		125.000
ALKALINITY	01/10/90	140.000	130.000	135.000		135.000
ALKALINITY	08/10/90	120.000	130.000	130.000		130.000
ALKALINITY	15/10/90	125.000	125.000	125.000		125.000
ALKALINITY	22/10/90	125.000	125.000	125.000		130.000
ALKALINITY	29/10/90	130.000	125.000	130.000		140.000
ALKALINITY	05/11/90		135.000	130.000		140.000
ALKALINITY	12/11/90	140.000	135.000	135.000		130.000
ALKALINITY	19/11/90	140.000	190.000	140.000		130.000
ALKALINITY	26/11/90	130.000	130.000	130.000		130.000
ALKALINITY	03/12/90	130.000	130.000	130.000		130.000
ALKALINITY	12/12/90	130.000	130.000	135.000		
ALKALINITY	17/12/90	130.000	130.000			130.000
ALKALINITY	07/01/91	110.000	130.000			140.000
ALKALINITY	14/01/91	130.000	140.000	140.000		130.000
ALKALINITY	21/01/91	135.000	140.000	125.000		135.000
ALKALINITY	28/01/91	135.000	140.000	135.000		135.000
ALKALINITY	04/02/91	140.000	185.000	135.000		170.000
ALKALINITY	20/02/91	125.000	120.000	120.000		130.000
ALKALINITY	25/02/91	130.000	125.000	120.000		150.000
ALKALINITY	04/03/91	130.000	120.000	120.000		150.000
ALKALINITY	11/03/91	150.000	180.000	170.000		180.000
ALKALINITY	18/03/91	130.000	130.000	120.000		140.000
ALKALINITY	26/03/91	120.000	120.000	120.000		120.000
ALKALINITY	03/04/91	125.000	120.000			130.000
ALKALINITY	08/04/91	120.000	125.000			125.000
ALKALINITY	16/04/91	130.000	125.000	130.000		125.000
ALKALINITY	22/04/91	125.000	130.000	125.000		130.000
ALKALINITY	30/04/91	120.000	125.000	120.000		120.000
ALKALINITY	07/05/91	120.000	120.000	130.000		120.000
ALKALINITY	13/05/91	135.000	125.000	120.000		130.000
ALKALINITY	20/05/91	125.000	130.000	130.000		125.000
ALKALINITY	28/05/91	130.000	125.000	125.000		130.000
ALKALINITY	03/06/91	135.000	140.000	125.000		125.000
ALKALINITY	10/06/91	130.000	130.000	130.000		130.000
ALKALINITY	17/06/91	118.000	121.000	120.000		119.000
ALKALINITY	24/06/91	110.000	115.000	110.000		115.000
ALKALINITY	01/07/91	118.000	118.000	117.000		117.000
ALKALINITY	08/07/91	117.000	117.000	116.000		113.000
ALKALINITY	15/07/91	118.000	121.000	121.000		120.000
ALKALINITY	22/07/91	117.000	117.000	117.000		117.000
ALKALINITY	29/07/91	110.000	120.000	110.000		140.000
ALKALINITY	05/08/91	111.000	113.000	113.000		111.000
ALKALINITY	12/08/91	114.000	110.000	113.000		112.000
ALKALINITY	20/08/91	120.000	115.000	117.000		119.000
ALKALINITY	27/08/91	108.000	107.000	110.000		109.000

DETERMINAND	DATE	N1	ST	S12	IN	LT
ALKALINITY	02/09/91	98.400	113.000	103.000		109.000
ALKALINITY	09/09/91	100.000	104.000	100.000		100.000
ALKALINITY	16/09/91	108.000	107.000	104.000		109.000
ALKALINITY	25/09/91	108.000	108.000			108.000
ALKALINITY	02/10/91	107.000	107.000	110.000		107.000
ALKALINITY	07/10/91	110.000	112.000	107.000		109.000
ALKALINITY	14/10/91	111.000	108.000	114.000		110.000
ALKALINITY	21/10/91	111.000	111.000	118.000		113.000
ALKALINITY	28/10/91	102.000	106.000	102.000		101.000
ALKALINITY	04/11/91	101.000	104.000	105.000		99.700
ALKALINITY	11/11/91	107.000	109.000	104.000		111.000
ALKALINITY	18/11/91	114.000	113.000	113.000		113.000
ALKALINITY	25/11/91	96.700	115.000	112.000		113.000
ALKALINITY	02/12/91	101.000	101.000	104.000		103.000
ALKALINITY	10/12/91	122.000	124.000	122.000		120.000
ALKALINITY	17/12/91	108.000	102.000	110.000		107.000
ALKALINITY	30/12/91	115.000	115.000	121.000		123.000
ALKALINITY	07/01/92	115.000	113.000	111.000		113.000
ALKALINITY	13/01/92	114.000	111.000	110.000		112.000
ALKALINITY	20/01/92	124.000	122.000	127.000		125.000
ALKALINITY	27/01/92	121.000	121.000	122.000		122.000
ALKALINITY	03/02/92	123.000	121.000	123.000		124.000
ALKALINITY	10/02/92	117.000	116.000	117.000		118.000
ALKALINITY	17/02/92	106.000	119.000	116.000		117.000
ALKALINITY	24/02/92	102.000	119.000	117.000		116.000
ALKALINITY	02/03/92	115.000	115.000	116.000		114.000
ALKALINITY	09/03/92	113.000	114.000	114.000		115.000
ALKALINITY	16/03/92	115.000	115.000	115.000		116.000
ALKALINITY	23/03/92	116.000	117.000	114.000		117.000
ALKALINITY	30/03/92	115.000	114.000	114.000		114.000
ALKALINITY	06/04/92	116.000	118.000	118.000		112.000
ALKALINITY	21/04/92	114.000	116.000	122.000		114.000
ALKALINITY	29/04/92	106.000	114.000	114.000		118.000
ALKALINITY	05/05/92	112.000	111.000	111.000	110.000	111.000
ALKALINITY	11/05/92	117.000	117.000	108.000	120.000	119.000
ALKALINITY	18/05/92	114.000	118.000	114.000	118.000	114.000
ALKALINITY	26/05/92	112.000	113.000	109.000	113.000	114.000
ALKALINITY	01/06/92	112.000	117.000	111.000	116.000	115.000
ALKALINITY	09/06/92	120.000	116.000	121.000	124.000	119.000
ALKALINITY	15/06/92	118.000	114.000	118.000		134.000
ALKALINITY	22/06/92	115.000	113.000	114.000		112.000
ALKALINITY	29/06/92	113.000	112.000	110.000		112.000
ALKALINITY	06/07/92	109.000	107.000	114.000	105.000	112.000
ALKALINITY	13/07/92	111.000	111.000	113.000	103.000	110.000
ALKALINITY	20/07/92	108.000	112.000	113.000	119.000	112.000
ALKALINITY	27/07/92	113.000	112.000	115.000	119.000	115.000
ALKALINITY	03/08/92	110.000	109.000	112.000	111.000	112.000
ALKALINITY	10/08/92	110.000	109.000	112.000	113.000	112.000
ALKALINITY	17/08/92	104.000	109.000	106.000	108.000	105.000
ALKALINITY	24/08/92	110.000	113.000	113.000	115.000	113.000
ALKALINITY	01/09/92	109.000	109.000	113.000	113.000	110.000
ALKALINITY	07/09/92	109.000	110.000	112.000	111.000	113.000
ALKALINITY	14/09/92	113.000	112.000	114.000	115.000	114.000
ALKALINITY	21/09/92	114.000	113.000	115.000	117.000	114.000
ALKALINITY	28/09/92	117.000	116.000	116.000	117.000	116.000
ALKALINITY	05/10/92	119.000	119.000	119.000	118.000	119.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
ALKALINITY	12/10/92	115.000	114.000	115.000	114.000	115.000
ALKALINITY	19/10/92	118.000	117.000	117.000	117.000	118.000
ALKALINITY	26/10/92	116.000	114.000	117.000	118.000	113.000
ALKALINITY	03/11/92	120.000	118.000	121.000	120.000	121.000
ALKALINITY	09/11/92	117.000	116.000	121.000	122.000	119.000
ALKALINITY	16/11/92	121.000	119.000	120.000		
ALKALINITY	23/11/92	119.000	118.000	117.000	117.000	116.000
ALKALINITY	03/12/92	127.000	127.000	125.000		123.000
ALKALINITY	07/12/92	116.000	120.000	118.000	118.000	118.000
ALKALINITY	14/12/92	118.000	117.000	119.000	117.000	117.000
ALKALINITY	04/01/93	124.000	123.000	121.000	123.000	121.000
ALKALINITY	18/01/93	120.000	121.000	119.000	120.000	133.000
ALKALINITY	25/01/93	131.000		131.000	130.000	131.000
ALKALINITY	01/02/93	119.000	124.000	124.000	122.000	123.000
ALKALINITY	08/02/93	128.000		129.000	125.000	127.000
ALKALINITY	15/02/93	122.000		120.000	120.000	120.000
ALKALINITY	22/02/93	122.000		127.000	130.000	122.000
ALKALINITY	01/03/93	127.000		132.000	131.000	129.000
ALKALINITY	08/03/93	125.000		126.000	131.000	133.000
ALKALINITY	15/03/93	131.000		130.000	135.000	133.000
ALKALINITY	22/03/93	103.000		148.000	124.000	122.000
ALKALINITY	29/03/93	134.000		124.000	138.000	151.000
ALKALINITY	05/04/93	124.000		132.000	127.000	128.000
ALKALINITY	13/04/93	129.000		128.000	134.000	129.000
ALKALINITY	19/04/93	130.000		136.000	132.000	131.000
ALKALINITY	26/04/93	132.000		128.000	132.000	134.000
ALKALINITY	04/05/93	131.000		133.000	133.000	132.000
ALKALINITY	10/05/93	130.000		133.000	134.000	135.000
ALKALINITY	17/05/93	133.000		130.000	136.000	133.000
ALKALINITY	24/05/93	130.000		131.000	130.000	134.000
ALKALINITY	01/06/93	130.000		128.000	130.000	129.000
ALKALINITY	07/06/93	127.000		128.000	125.000	128.000
ALKALINITY	14/06/93	120.000		117.000	124.000	119.000
ALKALINITY	21/06/93	121.000		124.000	123.000	129.000
ALKALINITY	28/06/93	121.000		120.000	127.000	123.000
ALKALINITY	05/07/93	116.000		114.000	112.000	113.000
ALKALINITY	12/07/93	113.000		114.000	111.000	104.000
ALKALINITY	19/07/93	112.000		111.000	113.000	108.000
ALKALINITY	26/07/93	112.000	114.000	112.000	113.000	110.000
ALKALINITY	02/08/93	109.000	110.000	112.000	113.000	111.000
ALKALINITY	09/08/93	110.000	109.000	112.000	112.000	111.000
ALKALINITY	16/08/93	109.000	110.000	106.000	108.000	363.000
ALKALINITY	23/08/93	111.000	111.000	111.000	114.000	114.000
ALKALINITY	31/08/93	113.000	107.000	111.000	110.000	110.000
ALKALINITY	06/09/93	110.000	109.000	111.000	109.000	110.000
ALKALINITY	13/09/93	112.000	112.000	113.000	115.000	115.000
ALKALINITY	20/09/93	114.000	113.000		114.000	113.000
ALKALINITY	27/09/93	112.000		117.000		
ALKALINITY	04/10/93	115.000	117.000	115.000	115.000	115.000
ALKALINITY	11/10/93	111.000	113.000	112.000	116.000	111.000
ALKALINITY	19/10/93	115.000	115.000	117.000	116.000	117.000
ALKALINITY	25/10/93	115.000	113.000	116.000	117.000	118.000
ALKALINITY	01/11/93	116.000	118.000	118.000	120.000	119.000
ALKALINITY	08/11/93	118.000	120.000	120.000	122.000	121.000
ALKALINITY	15/11/93	118.000	118.000	118.000	121.000	120.000
ALKALINITY	22/11/93	116.000	116.000	117.000	117.000	115.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
ALKALINITY	29/11/93	121.000		124.000		123.000
ALKALINITY	06/12/93	128.000	120.000	124.000	129.000	124.000
ALKALINITY	13/12/93	122.000	123.000	128.000	125.000	126.000
ALKALINITY	20/12/93	131.000	126.000	129.000	130.000	128.000
ALKALINITY	10/01/94	122.000	127.000	131.000	122.000	118.000
ALKALINITY	17/01/94	127.000		131.000	132.000	137.000
ALKALINITY	24/01/94		127.000	123.000	124.000	123.000
ALKALINITY	31/01/94		140.000	145.000	145.000	140.000
ALKALINITY	07/02/94		129.000	130.000	131.000	127.000
ALKALINITY	21/02/94		130.000	127.000	134.000	130.000
ALKALINITY	01/03/94		132.000	135.000	157.000	131.000
ALKALINITY	07/03/94		286.000	209.000	155.000	296.000
ALKALINITY	21/03/94		140.000	137.000	140.000	141.000
ALKALINITY	28/03/94	127.000	126.000	126.000	137.000	122.000
ALKALINITY	05/04/94	127.000	126.000	126.000	125.000	125.000
ALKALINITY	11/04/94	133.000	135.000	133.000	133.000	142.000
ALKALINITY	18/04/94	136.000	140.000	138.000	142.000	140.000
ALKALINITY	25/04/94	135.000	128.000	131.000	135.000	131.000
ALKALINITY	03/05/94	131.000	136.000	133.000	138.000	
ALKALINITY	09/05/94	133.000	132.000	136.000	132.000	145.000
ALKALINITY	16/05/94	135.000	137.000	138.000	140.000	139.000
ALKALINITY	23/05/94	127.000	133.000	134.000	137.000	136.000
ALKALINITY	31/05/94	130.000	133.000	135.000	202.000	132.000
ALKALINITY	06/06/94	137.000	137.000	135.000	139.000	137.000
ALKALINITY	13/06/94	133.000	131.000	133.000	134.000	130.000
ALKALINITY	20/06/94	132.000	132.000	131.000	133.000	130.000
ALKALINITY	27/06/94	142.000	144.000	149.000	146.000	147.000
ALKALINITY	04/07/94	127.000	132.000	130.000	131.000	128.000
ALKALINITY	11/07/94	131.000	130.000	130.000		135.000
ALKALINITY	18/07/94	129.000	132.000	124.000	135.000	131.000
ALKALINITY	25/07/94	124.000	124.000	122.000	122.000	126.000
ALKALINITY	01/08/94	124.000	121.000	122.000	127.000	125.000
ALKALINITY	08/08/94	122.000	124.000	121.000	121.000	126.000
ALKALINITY	15/08/94	117.000	111.000	118.000	116.000	120.000
ALKALINITY	22/08/94	118.000	118.000	116.000	118.000	121.000
ALKALINITY	30/08/94	119.000	117.000	120.000	121.000	118.000
ALKALINITY	05/09/94	112.000	114.000	117.000	117.000	115.000
ALKALINITY	12/09/94	116.000	119.000	118.000	121.000	119.000
ALKALINITY	19/09/94	116.000	112.000	115.000	115.000	116.000
ALKALINITY	26/09/94	113.000	111.000	116.000	118.000	116.000
ALKALINITY	03/10/94	113.000	114.000	116.000	118.000	118.000
ALKALINITY	10/10/94	119.000	120.000	119.000	118.000	121.000
ALKALINITY	17/10/94	112.000	121.000	115.000	119.000	117.000
ALKALINITY	24/10/94	120.000	122.000	125.000	125.000	121.000
ALKALINITY	31/10/94	116.000	117.000	114.000	118.000	117.000
ALKALINITY	07/11/94	139.000	116.000	115.000	119.000	121.000
ALKALINITY	14/11/94	117.000	48.000	118.000	116.000	118.000
ALKALINITY	21/11/94	129.000	127.000	133.000	134.000	129.000
ALKALINITY	28/11/94	119.000	125.000	123.000	134.000	119.000
ALKALINITY	05/12/94	123.000	137.000	128.000	126.000	124.000
ALKALINITY	12/12/94	133.000	137.000	138.000	139.000	140.000
ALKALINITY	19/12/94	117.000	117.000	128.000	128.000	123.000
DISS. OXYGEN	21/04/81		78.750			
DISS. OXYGEN	23/09/81		23.100			
DISS. OXYGEN	23/09/81		22.100			
DISS. OXYGEN	23/09/81		25.100			

DETERMINAND	DATE	NI	ST	SI2	IN	LT
DISS. OXYGEN	23/09/81		23.100			
DISS. OXYGEN	23/09/81		21.100			
DISS. OXYGEN	19/04/83	93.700	93.200			97.600
DISS. OXYGEN	26/04/83	86.100	89.500			79.100
DISS. OXYGEN	10/05/83	82.100	84.100			85.100
DISS. OXYGEN	17/05/83	92.200	90.400			93.100
DISS. OXYGEN	31/05/83	124.900	119.800			126.300
DISS. OXYGEN	22/06/83	116.200	112.400			122.500
DISS. OXYGEN	12/07/83	152.300	152.300			145.400
DISS. OXYGEN	19/07/83					151.400
DISS. OXYGEN	26/07/83	101.200	112.300			103.200
DISS. OXYGEN	02/08/83	87.600	90.600			98.100
DISS. OXYGEN	10/08/83	117.800	109.100			85.600
DISS. OXYGEN	16/08/83	108.300	109.100			85.700
DISS. OXYGEN	23/08/83	98.400	102.800			98.600
DISS. OXYGEN	31/08/83	109.400	92.500			83.700
DISS. OXYGEN	06/09/83	92.900	92.200			90.100
DISS. OXYGEN	10/10/83	99.000	99.000			100.000
DISS. OXYGEN	24/10/83					91.500
DISS. OXYGEN	02/04/84	95.000	96.000			95.000
DISS. OXYGEN	09/04/84	101.000	99.000			98.000
DISS. OXYGEN	16/04/84	104.000	102.000			100.000
DISS. OXYGEN	14/05/84	94.000	94.000			88.000
DISS. OXYGEN	21/05/84	106.000	104.000			100.000
DISS. OXYGEN	04/06/84	124.000	124.000			112.000
DISS. OXYGEN	11/06/84	128.000	120.000			103.000
DISS. OXYGEN	18/06/84		120.000			144.000
DISS. OXYGEN	11/07/84	140.000	156.000			160.000
DISS. OXYGEN	17/07/84	92.000	93.000			97.000
DISS. OXYGEN	23/07/84	106.000	101.000			91.000
DISS. OXYGEN	30/07/84	102.000	114.000			112.000
DISS. OXYGEN	07/08/84	96.000	97.000			92.000
DISS. OXYGEN	13/08/84	114.000	104.000			83.000
DISS. OXYGEN	29/08/84					112.000
DISS. OXYGEN	19/09/84					0.000
DISS. OXYGEN	08/10/84		98.000			94.000
DISS. OXYGEN	17/10/84					98.000
DISS. OXYGEN	30/10/84					95.000
DISS. OXYGEN	05/11/84	99.000	98.000			95.000
DISS. OXYGEN	13/11/84	88.000	88.000			88.000
DISS. OXYGEN	19/11/84	85.000	88.000			85.000
DISS. OXYGEN	26/11/84	90.000	87.000			88.000
DISS. OXYGEN	11/03/85	116.000	110.000			88.000
DISS. OXYGEN	04/02/85					95.000
DISS. OXYGEN	11/03/85					106.000
DISS. OXYGEN	18/03/85	118.000	118.000			114.000
DISS. OXYGEN	25/03/85	108.000	107.000			107.000
DISS. OXYGEN	01/04/85					89.000
DISS. OXYGEN	09/04/85	92.000	92.000			90.000
DISS. OXYGEN	15/04/85	90.000	93.000			92.000
DISS. OXYGEN	22/04/85	100.000	100.000			
DISS. OXYGEN	07/05/85	100.000	102.000			92.000
DISS. OXYGEN	13/05/85	99.000	95.000			92.000
DISS. OXYGEN	28/05/85		104.000			100.000
DISS. OXYGEN	11/06/85		97.000			
DISS. OXYGEN	18/06/85	104.000	104.000			100.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
DISS. OXYGEN	15/07/85		130.000			120.000
DISS. OXYGEN	12/08/85					100.000
DISS. OXYGEN	20/08/85	112.000	116.000			105.000
DISS. OXYGEN	02/09/85					106.000
DISS. OXYGEN	17/09/85	106.000	102.000			106.000
DISS. OXYGEN	23/09/85	106.000	108.000			
DISS. OXYGEN	02/10/85	120.000	128.000			110.000
DISS. OXYGEN	08/10/85	99.000	99.000			99.000
DISS. OXYGEN	29/10/85	82.000	82.000			
DISS. OXYGEN	04/11/85	86.000	94.000			88.000
DISS. OXYGEN	18/11/85					87.000
DISS. OXYGEN	25/11/85	86.000	86.000			84.000
DISS. OXYGEN	02/12/85	92.000				89.000
DISS. OXYGEN	09/12/85					89.000
DISS. OXYGEN	16/12/85	98.000	98.000			96.000
DISS. OXYGEN	06/01/86	93.000				90.000
DISS. OXYGEN	20/01/86	98.000				
DISS. OXYGEN	27/01/86	96.000				96.000
DISS. OXYGEN	03/02/86					98.000
DISS. OXYGEN	10/03/86					104.000
DISS. OXYGEN	17/03/86					110.000
DISS. OXYGEN	01/04/86					110.000
DISS. OXYGEN	07/04/86					100.000
DISS. OXYGEN	21/04/86	100.000	108.000			102.000
DISS. OXYGEN	21/04/86		100.000			
DISS. OXYGEN	29/04/86	114.000	120.000			114.000
DISS. OXYGEN	06/05/86	116.000	122.000			114.000
DISS. OXYGEN	12/05/86	100.000	98.000			98.000
DISS. OXYGEN	19/05/86	100.000	98.000			98.000
DISS. OXYGEN	16/06/86	144.000	144.000			128.000
DISS. OXYGEN	23/06/86	120.000	120.000			92.000
DISS. OXYGEN	30/06/86		134.000			134.000
DISS. OXYGEN	30/06/86		134.000			134.000
DISS. OXYGEN	11/08/86		128.000			124.000
DISS. OXYGEN	08/12/86	88.000	88.000			86.000
DISS. OXYGEN	16/12/86	83.000	83.000			85.000
DISS. OXYGEN	26/01/87	94.000	94.000			92.000
DISS. OXYGEN	23/02/87	94.000	94.000			
DISS. OXYGEN	10/03/87					98.000
DISS. OXYGEN	10/03/87					98.000
DISS. OXYGEN	14/09/89		94.000			
DISS. OXYGEN	18/09/89		108.000			
DISS. OXYGEN	21/09/89		101.000			
DISS. OXYGEN	25/09/89		109.000			
DISS. OXYGEN	28/09/89		96.500			
DISS. OXYGEN	03/10/89		108.000			
DISS. OXYGEN	10/10/89		70.300			
DISS. OXYGEN	17/10/89		90.000			
DISS. OXYGEN	20/05/91	100.29	100.98	103.7		106.2
DISS. OXYGEN	28/05/91	115.02	112.8	112.98		102.44
DISS. OXYGEN	03/06/91	96.54	93.9	90.54		91.17
DISS. OXYGEN	10/06/91	99.98	99.35	95.68		96.13
DISS. OXYGEN	17/06/91	107.74	99.41	99.44		97.7
DISS. OXYGEN	24/06/91	120.88	123.05	124.87		113.29
DISS. OXYGEN	01/07/91	104.2	105.95	114.99		123.39
DISS. OXYGEN	08/07/91	118.66	122.61	113.71		105.45

DETERMINAND	DATE	NI	ST	SI2	IN	LT
DISS. OXYGEN	15/07/91	103.81	103.59	105.32		104.32
DISS. OXYGEN	25/07/91	101.39				
DISS. OXYGEN	27/07/91	148.11	146.92	129.01		133.29
DISS. OXYGEN	05/08/91	138.04	139.96	134.91		117.8
DISS. OXYGEN	12/08/91	103.11	102.62	102.24		109.93
DISS. OXYGEN	20/08/91	111.51	113.94	108.21		117.84
DISS. OXYGEN	27/08/91	106.32	107.22	135.03		137.53
DISS. OXYGEN	02/09/91	132.14	130.19	130.61		98.3
DISS. OXYGEN	09/09/91	116.37	111.27	111.52		98.55
DISS. OXYGEN	16/09/91	95.07	93.92	92.91		88.82
DISS. OXYGEN	25/09/91	97.67	96.81	102.98		95.06
DISS. OXYGEN	01/10/91	90.94	89.98	89.51		88.43
DISS. OXYGEN	07/10/91	94.83	94.87	94.91		89.56
DISS. OXYGEN	21/10/91	94.25	92.14	89.07		88.64
DISS. OXYGEN	28/10/91	91.08	90.43	88.51		88.15
DISS. OXYGEN	04/11/91	95.45	95.24			
DISS. OXYGEN	11/11/91	105.48	101.44	101.39		100.59
DISS. OXYGEN	18/11/91	98.71	98.3	98.07		97.17
DISS. OXYGEN	25/11/91	98.72	97.25	97.52		96.09
DISS. OXYGEN	02/12/91	94.57	94.92	94.27		93.1
DISS. OXYGEN	10/12/91	95.97	95.66	94.74		94.88
DISS. OXYGEN	17/12/91	96.5	96.03	96.39		96.37
DISS. OXYGEN	07/01/92	98.92	98.19	98.16		97.73
DISS. OXYGEN	13/01/92	90.9	90.57	90.29		90.76
DISS. OXYGEN	20/01/92	98.05	97.32	96.9		96.65
DISS. OXYGEN	27/01/92	100.11	99.5	101.7		99.5
DISS. OXYGEN	03/02/92	100.58	100.75	102.65		
DISS. OXYGEN	10/02/92		102.55	102.52		
DISS. OXYGEN	17/02/92	104.82	104.39	104.83		105.1
DISS. OXYGEN	24/02/92	102.8	102.49	102.77		
DISS. OXYGEN	02/03/92	104.73	103.83	105.07		
DISS. OXYGEN	09/03/92	107.8	108.12	108.25		
DISS. OXYGEN	16/03/92	101.67	100.03	100.49		99.41
DISS. OXYGEN	23/03/92	106.01	106.03	106.89		104.51
DISS. OXYGEN	30/03/92	108.87	108.38	106.81		102.37
DISS. OXYGEN	06/04/92	107.83	107.76	108.45		102.68
DISS. OXYGEN	21/04/92	105.94	106.5	112.52		96.84
DISS. OXYGEN	29/04/92	110.3	110	110		107.4
DISS. OXYGEN	05/05/92	99.2				
DISS. OXYGEN	11/05/92	100.76	100.38		108.49	85.84
DISS. OXYGEN	18/05/92	128.59	120.03	134.95	112.42	106.3
DISS. OXYGEN	26/05/92	119.9	115.71			109.04
DISS. OXYGEN	09/06/92	109.81	101.67	99.42		93.71
DISS. OXYGEN	15/06/92	146.54	151.57	146.57		148.35
DISS. OXYGEN	22/06/92	103.78	102.13	105.48		99.3
DISS. OXYGEN	29/06/92	150.25	143.11	149.99		133.75
DISS. OXYGEN	06/07/92	106.15	100.88	99.04		96.64
DISS. OXYGEN	13/07/92	118.96	116.92	107.1		111.42
DISS. OXYGEN	20/07/92	115.64	114.35	112.8		120.78
DISS. OXYGEN	27/07/92	114.51	115.43	110.88		111.66
DISS. OXYGEN	03/08/92	119.52	118.36	115.24		118.44
DISS. OXYGEN	10/08/92	116.73	103.47	104.79		102.51
DISS. OXYGEN	17/08/92	109.91	102.25			
DISS. OXYGEN	24/08/92	107.97	106.08	107.75		105.03
DISS. OXYGEN	01/09/92	108.03	104.07	102.1		99.95
DISS. OXYGEN	07/09/92	102	101.43	104.22		98.95

DETERMINAND	DATE	NI	ST	SI2	IN	LT
DISS. OXYGEN	14/09/92	100.26	99.9	99.64		96.64
DISS. OXYGEN	21/09/92	96.63	98.13	104.97		100.24
DISS. OXYGEN	28/09/92	106.64	100.44	94.26		
DISS. OXYGEN	05/10/92	95.44	93.96	92.79		94.26
DISS. OXYGEN	12/10/92	97.73	90.74	91.91		90.81
DISS. OXYGEN	19/10/92	94.71	93.56	94.48		93.15
DISS. OXYGEN	26/10/92	97.36	96.9	96.54		95.4
DISS. OXYGEN	03/11/92	99.6	99.49	99.03		99.08
DISS. OXYGEN	09/11/92	101.68	99.06	98.98		98.29
DISS. OXYGEN	16/11/92	104.65	100.36	100.08		99.17
DISS. OXYGEN	23/11/92	100.83				
DISS. OXYGEN	03/12/92	103.23	104.28	104.13		104.4
DISS. OXYGEN	07/12/92	102.2	102.96	102.76		102.93
DISS. OXYGEN	14/12/92	106.39	97.69	98.33		97.78
DISS. OXYGEN	21/12/92	101.43	98.13	98.33		97.96
DISS. OXYGEN	04/01/93	110.2	98.77	98.81		97.49
DISS. OXYGEN	01/02/93	110.97	103.22	102.75		101.62
DISS. OXYGEN	08/02/93	100.34		100.26		98.88
DISS. OXYGEN	15/02/93			100.51		98.74
DISS. OXYGEN	22/02/93	104.08		103.82		103.04
DISS. OXYGEN	01/03/93	103.01		102.59		102.28
DISS. OXYGEN	08/03/93	114.72		110.97		109.43
DISS. OXYGEN	15/03/93	145.17		138.67		118.35
DISS. OXYGEN	22/03/93	112.6		113.56		111.06
DISS. OXYGEN	29/03/93	109.26		109.15		105.13
DISS. OXYGEN	05/04/93	118.36		106.12		104.35
DISS. OXYGEN	13/04/93	105.62		102.99		100.61
DISS. OXYGEN	19/04/93	101.56		104.21		101.47
DISS. OXYGEN	26/04/93	107.21		102.59	101.91	98.87
DISS. OXYGEN	04/05/93	98.27		98.28	98.76	98.35
DISS. OXYGEN	10/05/93	103.18		110.58	104.16	98.21
DISS. OXYGEN	17/05/93	104.96		107.61	105.8	104.2
DISS. OXYGEN	24/05/93	104.75		103.88	98.27	
DISS. OXYGEN	07/06/93	139.69			152.21	148.42
DISS. OXYGEN	14/06/93	10.45		10.14	10.17	10.42
DISS. OXYGEN	06/09/93	94.82	91.65			
DISS. OXYGEN	13/09/93	90.6		91.6		87.5
DISS. OXYGEN	20/09/93	92.2	94.2		88.6	89.7
DISS. OXYGEN	27/09/93	96.4		91		
DISS. OXYGEN	04/10/93	90.3	89.9	90.2		89.5
DISS. OXYGEN	11/10/93	87.9	87.3	87.3	86.6	86.4
DISS. OXYGEN	19/10/93	84.6	85.2	87.3	86.4	85.7
DISS. OXYGEN	25/10/93	86.7	88.2	87.5	86.2	86.1
DISS. OXYGEN	01/11/93	89.7	88.7	89.7	88.9	87.8
DISS. OXYGEN	08/11/93	88.1	87	87.7	87.2	87
DISS. OXYGEN	15/11/93	97.2	96.9			
DISS. OXYGEN	22/11/93	100.2	90.4	91.9	91.4	91.5
DISS. OXYGEN	06/12/93			104.21		
DISS. OXYGEN	10/01/94	105.6	106.3	105.9		
DISS. OXYGEN	24/01/94		102.9			
DISS. OXYGEN	07/02/94		106.4	105.3	105.6	105.9
DISS. OXYGEN	21/02/94	104.4			102.9	104
DISS. OXYGEN	01/03/94	100.71	136.15	136.81	134.95	134.58
DISS. OXYGEN	07/03/94		109.28	106.18	105.78	105.3
DISS. OXYGEN	15/03/94	107.85		107.91	107.12	107.39
DISS. OXYGEN	16/05/94	99.5		98.7	98.1	99.4

DETERMINAND	DATE	NI	ST	SI2	IN	LT
DISS. OXYGEN	23/05/94	101.8		98.8	97.7	97.5
DISS. OXYGEN	31/05/94	101.1		105.5	104.6	103.1
DISS. OXYGEN	06/06/94	102.7	103.1	104.2	103.4	105.6
DISS. OXYGEN	13/06/94	110.2		118.2	117.1	119.1
DISS. OXYGEN	20/06/94	104.2		105.5	109.9	111
DISS. OXYGEN	27/06/94	104.6		104.5	105.5	105.7
DISS. OXYGEN	04/07/94	124.6		122.2	121.8	119.4
DISS. OXYGEN	11/07/94	120		116.9	117.2	119.5
DISS. OXYGEN	18/07/94	114.1		112.3	110.9	104.2
DISS. OXYGEN	25/07/94	136.2		129.4	129.9	130.6
DISS. OXYGEN	01/08/94	122.4		117.2	111.5	114.5
DISS. OXYGEN	08/08/94	119.1		119.8	113.5	101.8
DISS. OXYGEN	15/08/94	105.5		100.8	101.9	99.9
DISS. OXYGEN	22/08/94	105.4		104.7	101	99.7
DISS. OXYGEN	30/08/94	107.5		107.6	105.5	105.9
DISS. OXYGEN	05/09/94	98.8		98	96.5	97.1
DISS. OXYGEN	12/09/94	98.6		97.4	96.2	96.5
DISS. OXYGEN	19/09/94	95		93.6	93.1	93.2
DISS. OXYGEN	26/09/94	106.3		107.3	102.8	103.9
DISS. OXYGEN	07/10/94	98		99	97.4	96.7
DISS. OXYGEN	10/10/94	100.7		98	96.1	96.3
DISS. OXYGEN	17/10/94	111.4		108.1	103.1	103.4
DISS. OXYGEN	24/10/94	99.6		100.2	100	98.8
DISS. OXYGEN	21/11/94	96.8		97.9	100.3	97.7
DISS. OXYGEN	05/12/94	101.1		100.7	100.2	100
DISS. OXYGEN	12/12/94	106.14		103.01	103.14	102.14
DISS. OXYGEN	19/12/94	123.56		116.5	118.89	119.92
CONDUCTIVITY	07/04/81	748.000	748.000			740.000
CONDUCTIVITY	13/04/81	757.000	758.000			762.000
CONDUCTIVITY	22/04/81	750.000	749.000			750.000
CONDUCTIVITY	06/05/81	739.000	738.000			740.000
CONDUCTIVITY	12/05/81	739.000	738.000			738.000
CONDUCTIVITY	19/05/81	740.000	735.000			735.000
CONDUCTIVITY	25/05/81	740.000	728.000			723.000
CONDUCTIVITY	02/06/81	723.000	728.000			728.000
CONDUCTIVITY	09/06/81	735.000	730.000			720.000
CONDUCTIVITY	23/06/81	705.000	720.000			720.000
CONDUCTIVITY	30/06/81	730.000	730.000			730.000
CONDUCTIVITY	07/07/81	741.000	744.000			730.000
CONDUCTIVITY	14/07/81	719.000	714.000			712.000
CONDUCTIVITY	21/07/81					720.000
CONDUCTIVITY	04/08/81	722.000	718.000			720.000
CONDUCTIVITY	11/08/81	719.000	719.000			719.000
CONDUCTIVITY	18/08/81	721.000	720.000			711.000
CONDUCTIVITY	25/08/81	712.000	710.000			710.000
CONDUCTIVITY	01/09/81	708.000	709.000			709.000
CONDUCTIVITY	08/09/81	720.000	713.000			709.000
CONDUCTIVITY	15/09/81	721.000	715.000			713.000
CONDUCTIVITY	23/09/81	710.000	710.000			715.000
CONDUCTIVITY	29/09/81	706.000	710.000			711.000
CONDUCTIVITY	06/10/81	710.000	708.000			715.000
CONDUCTIVITY	13/10/81	720.000	720.000			715.000
CONDUCTIVITY	20/10/81	725.000	725.000			735.000
CONDUCTIVITY	27/10/81	732.000	735.000			710.000
CONDUCTIVITY	10/11/81	715.000	725.000			720.000
CONDUCTIVITY	17/11/81	735.000	732.000			735.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
CONDUCTIVITY	25/11/81	732.000	728.000			730.000
CONDUCTIVITY	01/12/81	730.000	728.000			728.000
CONDUCTIVITY	09/12/81	735.000	730.000			740.000
CONDUCTIVITY	05/01/82					735.000
CONDUCTIVITY	02/02/82	735.000	735.000			730.000
CONDUCTIVITY	09/02/82	730.000	728.000			725.000
CONDUCTIVITY	16/02/82	735.000	735.000			738.000
CONDUCTIVITY	23/02/82	740.000	730.000			728.000
CONDUCTIVITY	10/03/82	723.000	728.000			730.000
CONDUCTIVITY	16/03/82	720.000	725.000			725.000
CONDUCTIVITY	23/03/82	720.000	718.000			722.000
CONDUCTIVITY	30/03/82	712.000	712.000			715.000
CONDUCTIVITY	19/04/83	735.000	736.000			730.000
CONDUCTIVITY	26/04/83	735.000	735.000			740.000
CONDUCTIVITY	17/05/83	740.000	731.000			740.000
CONDUCTIVITY	31/05/83	785.000	780.000			785.000
CONDUCTIVITY	07/06/83	720.000	720.000			730.000
CONDUCTIVITY	22/06/83	721.000	715.000			725.000
CONDUCTIVITY	12/07/83	683.000	681.000			796.000
CONDUCTIVITY	02/08/83	708.000	698.000			651.000
CONDUCTIVITY	10/08/83	688.000	700.000			750.000
CONDUCTIVITY	31/08/83	665.000	675.000			680.000
CONDUCTIVITY	06/09/83	700.000	702.000			715.000
CONDUCTIVITY	13/09/83	690.000	695.000			698.000
CONDUCTIVITY	20/09/83	701.000	700.000			
CONDUCTIVITY	10/10/83	680.000	680.000			705.000
CONDUCTIVITY	24/10/83					709.000
CONDUCTIVITY	07/11/83	693.000	694.000			696.000
CONDUCTIVITY	21/11/83					722.000
CONDUCTIVITY	28/11/83	730.000	730.000			731.000
CONDUCTIVITY	09/01/84	732.000	740.000			735.000
CONDUCTIVITY	30/01/84					723.000
CONDUCTIVITY	06/02/84					723.000
CONDUCTIVITY	20/02/84	715.000	692.000			735.000
CONDUCTIVITY	12/03/84	755.000	755.000			765.000
CONDUCTIVITY	19/03/84					713.000
CONDUCTIVITY	02/04/84	728.000	716.000			725.000
CONDUCTIVITY	09/04/84	738.000	730.000			739.000
CONDUCTIVITY	16/04/84	680.000	693.000			682.000
CONDUCTIVITY	14/05/84	709.000	703.000			719.000
CONDUCTIVITY	21/05/84	749.000	750.000			758.000
CONDUCTIVITY	04/06/84	744.000	748.000			753.000
CONDUCTIVITY	11/06/84	731.000	735.000			742.000
CONDUCTIVITY	18/06/84		691.000			723.000
CONDUCTIVITY	17/07/84	710.000	710.000			710.000
CONDUCTIVITY	23/07/84	689.000	690.000			697.000
CONDUCTIVITY	30/07/84	733.000	738.000			731.000
CONDUCTIVITY	07/08/84	715.000	721.000			705.000
CONDUCTIVITY	05/09/84					725.000
CONDUCTIVITY	19/09/84					730.000
CONDUCTIVITY	08/10/84		723.000			750.000
CONDUCTIVITY	17/10/84					763.000
CONDUCTIVITY	30/10/84					741.000
CONDUCTIVITY	05/11/84					10.500
CONDUCTIVITY	13/11/84	717.000	720.000			760.000
CONDUCTIVITY	26/11/84	719.000	721.000			740.000

DETERMINAND	DATE	NI	ST	S12	IN	LT
CONDUCTIVITY	17/12/84					730.000
CONDUCTIVITY	04/02/85					765.000
CONDUCTIVITY	12/02/85					768.000
CONDUCTIVITY	09/04/85					7.000
CONDUCTIVITY	20/05/91	902.18	902.29	636.64		905.17
CONDUCTIVITY	28/05/91	910.19	910.37	916.89		917.85
CONDUCTIVITY	03/06/91	912.79	912.45	918.83		917.43
CONDUCTIVITY	10/06/91	909.47	908.16	915.21		916.47
CONDUCTIVITY	17/06/91	913.52	915.1	922.11		918.78
CONDUCTIVITY	24/06/91	906.1	908.99	915.72		913.18
CONDUCTIVITY	01/07/91	907.81	906.95	915.05		909.46
CONDUCTIVITY	08/07/91	899.89	895.04	908.41		912.7
CONDUCTIVITY	15/07/91	917.09	915.87	916.75		914.26
CONDUCTIVITY	25/07/91	906.59				
CONDUCTIVITY	27/07/91	890.62	887.6	896.03		892.43
CONDUCTIVITY	05/08/91	891.81	889.49	890.62		892.07
CONDUCTIVITY	12/08/91	888.88	889.31	890.68		884.5
CONDUCTIVITY	20/08/91	884.05	892.4	895.1		895.12
CONDUCTIVITY	27/08/91	893.58	889.56	888.67		884.84
CONDUCTIVITY	02/09/91	880.03	881.06	875.65		888.78
CONDUCTIVITY	09/09/91	887.98	888	887.22		894.08
CONDUCTIVITY	16/09/91	899.24	898.22	895.48		899.64
CONDUCTIVITY	25/09/91	902.16	900.64	896.27		901.1
CONDUCTIVITY	01/10/91	895.68	898.81	905.27		904.46
CONDUCTIVITY	07/10/91	906.29	906.99	913.84		915.32
CONDUCTIVITY	21/10/91	915.58	914.62	920.55		920.19
CONDUCTIVITY	28/10/91	910.01	910.23	913.96		914.78
CONDUCTIVITY	04/11/91	912.21	912.86			
CONDUCTIVITY	11/11/91	914.03	914.32	926.1		922.85
CONDUCTIVITY	18/11/91	913.51	913.35	920.02		918.82
CONDUCTIVITY	25/11/91	907.71	912.72	914.5		921.15
CONDUCTIVITY	02/12/91	910.51	909.83	914.73		917.85
CONDUCTIVITY	10/12/91	909.45	912.86	919.43		928.39
CONDUCTIVITY	17/12/91	900.61	902	913.6		917.13
CONDUCTIVITY	07/01/92	917.47	919.49	930.79		928.33
CONDUCTIVITY	13/01/92	910.15	910.59	916.95		930.83
CONDUCTIVITY	20/01/92	913.5	915.18	919.46		925.69
CONDUCTIVITY	27/01/92	911.52	911.12	919.37		928.02
CONDUCTIVITY	03/02/92	911.65	912.72	927.73		
CONDUCTIVITY	10/02/92		924.38	945.5		
CONDUCTIVITY	17/02/92	927.89	930.97	948.94		939.95
CONDUCTIVITY	24/02/92	927.1	928.86	947.89		
CONDUCTIVITY	02/03/92	941.72	944.4	959.12		
CONDUCTIVITY	09/03/92	937.67	940.78	959.79		
CONDUCTIVITY	16/03/92	943.89	945.94	961.7		952.21
CONDUCTIVITY	23/03/92	951.22	952.47	966.24		962.08
CONDUCTIVITY	30/03/92	947.04	952.74	963.3		966.17
CONDUCTIVITY	06/04/92	953.47	955.07	959.18		963.4
CONDUCTIVITY	21/04/92	952.45	953.89	958.17		35.12
CONDUCTIVITY	29/04/92	955.63	955.7	965.57		869.43
CONDUCTIVITY	05/05/92	951.07				
CONDUCTIVITY	11/05/92	957.78	949.74		965.68	921.73
CONDUCTIVITY	18/05/92	946.7	948.83	956.34	957.39	967.37
CONDUCTIVITY	26/05/92	908.54	919.72			941.42
CONDUCTIVITY	09/06/92	953.94	954.57	948.02		946.51
CONDUCTIVITY	15/06/92	922.67	920.76	921.63		921.64

DETERMINAND	DATE	NI	ST	SI2	IN	LT
CONDUCTIVITY	22/06/92	941.32	941.28	942		947.39
CONDUCTIVITY	29/06/92	913.87	914.18	911.01		926.48
CONDUCTIVITY	06/07/92	942.36	942.66	944.33		942.35
CONDUCTIVITY	13/07/92	930.93	933.67	943.32		942.04
CONDUCTIVITY	20/07/92	917.79	918.97	928.99		928.28
CONDUCTIVITY	27/07/92	912.7	915.54	923.98		928.85
CONDUCTIVITY	03/08/92	915.74	917.18	919.85		926.43
CONDUCTIVITY	10/08/92	930.82	934.07	933.37		931.02
CONDUCTIVITY	17/08/92	915.5	920.38			
CONDUCTIVITY	24/08/92	925.8	924.1	921.42		922.35
CONDUCTIVITY	01/09/92	933.21	932.16	935.77		931.45
CONDUCTIVITY	07/09/92	928.82	929.77	932.32		933.09
CONDUCTIVITY	14/09/92	925.67	926.76	933.11		933.63
CONDUCTIVITY	21/09/92	930.17	928.66	932.37		934.21
CONDUCTIVITY	28/09/92	914.19	910.59	899.17		
CONDUCTIVITY	05/10/92	911.41	916.14	910.8		921.13
CONDUCTIVITY	12/10/92	911.47	913.55	909.36		917.7
CONDUCTIVITY	19/10/92	913.77	915.28	917.01		921.06
CONDUCTIVITY	26/10/92	916.77	911.5	912.12		920.73
CONDUCTIVITY	03/11/92	902.57	904.25	904.26		914.67
CONDUCTIVITY	09/11/92	897.65	902.51	905.55		912.78
CONDUCTIVITY	16/11/92	898.56	903.27	905.44		914.54
CONDUCTIVITY	23/11/92	880.1				
CONDUCTIVITY	03/12/92	890.43	894.83	893.26		905.51
CONDUCTIVITY	07/12/92	878.86	884.76	885.58		899.78
CONDUCTIVITY	14/12/92	879.77	881.27	885.6		894.01
CONDUCTIVITY	21/12/92	901.23	897.86	895.62		903.48
CONDUCTIVITY	04/01/93	886.89	888.33	886.56		898.08
CONDUCTIVITY	01/02/93	343.27	344.11	344.91		347.85
CONDUCTIVITY	08/02/93	342.19		344.02		346.9
CONDUCTIVITY	15/02/93			345.29		346.71
CONDUCTIVITY	22/02/93	344.56		348.22		348.5
CONDUCTIVITY	01/03/93	3.15		335.06		339.77
CONDUCTIVITY	08/03/93	330.34		329.27		334.23
CONDUCTIVITY	15/03/93	356.05		356.88		344.18
CONDUCTIVITY	22/03/93	363.86		374.05		370.46
CONDUCTIVITY	29/03/93	369.44		376.68		375.93
CONDUCTIVITY	05/04/93	384.6		389.3		384.44
CONDUCTIVITY	13/04/93	405.85		402.29		399.72
CONDUCTIVITY	19/04/93	410.07		416.26		415.7
CONDUCTIVITY	26/04/93	442.92		444.41	447.63	441.2
CONDUCTIVITY	04/05/93	468.01		475.96	473.27	485.24
CONDUCTIVITY	10/05/93	483.51		482.74	477.42	469.88
CONDUCTIVITY	17/05/93	481.75		482.92	487.03	476.22
CONDUCTIVITY	24/05/93	507.45		502.78	503.55	
CONDUCTIVITY	07/06/93	556.05			594.13	620.54
CONDUCTIVITY	14/06/93	559.03		557.89	557	559.76
CONDUCTIVITY	06/09/93	820.05	820.83			
CONDUCTIVITY	13/09/93	820.2		824.4		830
CONDUCTIVITY	20/09/93	821.4	823.6		826.6	830.2
CONDUCTIVITY	27/09/93	834.2		839.5		
CONDUCTIVITY	04/10/93	822.5	823.6	826.9		830.5
CONDUCTIVITY	11/10/93	817.2	824.5	820.4	825.1	833.3
CONDUCTIVITY	19/10/93	830.4	832.3	830.4	827	835.9
CONDUCTIVITY	25/10/93	820.6	821.8	824.4	828.5	834.8
CONDUCTIVITY	01/11/93	820.2	822.8	828.4	836.6	836.3

DETERMINAND	DATE	NT	ST	ST2	IN	LT
CONDUCTIVITY	08/11/93	821.6	823.4	828.1	833.4	839.2
CONDUCTIVITY	15/11/93	822.8	821.1			
CONDUCTIVITY	22/11/93	817.5	826.2	825.8	831.1	838.8
CONDUCTIVITY	06/12/93			810.75		
CONDUCTIVITY	10/01/94	775	784.1	781		
CONDUCTIVITY	24/01/94		775.7			
CONDUCTIVITY	07/02/94		777.3	780.1	785.9	792.8
CONDUCTIVITY	21/02/94	778.1			787.9	796.1
CONDUCTIVITY	01/03/94	515.69	782.43	776.67	789.54	795.76
CONDUCTIVITY	07/03/94		764.93	766.79	768.78	138.03
CONDUCTIVITY	15/03/94	8.37		8.55	8.51	8.51
CONDUCTIVITY	16/05/94	775.6		784.9	796.4	0.4
CONDUCTIVITY	23/05/94	769.2		774	782.5	790.6
CONDUCTIVITY	31/05/94	765.5		764.3	768.6	774.1
CONDUCTIVITY	06/06/94	769.1	768.4	776.1	795.1	780.3
CONDUCTIVITY	13/06/94	775.2		774.2	775.5	778.9
CONDUCTIVITY	20/06/94	771.3		778.7	774.7	780.2
CONDUCTIVITY	27/06/94	772		769.9	769.2	771.2
CONDUCTIVITY	04/07/94	758		761.8	761.9	767.8
CONDUCTIVITY	11/07/94	754.3		755.3	754.9	756.9
CONDUCTIVITY	18/07/94	769		765.7	767.2	773.3
CONDUCTIVITY	25/07/94	735.7		743.4	749.4	754.9
CONDUCTIVITY	01/08/94	744.4		749.2	750.9	750.4
CONDUCTIVITY	08/08/94	754.5		754.4	761	772.2
CONDUCTIVITY	15/08/94	759.3		770.1	772.2	774.5
CONDUCTIVITY	22/08/94	758.1		760.1	762.4	765.8
CONDUCTIVITY	30/08/94	761.5		766.8	768.6	771.2
CONDUCTIVITY	05/09/94	767.1		778.3	786.4	776.4
CONDUCTIVITY	12/09/94	764.5		775	779.6	778.6
CONDUCTIVITY	19/09/94	7.79		8.11	8.13	8.05
CONDUCTIVITY	26/09/94	767		766.3	778.7	774
CONDUCTIVITY	07/10/94	772.2		779.7	781.7	784
CONDUCTIVITY	10/10/94	767.5		776	777.3	776.8
CONDUCTIVITY	17/10/94	770.4		776.5	821.1	785.4
CONDUCTIVITY	24/10/94	772.8		779.4	780.2	250.7
CONDUCTIVITY	21/11/94	770.3		773.7	789.4	781.1
CONDUCTIVITY	05/12/94	769.5		776.8	778.9	783.5
CONDUCTIVITY	12/12/94	769.87		777.14	780.52	782.48
CONDUCTIVITY	19/12/94	768.27		777.95	784.85	788.42
TOTAL P	21/04/86	0.140				
TOTAL P	29/04/86	0.120				
TOTAL P	06/05/86	0.120				
TOTAL P	12/05/86	0.120				
TOTAL P	19/05/86	0.110				
TOTAL P	16/06/86	0.070				
TOTAL P	23/06/86	0.090				
TOTAL P	22/07/86	0.080				
TOTAL P	02/09/86	0.160				
TOTAL P	08/09/86	0.150				
TOTAL P	30/09/86	0.150				
TOTAL P	08/12/86	0.090				
TOTAL P	25/11/87	0.170				
TOTAL P	01/12/87	0.120				
TOTAL P	06/04/88	0.130				
TOTAL P	13/04/88	0.240				
TOTAL P	20/04/88	0.100				

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL P	27/04/88	0.130				
TOTAL P	11/05/88	0.100				
TOTAL P	17/05/88	0.100				
TOTAL P	01/06/88	0.080				
TOTAL P	07/06/88	0.060				
TOTAL P	14/06/88	0.120				
TOTAL P	21/06/88	0.080				
TOTAL P	29/06/88	0.080				
TOTAL P	06/07/88	0.090				
TOTAL P	12/07/88	0.140				
TOTAL P	20/07/88	0.090				
TOTAL P	17/08/88	0.110				
TOTAL P	24/08/88	0.130				
TOTAL P	07/09/88	0.100				
TOTAL P	14/09/88	0.140				
TOTAL P	28/09/88	0.150				
TOTAL P	11/10/88	0.170				
TOTAL P	19/10/88	0.200				
TOTAL P	29/05/90	0.100				
TOTAL P	29/05/90	0.100				
TOTAL P	29/05/90	0.100				0.240
TOTAL P	04/06/90		0.220	0.250		0.190
TOTAL P	11/06/90		0.120	0.210		0.210
TOTAL P	18/06/90	0.200	0.130	0.190		1.230
TOTAL P	25/06/90	1.210	0.250	0.250		0.030
TOTAL P	02/07/90	0.126	0.140	0.160		0.120
TOTAL P	09/07/90	0.090	0.120	0.240		0.149
TOTAL P	16/07/90	0.097	0.114	0.129		0.124
TOTAL P	23/07/90	0.106	0.102	0.087		0.157
TOTAL P	30/07/90	0.064	0.060	0.060		0.060
TOTAL P	06/08/90	0.100	0.100	0.100		0.100
TOTAL P	13/08/90	0.100	0.100	0.100		0.100
TOTAL P	20/08/90	0.100	0.110	0.120		0.100
TOTAL P	29/08/90	0.100	0.100	0.160		
TOTAL P	03/09/90	0.100	0.100	0.100		0.100
TOTAL P	10/09/90	0.100	0.100	0.100		0.100
TOTAL P	24/09/90	0.100	0.100	0.100		0.100
TOTAL P	01/10/90	0.100	0.100	0.100		0.100
TOTAL P	08/10/90	0.100	0.100	0.100		0.100
TOTAL P	15/10/90	0.050	0.040	0.065		0.132
TOTAL P	22/10/90	0.096	0.084	0.099		0.094
TOTAL P	29/10/90	0.098	0.089	0.112		0.094
TOTAL P	05/11/90		0.095	0.125		0.134
TOTAL P	12/11/90	0.160	0.118	0.158		
TOTAL P	19/11/90	0.190	0.180	0.250		0.180
TOTAL P	26/11/90	0.172	0.154	0.359		0.221
TOTAL P	03/12/90	0.144	0.176	0.252		0.279
TOTAL P	12/12/90	0.186	0.199			
TOTAL P	17/12/90	0.170	0.091	0.209		0.328
TOTAL P	07/01/91	0.350	0.330			0.380
TOTAL P	14/01/91	0.350	0.700	0.590		0.640
TOTAL P	28/01/91	0.199	0.244	0.156		0.221
TOTAL P	04/02/91	0.219	0.239	0.141		0.224
TOTAL P	20/02/91	0.106	0.121	0.101		0.106
TOTAL P	25/02/91	0.103	0.155	0.150		0.085
TOTAL P	04/03/91	0.083	0.084	0.090		0.097

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL P	11/03/91		0.069	0.102		0.069
TOTAL P	18/03/91	0.099	0.070	0.063		0.071
TOTAL P	26/03/91	0.090	0.084	0.088		0.082
TOTAL P	03/04/91	0.057	0.062			0.079
TOTAL P	08/04/91	0.053	0.067			0.057
TOTAL P	16/04/91	0.061	0.148	0.071		0.050
TOTAL P	22/04/91	0.047	0.095	0.058		0.045
TOTAL P	30/04/91	0.105	0.020	0.106		0.042
TOTAL P	07/05/91	0.099	0.054	0.102		0.102
TOTAL P	13/05/91	0.076	0.055	0.093		0.102
TOTAL P	20/05/91	0.071	0.053	0.077		0.068
TOTAL P	28/05/91	0.048	0.041	0.073		0.038
TOTAL P	03/06/91	0.044	0.081	0.081		0.083
TOTAL P	10/06/91	0.049	0.056	0.059		0.060
TOTAL P	17/06/91	0.073	0.075	0.079		0.070
TOTAL P	24/06/91	0.076	0.058	0.087		0.112
TOTAL P	01/07/91	0.028	0.040	0.066		0.062
TOTAL P	08/07/91	0.054	0.050	0.053		0.057
TOTAL P	15/07/91	0.077	0.061	0.057		0.057
TOTAL P	22/07/91	0.040	0.035	0.053		0.046
TOTAL P	29/07/91	0.076	0.060	0.045		0.056
TOTAL P	05/08/91	0.044	0.038	0.044		0.056
TOTAL P	12/08/91	0.050	0.048	0.027		0.076
TOTAL P	20/08/91	0.036	0.036	0.027		0.047
TOTAL P	27/08/91	0.042	0.029	0.055		0.045
TOTAL P	02/09/91	0.039	0.037	0.038		0.038
TOTAL P	09/09/91	0.063	0.035	0.042		0.037
TOTAL P	16/09/91	0.036	0.036	0.041		0.082
TOTAL P	25/09/91	0.024	0.028			0.028
TOTAL P	02/10/91	0.041	0.089	0.107		0.146
TOTAL P	07/10/91	0.058	0.054	0.109		0.070
TOTAL P	14/10/91	0.092	0.077	0.089		0.075
TOTAL P	21/10/91	0.070	0.056	0.081		0.067
TOTAL P	28/10/91	0.061	0.062	0.073		0.057
TOTAL P	04/11/91	0.079	0.066	0.112		0.073
TOTAL P	11/11/91	0.086	0.073	0.125		0.099
TOTAL P	18/11/91	0.078	0.076	0.086		0.083
TOTAL P	25/11/91	0.084	0.093	0.128		0.100
TOTAL P	02/12/91	0.092	0.075	0.095		0.107
TOTAL P	10/12/91	0.073	0.072	0.084		0.091
TOTAL P	17/12/91	0.080	0.073	0.098		0.120
TOTAL P	30/12/91	0.079	0.077	0.102		0.076
TOTAL P	07/01/92	0.073	0.065	0.064		0.069
TOTAL P	13/01/92	0.068	0.066	0.096		0.076
TOTAL P	20/01/92	0.071	0.074	0.102		0.093
TOTAL P	27/01/92	0.079	0.084	0.082		0.087
TOTAL P	03/02/92	0.095	0.103	0.131		0.112
TOTAL P	10/02/92	0.112	0.100	0.105		0.096
TOTAL P	17/02/92	0.100	0.102	0.104		0.110
TOTAL P	24/02/92	0.094	0.087	0.089		0.093
TOTAL P	02/03/92	0.075	0.077	0.094		0.083
TOTAL P	09/03/92	0.068	0.071	0.079		0.081
TOTAL P	16/03/92	0.049	0.067	0.069		0.068
TOTAL P	23/03/92	0.062	0.070	0.084		0.065
TOTAL P	30/03/92	0.063	0.061	0.067		0.056
TOTAL P	06/04/92	0.051	0.052	0.060		0.056

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL P	21/04/92	0.039	0.037	0.025		0.033
TOTAL P	29/04/92	0.047	0.037	0.055		0.110
TOTAL P	05/05/92	0.066	0.050	0.061	0.129	0.059
TOTAL P	11/05/92	0.038	0.028	0.033	0.073	0.045
TOTAL P	18/05/92	0.044	0.043	0.050	0.068	0.042
TOTAL P	26/05/92	0.033	0.015	0.051	0.034	0.050
TOTAL P	01/06/92	0.044	0.042	0.037	0.037	0.039
TOTAL P	09/06/92	0.042	0.050	0.037	0.198	0.043
TOTAL P	15/06/92	0.038	0.062	0.086		0.038
TOTAL P	22/06/92	0.046	0.034	0.042		0.041
TOTAL P	29/06/92	0.021	0.028	0.026		0.026
TOTAL P	06/07/92	0.036	0.039	0.051	0.189	0.048
TOTAL P	13/07/92	0.045	0.043	0.067	0.136	0.041
TOTAL P	20/07/92	0.036	0.037	0.050	0.298	0.050
TOTAL P	27/07/92	0.038	0.035	0.042	0.101	0.043
TOTAL P	03/08/92	0.027	0.037	0.029	0.048	0.031
TOTAL P	10/08/92	0.032	0.024	0.041	0.068	0.025
TOTAL P	17/08/92	0.030	0.030	0.040	0.074	0.041
TOTAL P	24/08/92	0.037	0.095	0.049	0.093	0.044
TOTAL P	01/09/92	0.029	0.035	0.062	0.076	0.038
TOTAL P	07/09/92	0.042	0.041	0.062	0.149	0.047
TOTAL P	14/09/92	0.044	0.040	0.048	0.047	0.040
TOTAL P	21/09/92	0.036	0.036	0.040	0.12	0.044
TOTAL P	28/09/92	0.037	0.050	0.033	0.035	0.034
TOTAL P	05/10/92	0.057	0.055	0.052	0.053	0.054
TOTAL P	12/10/92	0.052	0.045	0.038	0.037	0.031
TOTAL P	19/10/92	0.051	0.053	0.035	0.034	0.041
TOTAL P	26/10/92	0.036	0.035	0.037	0.039	0.040
TOTAL P	03/11/92	0.055	0.048	0.049	0.055	0.048
TOTAL P	09/11/92	0.042	0.034	0.034	0.038	0.036
TOTAL P	16/11/92	0.050	0.046	0.054		
TOTAL P	23/11/92	0.055	0.040	0.039	0.043	0.039
TOTAL P	03/12/92	0.043	0.042	0.046		0.041
TOTAL P	07/12/92	0.041	0.041	0.041	0.0416	0.041
TOTAL P	14/12/92	0.056	0.051	0.042	0.0414	0.040
TOTAL P	04/01/93	0.040	0.040	0.039	0.0438	0.041
TOTAL P	18/01/93	0.044	0.044	0.045	0.0468	0.041
TOTAL P	25/01/93	0.046		0.050	0.0476	0.048
TOTAL P	01/02/93	0.044	0.042	0.041	0.0404	0.041
TOTAL P	08/02/93	0.045		0.039	0.0397	0.039
TOTAL P	15/02/93	0.041		0.037	0.0468	0.039
TOTAL P	22/02/93	0.041		0.068	0.101	0.045
TOTAL P	01/03/93	0.046		0.073	0.1	0.062
TOTAL P	08/03/93	0.047		0.073	0.0645	0.060
TOTAL P	15/03/93	0.055		0.074	0.119	0.061
TOTAL P	22/03/93	0.060		0.088	0.112	0.066
TOTAL P	29/03/93	0.060		0.090	0.141	0.071
TOTAL P	05/04/93	0.052		0.104	0.123	0.070
TOTAL P	13/04/93	0.094		0.103	0.504	0.106
TOTAL P	19/04/93	0.099		0.130	0.0903	0.116
TOTAL P	26/04/93	0.063		0.059	0.0621	0.058
TOTAL P	04/05/93	0.062		0.063	0.116	0.062
TOTAL P	10/05/93	0.059		0.060	0.0644	0.063
TOTAL P	17/05/93	0.053		0.051	0.0921	0.060
TOTAL P	24/05/93	0.044		0.039	0.0408	0.041
TOTAL P	01/06/93	0.054		0.048	0.14	0.051

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL P	07/06/93	0.044		0.056	0.0446	0.058
TOTAL P	14/06/93	0.037		0.038	0.0663	0.063
TOTAL P	21/06/93	0.033		0.059	0.0604	0.044
TOTAL P	28/06/93	0.040		0.058	0.0669	0.053
TOTAL P	05/07/93	0.041		0.052	0.0569	0.048
TOTAL P	12/07/93	0.035		0.031	0.032	0.083
TOTAL P	19/07/93	0.042		0.044	0.0432	0.064
TOTAL P	26/07/93	0.052	0.050	0.051	0.0415	0.053
TOTAL P	02/08/93	0.036	0.037	0.037	0.0336	0.040
TOTAL P	09/08/93	0.050	0.034	0.035	0.0356	0.040
TOTAL P	16/08/93	0.060	0.045	0.053	0.0468	0.044
TOTAL P	23/08/93	0.042	0.037	0.044	0.0459	0.032
TOTAL P	31/08/93	0.034	0.024	0.032	0.0327	0.023
TOTAL P	06/09/93	0.020	0.023	0.023	0.0125	0.024
TOTAL P	13/09/93	0.035	0.025	0.032	0.0414	0.029
TOTAL P	20/09/93	0.025	0.026		0.0265	0.022
TOTAL P	27/09/93	0.026		0.022		
TOTAL P	04/10/93	0.036	0.037	0.036	0.0364	0.034
TOTAL P	11/10/93	0.031	0.034	0.033	0.0326	0.029
TOTAL P	19/10/93	0.038	0.034	0.034	0.0343	0.033
TOTAL P	25/10/93	0.290	0.039	0.034	0.0381	0.045
TOTAL P	01/11/93	0.051	0.038	0.041	0.0323	0.052
TOTAL P	08/11/93	0.027	0.026	0.025	0.0184	0.025
TOTAL P	15/11/93	0.032	0.038	0.032	0.0485	0.032
TOTAL P	22/11/93	0.097	0.035	0.038	0.0355	0.036
TOTAL P	29/11/93	0.042		0.043		0.041
TOTAL P	06/12/93	0.029	0.030	0.039	0.0397	0.035
TOTAL P	13/12/93	0.048	0.043	0.054	0.0988	0.047
TOTAL P	10/01/94	0.033	0.031	0.032	0.031	0.035
TOTAL P	17/01/94	0.045		0.045	0.028	0.040
TOTAL P	24/01/94		0.049	0.042	0.049	0.043
TOTAL P	31/01/94		0.200	0.200	0.2	0.200
TOTAL P	07/02/94		0.200	0.200	0.2	
TOTAL P	21/02/94			0.040	0.049	0.042
TOTAL P	01/03/94		0.055	0.200	0.2	0.200
TOTAL P	07/03/94		0.051	0.055	0.032	0.048
TOTAL P	15/03/94		0.043	0.055	0.047	0.064
TOTAL P	21/03/94		0.045	0.038	0.039	0.035
TOTAL P	28/03/94	0.083	0.032	0.035	0.043	0.037
TOTAL P	11/04/94	0.020	0.023	0.024	0.022	0.025
TOTAL P	18/04/94	0.024	0.022	0.027	0.025	0.024
TOTAL P	25/04/94	0.021	0.020	0.020	0.02	0.031
TOTAL P	03/05/94	0.020	0.020	0.020	0.02	
TOTAL P	09/05/94	0.026	0.027	0.029	0.029	0.029
TOTAL P	16/05/94	0.020	0.044	0.025	0.043	0.020
TOTAL P	23/05/94	0.032	0.024	0.033	0.066	0.040
TOTAL P	31/05/94	0.025	0.014	0.011	0.019	0.006
TOTAL P	06/06/94	0.034	0.045	0.041	0.044	0.040
TOTAL P	13/06/94	0.028	0.023	0.034	0.03	0.035
TOTAL P	20/06/94	0.048	0.022	0.057	0.034	0.065
TOTAL P	27/06/94	0.041	0.034	0.044	0.068	0.053
TOTAL P	04/07/94	0.019	0.010	0.017	0.008	0.018
TOTAL P	11/07/94	0.184	0.105	0.148	0.134	0.143
TOTAL P	18/07/94	0.066	0.060	0.051	0.076	0.073
TOTAL P	25/07/94	0.069	0.068	0.063	0.064	0.072
TOTAL P	01/08/94	0.051	0.065	0.054	0.054	0.112

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL P	08/08/94	0.020	0.040	0.020	0.04	0.020
TOTAL P	15/08/94	0.025	0.030	0.028	0.034	0.030
TOTAL P	22/08/94	0.025	0.026	0.035	0.03	0.023
TOTAL P	30/08/94	0.028	0.020	0.021	0.023	0.040
TOTAL P	05/09/94	0.020	0.020	0.020	0.02	0.020
TOTAL P	12/09/94	0.021	0.020	0.025	0.022	0.020
TOTAL P	19/09/94	0.020	0.022	0.031	0.033	0.024
TOTAL P	26/09/94	0.020	0.020	0.020	0.071	0.020
TOTAL P	03/10/94	0.020	0.020	0.020	0.063	0.020
TOTAL P	10/10/94	0.020	0.020	0.020	0.021	0.020
TOTAL P	17/10/94	0.020	0.023	0.015	0.023	0.012
TOTAL P	24/10/94	0.030	0.008	0.012	0.012	0.018
TOTAL P	31/10/94	0.013	0.013	0.017	0.018	0.011
TOTAL P	07/11/94	0.043	0.050	0.049	0.049	0.054
TOTAL P	14/11/94	0.008	0.010	0.014	0.018	0.013
TOTAL P	21/11/94	0.102	0.087	0.049	0.0982	0.098
TOTAL P	28/11/94	0.047	0.046	0.056	0.0827	0.057
TOTAL P	05/12/94	0.037	0.026	0.014	0.032	0.028
TOTAL P	12/12/94	0.088	0.066	0.060	0.068	0.083
TOTAL P	19/12/94	0.061	0.110	0.090	0.0922	0.060
TOTAL N	07/04/81	2.060	2.050			2.290
TOTAL N	13/04/81	2.060	2.050			2.140
TOTAL N	22/04/81	2.070	2.060			2.180
TOTAL N	06/05/81	2.190	2.230			2.260
TOTAL N	12/05/81	2.180	2.220			2.190
TOTAL N	19/05/81	2.150	2.060			2.180
TOTAL N	25/05/81	2.000	2.040			2.020
TOTAL N	02/06/81	1.970	1.970			2.040
TOTAL N	09/06/81	1.930	1.930			1.980
TOTAL N	23/06/81	1.820	1.820			1.880
TOTAL N	30/06/81	1.890	1.800			1.880
TOTAL N	07/07/81	1.870	1.830			1.830
TOTAL N	14/07/81	1.870	1.820			1.920
TOTAL N	21/07/81					1.920
TOTAL N	04/08/81	1.420	1.460			1.440
TOTAL N	11/08/81	1.620	1.570			1.560
TOTAL N	18/08/81	1.470	1.470			1.370
TOTAL N	25/08/81	1.450	1.410			1.490
TOTAL N	01/09/81	1.320	1.270			1.310
TOTAL N	08/09/81	1.350	1.300			1.350
TOTAL N	15/09/81	1.260	1.250			1.370
TOTAL N	23/09/81	1.110	1.140			1.240
TOTAL N	29/09/81	1.180	1.220			1.230
TOTAL N	06/10/81	1.130	1.080			1.300
TOTAL N	13/10/81	1.180	1.140			1.230
TOTAL N	20/10/81	1.240	1.230			1.250
TOTAL N	27/10/81	1.230	1.320			1.320
TOTAL N	10/11/81	1.240	1.290			1.250
TOTAL N	17/11/81	1.370	1.270			1.310
TOTAL N	25/11/81	1.310	1.210			1.300
TOTAL N	01/12/81	1.400	1.400			1.330
TOTAL N	09/12/81	1.420	1.420			1.410
TOTAL N	05/01/82					1.700
TOTAL N	02/02/82	2.050	1.960			1.950
TOTAL N	09/02/82	1.980	1.980			2.010
TOTAL N	16/02/82	1.920	1.920			2.010

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL N	23/02/82	2.050	1.900			2.040
TOTAL N	10/03/82	2.400	2.220			2.170
TOTAL N	16/03/82	2.150	2.140			2.120
TOTAL N	23/03/82	2.310	2.170			2.310
TOTAL N	30/03/82	2.280	2.230			2.410
TOTAL N	06/04/82	2.280	2.190			2.310
TOTAL N	13/04/82	2.340	2.160			2.210
TOTAL N	21/04/82	2.120	2.070			2.170
TOTAL N	27/04/82	2.380	2.330			2.330
TOTAL N	04/05/82	2.140	2.230			2.330
TOTAL N	11/05/82	2.340				
TOTAL N	18/05/82	2.140	2.140			2.230
TOTAL N	02/06/82	2.160	2.040			2.080
TOTAL N	08/06/82	1.920	1.970			1.970
TOTAL N	16/06/82	2.080	2.080			1.990
TOTAL N	29/06/82	2.060	1.970			1.990
TOTAL N	06/07/82	1.850	1.850			1.900
TOTAL N	14/07/82	1.720	1.660			1.850
TOTAL N	20/07/82	1.620	1.620			1.690
TOTAL N	27/07/82	1.730	1.680			1.730
TOTAL N	03/08/82	1.530	1.390			1.530
TOTAL N	10/08/82	1.460	1.410			1.410
TOTAL N	17/08/82	1.360	1.360			1.440
TOTAL N	24/08/82	1.370	1.420			1.480
TOTAL N	31/08/82	1.250	1.210			1.350
TOTAL N	07/09/82	1.170	1.170			1.310
TOTAL N	14/09/82	1.280	1.240			1.190
TOTAL N	22/09/82					1.140
TOTAL N	28/09/82	1.150	1.110			1.200
TOTAL N	05/10/82	1.100	1.050			1.130
TOTAL N	12/10/82	1.180	1.130			1.260
TOTAL N	19/10/82	1.140	1.090			1.200
TOTAL N	26/10/82	1.140	1.180			1.330
TOTAL N	02/11/82	1.270	1.310			1.360
TOTAL N	09/11/82	1.340	1.330			1.320
TOTAL N	23/11/82	1.430	1.390			1.440
TOTAL N	30/11/82	1.520	1.510			1.460
TOTAL N	07/12/82	1.550	1.500			1.440
TOTAL N	14/12/82	1.550	1.460			1.650
TOTAL N	05/01/83	1.790	1.790			1.840
TOTAL N	25/01/83	1.970	2.170			2.190
TOTAL N	02/02/83	2.180	2.240			2.210
TOTAL N	01/03/83	2.360	2.200			2.310
TOTAL N	08/03/83	2.480	2.480			2.520
TOTAL N	16/03/83	2.560	2.430			2.470
TOTAL N	18/12/84		1.250			
TOTAL N	18/12/84		0.930			
TOTAL N	18/12/84		1.250			
TOTAL N	01/09/88		2.100			2.220
TOTAL N	29/05/90	2.740				2.880
TOTAL N	29/05/90	2.740				2.880
TOTAL N	29/05/90	2.740				2.880
TOTAL N	04/06/90		3.010	3.040		3.050
TOTAL N	11/06/90		2.900	2.880		2.940
TOTAL N	18/06/90	3.580	2.710	2.810		2.770
TOTAL N	25/06/90	2.880	2.970	2.950		2.970

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL N	02/07/90	2.540	2.500	2.510		2.600
TOTAL N	09/07/90	2.500	2.330	2.390		2.460
TOTAL N	16/07/90	2.120	2.060	2.010		2.080
TOTAL N	23/07/90	1.810	1.940	1.800		2.150
TOTAL N	30/07/90	1.620	1.610	1.730		1.530
TOTAL N	06/08/90	0.788	1.620	1.640		1.560
TOTAL N	13/08/90	1.420	1.460	1.340		1.460
TOTAL N	20/08/90	1.440	1.830	1.710		1.550
TOTAL N	29/08/90	1.250	1.260	1.270		1.240
TOTAL N	03/09/90	3.330	1.430	1.490		1.460
TOTAL N	10/09/90	0.845	0.751	1.060		0.749
TOTAL N	18/09/90	1.330	1.280	1.200		1.080
TOTAL N	24/09/90	1.270	1.300	1.260		1.210
TOTAL N	01/10/90	1.210	1.200	1.120		1.180
TOTAL N	08/10/90	1.130	1.040	1.140		1.150
TOTAL N	15/10/90	1.140	1.210	1.080		1.270
TOTAL N	22/10/90	1.050	1.150	1.110		1.110
TOTAL N	29/10/90	1.180	1.140	1.250		1.210
TOTAL N	05/11/90		0.865	1.040		1.000
TOTAL N	12/11/90	1.160	1.170	1.170		1.180
TOTAL N	19/11/90	1.370	1.410	1.670		4.080
TOTAL N	26/11/90	1.490	1.420	1.680		1.800
TOTAL N	03/12/90	0.500	0.500	0.500		0.500
TOTAL N	12/12/90	1.310	1.390			
TOTAL N	17/12/90	0.500	0.500	0.500		0.500
TOTAL N	07/01/91	0.870	0.940			1.000
TOTAL N	14/01/91	1.510	1.460	2.300		1.680
TOTAL N	21/01/91	2.790	2.870	4.000		3.250
TOTAL N	28/01/91	2.720	2.700	3.820		3.530
TOTAL N	04/02/91	2.790	2.830	3.690		3.530
TOTAL N	20/02/91	4.180	4.240	4.910		4.350
TOTAL N	25/02/91	4.070	4.100	4.960		4.600
TOTAL N	04/03/91	4.560	4.560	5.480		5.080
TOTAL N	11/03/91	4.810	4.810	5.970		5.580
TOTAL N	18/03/91	5.240	5.270	6.700		6.370
TOTAL N	26/03/91	6.090	6.100	6.780		6.650
TOTAL N	03/04/91	6.520	6.430			6.650
TOTAL N	08/04/91	6.460	6.530			6.620
TOTAL N	16/04/91	6.560	6.570	6.650		6.800
TOTAL N	22/04/91	6.610	6.660	6.590		6.820
TOTAL N	30/04/91	5.420	6.310	6.460		6.710
TOTAL N	07/05/91	6.640	6.560	6.620		6.660
TOTAL N	13/05/91	6.600	6.580	6.500		6.560
TOTAL N	20/05/91	6.540	6.550	6.590		6.510
TOTAL N	28/05/91	6.070	6.140	6.170		6.200
TOTAL N	03/06/91	5.770	5.870	5.880		5.930
TOTAL N	10/06/91	6.010	6.030	5.970		6.110
TOTAL N	17/06/91	6.050	6.160	6.020		6.100
TOTAL N	24/06/91	6.230	6.080	6.230		6.360
TOTAL N	01/07/91	5.990	5.580	5.810		5.610
TOTAL N	08/07/91	5.400	5.570	5.510		5.590
TOTAL N	15/07/91	5.480	5.260	5.540		5.610
TOTAL N	22/07/91	5.130	6.610	5.460		5.510
TOTAL N	29/07/91	4.790	4.780	5.100		4.830
TOTAL N	05/08/91	4.660	4.880	4.890		4.650
TOTAL N	12/08/91	4.790	4.790	4.800		4.640

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL N	20/08/91	4.360	4.290	4.330		4.510
TOTAL N	27/08/91	4.040	4.040	4.050		4.020
TOTAL N	02/09/91	3.820	3.880	3.790		3.980
TOTAL N	09/09/91	3.680	3.800	3.680		3.880
TOTAL N	16/09/91	3.590	3.430	3.340		3.440
TOTAL N	25/09/91	3.290	3.330			3.400
TOTAL N	02/10/91	3.430	3.290	3.370		3.280
TOTAL N	07/10/91	3.210	3.190	3.280		3.270
TOTAL N	14/10/91	3.190	3.120	3.170		3.250
TOTAL N	21/10/91	3.140	3.140	3.120		3.140
TOTAL N	28/10/91	3.200	3.270			
TOTAL N	04/11/91	3.120	2.860	3.180		3.140
TOTAL N	11/11/91	3.030	3.100	3.320		3.160
TOTAL N	18/11/91	3.230	3.150	3.280		3.260
TOTAL N	25/11/91	3.070	3.130	3.730		3.290
TOTAL N	02/12/91	3.170	3.060	3.550		3.710
TOTAL N	10/12/91	3.070	3.020	3.470		3.520
TOTAL N	17/12/91	3.150	3.260	3.650		3.620
TOTAL N	30/12/91	3.900	3.860	4.320		3.770
TOTAL N	07/01/92	4.030	3.950	4.300		4.200
TOTAL N	13/01/92	4.300	4.190	5.290		4.280
TOTAL N	20/01/92	4.360	4.510	5.750		5.250
TOTAL N	27/01/92	4.830	4.950	5.880		5.480
TOTAL N	03/02/92	4.790	4.780	5.490		4.970
TOTAL N	10/02/92	5.240	5.280	5.790		5.360
TOTAL N	17/02/92	5.600	5.540	6.090		5.660
TOTAL N	24/02/92	5.580	5.530	5.860		5.670
TOTAL N	02/03/92	6.140	6.120	6.420		6.090
TOTAL N	09/03/92	6.470	6.430	6.690		6.580
TOTAL N	16/03/92	6.300	6.320	6.460		6.350
TOTAL N	23/03/92	6.180	6.180	6.320		6.230
TOTAL N	30/03/92	6.430	6.460	6.790		6.670
TOTAL N	06/04/92	6.270	6.370	7.040		6.600
TOTAL N	21/04/92	6.870	6.800	7.080		7.040
TOTAL N	29/04/92	6.740	6.730	6.880		6.780
TOTAL N	05/05/92	6.960	6.970	6.740	7.150	6.850
TOTAL N	11/05/92	6.680	6.680	6.730	6.700	6.710
TOTAL N	18/05/92	6.340	6.400	6.280	6.580	6.510
TOTAL N	26/05/92	6.370	6.450	6.310	6.440	6.580
TOTAL N	01/06/92	5.970	5.900	5.970	6.060	6.110
TOTAL N	09/06/92	6.140	6.200	6.080	6.700	6.080
TOTAL N	15/06/92	6.040	6.030	6.040		6.040
TOTAL N	22/06/92	6.090	6.060	5.960		6.110
TOTAL N	29/06/92	5.860	5.870	5.770		5.940
TOTAL N	06/07/92	5.730	5.740	5.650	5.890	5.750
TOTAL N	13/07/92	5.360	5.410	5.420	5.870	5.410
TOTAL N	20/07/92	5.360	5.380	5.430	5.540	5.400
TOTAL N	27/07/92	5.350	5.420	5.300	5.480	5.340
TOTAL N	03/08/92	5.090	5.300	5.240	5.200	5.160
TOTAL N	10/08/92	4.950	4.940	4.970	5.070	5.030
TOTAL N	17/08/92	4.780	4.760	4.960	5.000	4.990
TOTAL N	24/08/92	4.590	4.690	4.800	4.930	4.780
TOTAL N	01/09/92	4.410	4.520	4.760	5.020	4.830
TOTAL N	07/09/92	4.710	4.770	4.840	5.210	4.740
TOTAL N	14/09/92	4.660	4.610	4.820	4.920	4.890
TOTAL N	21/09/92	4.600	4.610	4.700	4.930	4.720

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TOTAL N	28/09/92	4.600	4.490	5.190	5.190	4.610
TOTAL N	05/10/92	4.350	4.490	5.020	5.090	5.230
TOTAL N	12/10/92	4.580	4.610	4.890	4.910	4.890
TOTAL N	19/10/92	4.510	4.700	4.930	4.780	4.890
TOTAL N	26/10/92	4.710	4.730	4.830	4.860	4.820
TOTAL N	03/11/92	4.700	4.750	4.770	4.990	4.860
TOTAL N	09/11/92	4.750	4.770	4.800	4.960	4.840
TOTAL N	16/11/92	4.740	4.770	4.820		
TOTAL N	23/11/92	4.940	4.910	4.970	4.940	4.940
TOTAL N	03/12/92	4.850	4.890	4.920		4.860
TOTAL N	07/12/92	4.800	4.800	4.860	4.860	4.850
TOTAL N	14/12/92	4.860	4.850	4.820	4.890	4.850
TOTAL N	04/01/93	4.760	4.790	4.740	4.790	4.810
TOTAL N	18/01/93	4.880	4.910	4.900	4.850	4.820
TOTAL N	25/01/93	4.790		4.800	4.810	4.880
TOTAL N	01/02/93	5.000	4.920	4.880	5.010	4.950
TOTAL N	08/02/93	4.800		4.910	4.970	4.860
TOTAL N	15/02/93	4.600		4.760	4.820	4.780
TOTAL N	22/02/93	4.960		5.220	5.640	4.970
TOTAL N	01/03/93	4.800		5.140	5.400	5.030
TOTAL N	08/03/93	4.560		4.900	4.820	4.900
TOTAL N	15/03/93	4.640		4.860	5.320	4.980
TOTAL N	22/03/93	5.000		5.320	5.450	5.180
TOTAL N	29/03/93	4.840		5.040	5.360	4.990
TOTAL N	05/04/93	5.110		5.340	5.470	5.250
TOTAL N	13/04/93	5.130		5.130	5.840	5.180
TOTAL N	19/04/93	4.910		5.170	5.370	5.100
TOTAL N	26/04/93	5.050		5.200	5.290	5.300
TOTAL N	04/05/93	5.190		5.320	5.450	5.220
TOTAL N	10/05/93	5.170		5.230	5.120	5.430
TOTAL N	17/05/93	4.930		4.830	5.250	4.850
TOTAL N	24/05/93	4.850		4.760	4.850	4.880
TOTAL N	01/06/93	4.940		4.460	5.220	4.920
TOTAL N	07/06/93	4.590		4.590	4.440	4.640
TOTAL N	14/06/93	4.790		4.560	4.850	4.480
TOTAL N	21/06/93	4.420		4.660	4.660	4.430
TOTAL N	28/06/93	4.280		4.310	4.440	4.200
TOTAL N	05/07/93	4.220		4.120	4.100	4.080
TOTAL N	12/07/93	4.020		4.050	4.090	3.990
TOTAL N	19/07/93	3.590		3.750	3.800	3.530
TOTAL N	26/07/93	3.630	3.690	3.690	3.770	3.630
TOTAL N	02/08/93	3.500	3.540	3.600	3.620	3.600
TOTAL N	09/08/93	3.350	3.410	3.400	3.460	3.470
TOTAL N	16/08/93	3.480	3.390	3.690	3.470	3.420
TOTAL N	23/08/93	3.290	3.400	3.330	3.440	3.330
TOTAL N	31/08/93	3.270	3.250	3.360	3.320	3.320
TOTAL N	06/09/93	3.180	3.200	3.140	3.200	3.190
TOTAL N	13/09/93	3.110	3.190	3.010	3.170	3.250
TOTAL N	20/09/93	3.090	3.090		3.090	3.100
TOTAL N	27/09/93	2.950		2.960		
TOTAL N	04/10/93	2.850	2.940	2.900	2.960	2.900
TOTAL N	11/10/93	2.960	2.920	3.010	3.230	3.000
TOTAL N	19/10/93	2.980	2.940	3.020	2.980	3.000
TOTAL N	25/10/93	2.990	2.970	3.040	3.030	3.150
TOTAL N	01/11/93	2.770	3.060	3.160	3.340	3.230
TOTAL N	08/11/93	3.170	2.740	3.250	3.300	3.350

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TOTAL N	15/11/93	3.180	3.290	3.370	3.770	3.320
TOTAL N	22/11/93	3.230	3.340	3.420	3.410	3.360
TOTAL N	29/11/93	3.280		3.430		3.420
TOTAL N	06/12/93	3.260	3.430	3.550	3.550	3.430
TOTAL N	13/12/93	3.390	3.510	3.710	3.960	3.540
TOTAL N	20/12/93	3.740	3.660	3.800	4.100	3.690
TOTAL N	10/01/94	3.800	3.800	3.900	4.000	3.900
TOTAL N	17/01/94	3.700		4.000	3.900	3.800
TOTAL N	24/01/94		4.100	4.600	4.000	4.100
TOTAL N	31/01/94		3.900	3.900	4.300	3.900
TOTAL N	07/02/94		3.800	4.100	4.500	4.000
TOTAL N	21/02/94		4.100	4.200	4.300	4.200
TOTAL N	01/03/94		4.000	4.100	4.100	4.100
TOTAL N	07/03/94		4.000	4.000	4.000	4.000
TOTAL N	15/03/94		4.300	4.300	4.300	4.400
TOTAL N	21/03/94		3.700	3.800	4.400	4.000
TOTAL N	28/03/94	3.800	3.800	3.800	3.800	3.900
TOTAL N	05/04/94	4.100	4.100	4.100	4.200	4.100
TOTAL N	11/04/94	4.000	4.000	3.900	4.000	4.000
TOTAL N	18/04/94	3.800	3.900	3.800	4.000	4.000
TOTAL N	25/04/94	3.900	3.900	3.900	4.000	4.000
TOTAL N	03/05/94	3.700	4.100	4.100	4.300	
TOTAL N	09/05/94	3.900	3.700	3.800	3.800	3.900
TOTAL N	16/05/94	3.600	3.700	3.700	3.800	3.800
TOTAL N	23/05/94	8.700	2.800	3.700	3.900	3.800
TOTAL N	31/05/94	3.900	3.900	4.000	4.100	4.100
TOTAL N	06/06/94	3.500	3.600	3.700	3.800	3.600
TOTAL N	13/06/94	3.600	3.600	3.700	3.700	3.600
TOTAL N	20/06/94	3.900	3.800	3.200	3.900	3.800
TOTAL N	27/06/94	3.700	3.700	3.700	3.700	3.700
TOTAL N	04/07/94	3.500	3.500	3.500	3.500	3.500
TOTAL N	11/07/94	3.500	3.500	3.600	3.600	3.600
TOTAL N	18/07/94	3.400	3.400	3.300	3.400	3.500
TOTAL N	25/07/94	3.100	3.000	3.000	3.000	3.100
TOTAL N	01/08/94	3.100	3.200	3.200	3.100	3.200
TOTAL N	08/08/94		3.200	3.100	3.200	3.300
TOTAL N	15/08/94	3.000	3.000	3.000	3.000	3.100
TOTAL N	22/08/94	2.900	3.000	3.000	3.000	3.100
TOTAL N	30/08/94	2.600	2.700	2.800	2.800	2.900
TOTAL N	05/09/94	2.800	2.800	2.900	3.000	3.000
TOTAL N	12/09/94	2.900	3.000	3.000	3.100	3.100
TOTAL N	19/09/94	2.700	2.800	2.900	3.000	3.000
TOTAL N	26/09/94	2.900	2.900	3.100	3.900	3.200
TOTAL N	03/10/94	3.000	3.000	3.200	3.400	3.100
TOTAL N	10/10/94	3.200	3.200	3.300	3.400	3.300
TOTAL N	17/10/94	3.200	2.900	3.100	3.400	3.000
TOTAL N	24/10/94	3.200	3.200	3.300	3.300	3.300
TOTAL N	31/10/94	3.300	3.300	3.300	3.300	3.300
TOTAL N	07/11/94	3.200	3.200	3.500	3.300	4.200
TOTAL N	14/11/94	3.200	3.200	3.900	3.800	3.400
TOTAL N	21/11/94	3.500	3.600	4.100	4.300	3.800
TOTAL N	28/11/94	3.900	3.800	4.500	4.700	4.200
TOTAL N	05/12/94	3.500	3.600	3.800	3.800	3.700
TOTAL N	12/12/94	3.900	3.900	4.300	4.300	4.200
TOTAL N	19/12/94	4.300	4.400	5.000	4.900	4.700

II (b) Physical measurements in Rutland Water 1981 - 1994

DETERMINAND	DATE	NI	ST	S12	IN	LT
SECCHI DEPTH	31/05/83	5.000				4.500
SECCHI DEPTH	07/06/83	3.750				3.500
SECCHI DEPTH	22/06/83	5.000				5.500
SECCHI DEPTH	12/07/83	3.500				3.750
SECCHI DEPTH	19/07/83					3.500
SECCHI DEPTH	26/07/83	4.750				5.250
SECCHI DEPTH	02/08/83	3.750				3.250
SECCHI DEPTH	10/08/83	2.500				4.000
SECCHI DEPTH	16/08/83	3.500				3.500
SECCHI DEPTH	23/08/83	3.750				3.000
SECCHI DEPTH	31/08/83	2.250				4.500
SECCHI DEPTH	06/09/83	2.750				2.500
SECCHI DEPTH	13/09/83	3.000				3.000
SECCHI DEPTH	20/09/83	2.500				
SECCHI DEPTH	10/10/83					2.750
SECCHI DEPTH	24/10/83					3.750
SECCHI DEPTH	07/11/83	4.000				3.500
SECCHI DEPTH	21/11/83					4.000
SECCHI DEPTH	09/01/84	2.500				3.000
SECCHI DEPTH	13/02/84	1.800				1.500
SECCHI DEPTH	20/02/84	1.500				1.500
SECCHI DEPTH	08/03/84	1.500				1.500
SECCHI DEPTH	12/03/84	1.750				2.000
SECCHI DEPTH	19/03/84					2.000
SECCHI DEPTH	02/04/84	2.500				2.500
SECCHI DEPTH	09/04/84	2.500				2.500
SECCHI DEPTH	16/04/84	2.500				2.250
SECCHI DEPTH	14/05/84	4.250				3.500
SECCHI DEPTH	21/05/84	5.500				5.500
SECCHI DEPTH	04/06/84	3.500				3.000
SECCHI DEPTH	11/06/84	3.250				3.250
SECCHI DEPTH	18/06/84					3.000
SECCHI DEPTH	11/07/84	3.000				2.750
SECCHI DEPTH	17/07/84	5.750				4.000
SECCHI DEPTH	23/07/84					4.250
SECCHI DEPTH	30/07/84	3.500				2.500
SECCHI DEPTH	07/08/84	4.500				3.500
SECCHI DEPTH	13/08/84	5.250				5.500
SECCHI DEPTH	29/08/84					3.750
SECCHI DEPTH	19/09/84					2.750
SECCHI DEPTH	08/10/84					3.250
SECCHI DEPTH	17/10/84					3.500
SECCHI DEPTH	30/10/84					3.000
SECCHI DEPTH	05/11/84	3.250				3.250
SECCHI DEPTH	13/11/84	3.750				3.500
SECCHI DEPTH	19/11/84	3.250				3.750
SECCHI DEPTH	26/11/84	3.000				2.750
SECCHI DEPTH	17/12/84					3.750
SECCHI DEPTH	04/02/85					2.250
SECCHI DEPTH	11/03/85	1.250				1.750
SECCHI DEPTH	18/03/85	1.250				1.500
SECCHI DEPTH	25/03/85	1.750				1.750
SECCHI DEPTH	01/04/85					1.750
SECCHI DEPTH	09/04/85	1.500				1.500
SECCHI DEPTH	15/04/85	1.250				1.250

DETERMINAND	DATE	NI	ST	ST2	IN	LT
SECCHI DEPTH	22/04/85	1.750				1.750
SECCHI DEPTH	07/05/85	2.250				3.000
SECCHI DEPTH	28/05/85					4.250
SECCHI DEPTH	18/06/85	4.750				3.500
SECCHI DEPTH	15/07/85					3.750
SECCHI DEPTH	23/07/85					4.000
SECCHI DEPTH	20/08/85	2.750				3.000
SECCHI DEPTH	27/08/85	3.250				2.500
SECCHI DEPTH	02/09/85					2.500
SECCHI DEPTH	17/09/85	3.000				2.000
SECCHI DEPTH	23/09/85	2.750				2.500
SECCHI DEPTH	02/10/85	2.500				3.250
SECCHI DEPTH	08/10/85	3.250				2.750
SECCHI DEPTH	29/10/85	3.750				3.500
SECCHI DEPTH	04/11/85					3.000
SECCHI DEPTH	18/11/85					3.500
SECCHI DEPTH	02/12/85	3.250				3.000
SECCHI DEPTH	09/12/85					3.000
SECCHI DEPTH	16/12/85	2.500				2.750
SECCHI DEPTH	20/01/86					1.250
SECCHI DEPTH	03/02/86					1.300
SECCHI DEPTH	10/03/86					1.750
SECCHI DEPTH	01/04/86					1.500
SECCHI DEPTH	21/04/86	1.750				1.500
SECCHI DEPTH	29/04/86	1.750				1.750
SECCHI DEPTH	06/05/86	2.000				1.750
SECCHI DEPTH	12/05/86					2.500
SECCHI DEPTH	19/05/86	4.000				4.250
SECCHI DEPTH	16/06/86	4.500				5.250
SECCHI DEPTH	23/06/86	3.750				4.250
SECCHI DEPTH	30/06/86					2.500
SECCHI DEPTH	30/06/86					2.500
SECCHI DEPTH	11/08/86					3.000
SECCHI DEPTH	08/09/86	3.750				3.250
SECCHI DEPTH	16/09/86	2.750				3.000
SECCHI DEPTH	30/09/86	3.250				3.000
SECCHI DEPTH	06/10/86	3.250				3.000
SECCHI DEPTH	11/11/86	3.250				3.000
SECCHI DEPTH	08/12/86	3.000				3.000
SECCHI DEPTH	16/12/86	2.000				2.250
SECCHI DEPTH	26/01/87	4.500				4.000
SECCHI DEPTH	16/02/87	2.500				2.750
SECCHI DEPTH	23/02/87	2.750				3.000
SECCHI DEPTH	10/03/87					1.500
SECCHI DEPTH	10/03/87					1.500
SECCHI DEPTH	23/03/87	2.250				2.000
SECCHI DEPTH	23/03/87	2.250				2.000
SECCHI DEPTH	30/03/87	2.500				2.500
SECCHI DEPTH	30/03/87	2.500				2.500
SECCHI DEPTH	06/04/87	1.750				2.000
SECCHI DEPTH	27/04/87	3.000				3.000
SECCHI DEPTH	05/05/87	3.500				3.500
SECCHI DEPTH	19/05/87	4.750				4.500
SECCHI DEPTH	08/06/87	3.500				3.500
SECCHI DEPTH	23/06/87	3.000				3.500
SECCHI DEPTH	30/06/87	3.750				3.500

DETERMINAND	DATE	NI	ST	ST2	IN	LT
SECCHI DEPTH	07/07/87					3.000
SECCHI DEPTH	13/07/87	4.000				4.000
SECCHI DEPTH	28/07/87	3.750				3.500
SECCHI DEPTH	11/08/87	4.250				4.000
SECCHI DEPTH	17/08/87	4.500				5.000
SECCHI DEPTH	01/09/87	4.500				4.500
SECCHI DEPTH	08/09/87	3.500				3.500
SECCHI DEPTH	21/09/87	4.250				4.000
SECCHI DEPTH	30/09/87	3.250				3.750
SECCHI DEPTH	14/10/87	3.500				3.500
SECCHI DEPTH	28/10/87	4.750				4.250
SECCHI DEPTH	04/11/87	4.000				4.500
SECCHI DEPTH	25/11/87	3.000				3.000
SECCHI DEPTH	01/12/87	3.250				3.250
SECCHI DEPTH	13/04/88	3.500				3.500
SECCHI DEPTH	20/04/88	3.250				3.000
SECCHI DEPTH	27/04/88	3.500				3.750
SECCHI DEPTH	04/05/88	4.500				4.750
SECCHI DEPTH	11/05/88	4.500				4.250
SECCHI DEPTH	17/05/88	5.000				5.000
SECCHI DEPTH	25/05/88	5.000				5.500
SECCHI DEPTH	01/06/88	5.500				5.000
SECCHI DEPTH	07/06/88	5.000				5.500
SECCHI DEPTH	21/06/88	6.000				6.000
SECCHI DEPTH	29/06/88	5.500				5.250
SECCHI DEPTH	06/07/88	5.000				5.000
SECCHI DEPTH	12/07/88	5.500				5.000
SECCHI DEPTH	20/07/88	5.500				5.500
SECCHI DEPTH	10/08/88					6.000
SECCHI DEPTH	17/08/88	6.500				6.500
SECCHI DEPTH	24/08/88	6.500				6.000
SECCHI DEPTH	07/09/88	6.000				6.500
SECCHI DEPTH	11/10/88	5.000				5.500
SECCHI DEPTH	19/10/88	5.000				5.500
SECCHI DEPTH	25/05/90		1.25	1.25		1.25
SECCHI DEPTH	04/06/90		3	2.5		2.25
SECCHI DEPTH	11/06/90		5	4		3.5
SECCHI DEPTH	18/06/90		1.5	3		4
SECCHI DEPTH	25/06/90		2.25	2.1		2
SECCHI DEPTH	02/07/90		2.75			1.5
SECCHI DEPTH	09/07/90		2.25	1.5		2
SECCHI DEPTH	16/07/90	1.75	1.6	2.8		2.25
SECCHI DEPTH	23/07/90	1.5	1.75	1.5		1.5
SECCHI DEPTH	30/07/90	1.75	1.5	2		1.5
SECCHI DEPTH	06/08/90	2	2.5	1.75		2
SECCHI DEPTH	13/08/90	3.3	3	2.5		2
SECCHI DEPTH	02/08/90		2			2.25
SECCHI DEPTH	29/08/90	2.1	3.25	3.25		2.25
SECCHI DEPTH	03/09/90	3	2.75	2.5		3
SECCHI DEPTH	10/09/90	2.9	3.3	2.5		3
SECCHI DEPTH	18/09/90	2	2.3	2.1		2.5
SECCHI DEPTH	24/09/90	2.25	2.25	2		2.25
SECCHI DEPTH	01/10/90	3	2.9	2.5		2.8
SECCHI DEPTH	08/10/90	2.25	2.5	2		3
SECCHI DEPTH	15/10/90	2.3	3.15	3.5		3.25
SECCHI DEPTH	22/10/90	1.7	1.9	2.6		2.1

DETERMINAND	DATE	NI	ST	ST2	IN	LT
SECCHI DEPTH	30/10/90	2	2	1.9		2.4
SECCHI DEPTH	05/11/90	1.95	2	2		2.1
SECCHI DEPTH	12/11/90	1.95	2	2.6		2.5
SECCHI DEPTH	19/11/90	1.95	2	2.6		2.5
SECCHI DEPTH	26/11/90	1.2	1.6			2.3
SECCHI DEPTH	03/12/90	2.6		2.5		2.5
SECCHI DEPTH	12/12/90	1.7	1.8			
SECCHI DEPTH	17/12/90	2.7	2.1	2.1		3
SECCHI DEPTH	07/01/91		1.25			1.5
SECCHI DEPTH	14/01/91	2.7	2	1		1.9
SECCHI DEPTH	21/01/91	2.2	2	2		2.2
SECCHI DEPTH	28/01/91	2.1	2.25	2.5		3
SECCHI DEPTH	04/02/91	2.2	2.2	2.1		2.6
SECCHI DEPTH	20/02/91	1.75	2	1.5		2
SECCHI DEPTH	25/02/91	1.5	1.4	1.2		1.2
SECCHI DEPTH	04/03/91	1.5	1.4	1.2		1.2
SECCHI DEPTH	11/03/91	1.25		1.25		2.25
SECCHI DEPTH	18/03/91	1.25	1.75	1.5		2
SECCHI DEPTH	16/04/91	1.25	1.5	1.5		1.75
SECCHI DEPTH	22/04/91	1.5	1.5	1.75		1.25
SECCHI DEPTH	30/04/91	2.75	2.75			
SECCHI DEPTH	07/05/91	3.25	2.75	2.9		2.75
SECCHI DEPTH	13/05/91	2.5	2.6	2.2		2.25
SECCHI DEPTH	20/05/91		3	2.5		3.75
SECCHI DEPTH	28/05/91	4.25	5	3		3.6
SECCHI DEPTH	03/06/91	4.5	4.25	4.25		4.5
SECCHI DEPTH	10/06/91	3.75	3.5	3.25		3.75
SECCHI DEPTH	17/06/91	1.75	2.5	2		3.25
SECCHI DEPTH	24/06/91	2.5	2.25	2.25		2.75
SECCHI DEPTH	01/07/91	4.25	3.75	2.5		
SECCHI DEPTH	08/07/91	3.5	3.25	4.25		3.5
SECCHI DEPTH	15/07/91	3.25	3.5	3.25		2.75
SECCHI DEPTH	29/07/91	3.5	3.25	4.25		3.5
SECCHI DEPTH	05/08/91	2.5	2.5	2.5		1.75
SECCHI DEPTH	12/08/91	3.25	3.25	3		1.75
SECCHI DEPTH	20/08/91	3.25	3	4		3
SECCHI DEPTH	27/08/91	3.25	3.25	2.5		2.25
SECCHI DEPTH	02/09/91	1.5	1.5	1.75		3
SECCHI DEPTH	09/09/91	1.75	2	2		3.25
SECCHI DEPTH	16/09/91	2.5	2.5	2		2.75
SECCHI DEPTH	25/09/91	3.25	3	1.75		2.75
SECCHI DEPTH	01/10/91	4	3.5	2.25		4
SECCHI DEPTH	14/10/91	3.75	3.5	3		3.25
SECCHI DEPTH	21/10/91	3	2.75	3		3.75
SECCHI DEPTH	28/10/91	3	2.75	3		3.75
SECCHI DEPTH	04/11/91	2.5	2.5	2.5		2.5
SECCHI DEPTH	11/11/91	2.5	2.5	2.25		2.5
SECCHI DEPTH	18/11/91	3.75	3.5	3.25		4
SECCHI DEPTH	25/11/91	3	3.25	2		3
SECCHI DEPTH	02/12/91	2.75	3.25	2.5		3.5
SECCHI DEPTH	10/12/91	2.7	3.4	3.1		4.25
SECCHI DEPTH	17/12/91	2.25	3.75	4.25		3.75
SECCHI DEPTH	07/01/92	3.25	3.25	2.75		2.5
SECCHI DEPTH	13/01/92	1.75	2	0.8		2.75
SECCHI DEPTH	20/01/92	2.5	2.25	1.5		1.5
SECCHI DEPTH	27/01/92	3.2	3.7	2		2.75

DETERMINAND	DATE	NI	ST	SI2	IN	LT
SECCHI DEPTH	03/02/92	2.5	2.25	1.4		
SECCHI DEPTH	10/02/92		2.1	2.1		
SECCHI DEPTH	17/02/92	2.1	2	1.5		2
SECCHI DEPTH	02/03/92	2.25	2.25	1.5		2.25
SECCHI DEPTH	09/03/92	2	2	1.5		
SECCHI DEPTH	16/03/92	2	2	1.7		1.75
SECCHI DEPTH	23/03/92	1.9	2	1.6		1.75
SECCHI DEPTH	30/03/92	1.75	2	1.6		2
SECCHI DEPTH	06/04/92	2.25	2.1	2		2.25
SECCHI DEPTH	21/04/92	2.1	2.1	1.5		1.25
SECCHI DEPTH	29/04/92	2.25	2.1	2		2.25
SECCHI DEPTH	05/05/92	3.2	3.2	2.6	1.2	4.75
SECCHI DEPTH	11/05/92	3.5	3.5	3.75	1.25	4.5
SECCHI DEPTH	18/05/92	2.25	3.25	2.1	4	3.25
SECCHI DEPTH	26/05/92	2.25	5	4.25	4.3	4.75
SECCHI DEPTH	09/06/92	2.5	3	3		4
SECCHI DEPTH	15/06/92	2.5	2.5	2.1		1.75
SECCHI DEPTH	22/06/92	4.25	5	3		4.25
SECCHI DEPTH	29/06/92	5.5	5.5	4.75		5.5
SECCHI DEPTH	06/07/92	4.5	5	3.25		4.5
SECCHI DEPTH	13/07/92	3	3	2.5		3
SECCHI DEPTH	20/07/92	3.5	3	2.5		2.25
SECCHI DEPTH	17/08/92	3	3	3		3.5
SECCHI DEPTH	24/08/92	3	3	2.75		3.5
SECCHI DEPTH	07/09/92	3	3	2		3
SECCHI DEPTH	14/09/92	2.5	3	2.25		3.5
SECCHI DEPTH	21/09/92	3.25	3.25	2		3
SECCHI DEPTH	28/09/92	5	4	3.5		
SECCHI DEPTH	05/10/92	3.5	4	2.5		2.5
SECCHI DEPTH	19/10/92	5.5	5.5	4.25		5.5
SECCHI DEPTH	26/10/92	5	5	4.25		4.5
SECCHI DEPTH	03/11/92	4.5	3.5	3.25		3
SECCHI DEPTH	09/11/92		5.5	5		5.5
SECCHI DEPTH	16/11/92		5.5	4		4.25
SECCHI DEPTH	23/11/92	4.5	4.75	3.5		4.5
SECCHI DEPTH	03/12/92	2.25	2.25	1.5		2.25
SECCHI DEPTH	07/12/92	4	3	2.25		3.25
SECCHI DEPTH	14/12/92	3.25	3.25	2.75		3.25
SECCHI DEPTH	21/12/92	3.75	3.75	3.25		4
SECCHI DEPTH	04/01/93	4.25	4.75	3.75		4.25
SECCHI DEPTH	01/02/93	3	2.5	3		2
SECCHI DEPTH	08/02/93	4.5		3.5		4
SECCHI DEPTH	15/02/93	4.25				5
SECCHI DEPTH	22/02/93	3.5		2.75		
SECCHI DEPTH	01/03/93	2.5		3		3.25
SECCHI DEPTH	08/03/93	3		2.75		4
SECCHI DEPTH	15/03/93	2		2.5		3.25
SECCHI DEPTH	22/03/93	2.75		2.5		3
SECCHI DEPTH	29/03/93	3.25		2.75		3.75
SECCHI DEPTH	05/04/93	3.5		2.75		
SECCHI DEPTH	13/04/93	2.25		2.5		3.5
SECCHI DEPTH	19/04/93	3		2.5		2.75
SECCHI DEPTH	26/04/93	2.5		1.75	3.5	4.5
SECCHI DEPTH	04/05/93	5		3.75	2.25	7.25
SECCHI DEPTH	10/05/93	3		2.75	2.5	3
SECCHI DEPTH	17/05/93	4		2.75	2.5	4

DETERMINAND	DATE	N1	ST	ST2	IN	LT
SECCHI DEPTH	24/05/93	4		3	3.5	
SECCHI DEPTH	01/06/93	4.5		3	0.5	4
SECCHI DEPTH	07/06/93	4		4.5	3.5	3.5
SECCHI DEPTH	14/06/93	3.25		2.25	3	3.25
SECCHI DEPTH	21/06/93	4		3		3
SECCHI DEPTH	28/06/93	3.000		2.000	2.000	1.750
SECCHI DEPTH	05/07/93	2.000		1.250	1.000	1.500
SECCHI DEPTH	12/07/93	1.750		1.500	1.750	1.000
SECCHI DEPTH	19/07/93	1.750		1.250	1.400	0.750
SECCHI DEPTH	26/07/93	2.000	2.250	2.000	1.750	2.250
SECCHI DEPTH	02/08/93	2.000	1.500	2.000	1.750	2.000
SECCHI DEPTH	09/08/93	2.500	1.750	2.250	1.750	2.500
SECCHI DEPTH	16/08/93	3.000	2.500	1.750	1.250	1.500
SECCHI DEPTH	23/08/93	2.750	2.250	1.750	1.750	2.250
SECCHI DEPTH	31/08/93	2.750	2.250	1.750	2.000	2.250
SECCHI DEPTH	06/09/93	3.750	3.500	3.000	2.500	2.000
SECCHI DEPTH	27/09/93	4.500		3.000		
SECCHI DEPTH	04/10/93	4.250	4.750	4.750	4.500	4.250
SECCHI DEPTH	11/10/93	3.500	3.750	3.500	3.500	4.500
SECCHI DEPTH	19/10/93	4.250	3.750	3.500	4.250	4.000
SECCHI DEPTH	25/10/93	3.750	4.000	4.000	3.500	4.000
SECCHI DEPTH	01/11/93	5.000	4.500	4.000	4.000	6.000
SECCHI DEPTH	08/11/93	4.500	5.500	5.000	4.500	4.500
SECCHI DEPTH	15/11/93	3.000	3.000	1.500	0.500	2.500
SECCHI DEPTH	22/11/93	3.750	3.000	2.500	2.750	3.000
SECCHI DEPTH	29/11/93			2.000		4.000
SECCHI DEPTH	06/12/93	3.750		2.500	2.500	3.500
SECCHI DEPTH	13/12/93	2.000	2.500	1.500	0.200	2.500
SECCHI DEPTH	20/12/93	2.000	1.500	1.250	1.750	1.000
SECCHI DEPTH	10/01/94	2.000	2.000	1.250		2.250
SECCHI DEPTH	17/01/94			2.000	1.500	2.000
SECCHI DEPTH	24/01/94		3.000	2.250	2.750	2.750
SECCHI DEPTH	31/01/94		2.500	2.500	1.250	2.000
SECCHI DEPTH	07/02/94		2.000	1.250	1.250	2.750
SECCHI DEPTH	21/02/94		3.500		2.000	2.500
SECCHI DEPTH	07/03/94		2.750	2.750	2.250	2.500
SECCHI DEPTH	15/03/94		2.000	1.750	1.250	1.750
SECCHI DEPTH	21/03/94		2.250	1.500	1.500	2.000
SECCHI DEPTH	05/04/94	1.500	2.000	2.250	2.750	2.750
SECCHI DEPTH	11/04/94	2.750	3.000	2.500	2.750	2.750
SECCHI DEPTH	18/04/94	3.250	3.250	3.250	3.500	4.500
SECCHI DEPTH	25/04/94	3.500	3.750	3.750	3.750	4.500
SECCHI DEPTH	03/05/94	5.000	4.500	3.500	3.250	
SECCHI DEPTH	09/05/94	4.750	4.750	4.750	4.750	6.500
SECCHI DEPTH	16/05/94	5.000	4.500	5.000	5.000	4.250
SECCHI DEPTH	23/05/94	6.000	6.250	6.000	5.250	5.750
SECCHI DEPTH	31/05/94	5.500	5.000	4.500	5.000	5.000
SECCHI DEPTH	06/06/94	3.500	4.000	2.500	2.500	4.250
SECCHI DEPTH	13/06/94	4.750	5.000	3.500	3.250	3.250
SECCHI DEPTH	20/06/94	5.500	4.500	4.000	3.250	4.000
SECCHI DEPTH	27/06/94	6.750	6.000	6.500	6.000	6.000
SECCHI DEPTH	04/07/94	3.000	3.750	4.250	4.250	4.250
SECCHI DEPTH	18/07/94	3.750	4.000	4.500	3.500	3.500
SECCHI DEPTH	25/07/94	2.750	2.750	2.250	2.500	3.000
SECCHI DEPTH	01/08/94	3.500	3.000	3.250	3.500	3.500
SECCHI DEPTH	08/08/94	2.750	3.000	2.750	2.750	3.250

DETERMINAND	DATE	NI	ST	SI2	IN	LT
SECCHI DEPTH	15/08/94	4.000	4.750	3.750	3.000	5.000
SECCHI DEPTH	22/08/94	4.250	4.500	3.500	4.500	5.000
SECCHI DEPTH	30/08/94	5.000	4.500	3.750	4.000	4.250
SECCHI DEPTH	05/09/94	4.500	5.750	3.500	3.750	5.250
SECCHI DEPTH	12/09/94	5.500	5.500	4.250	4.750	5.500
SECCHI DEPTH	19/09/94	4.500	6.000	4.500	4.500	4.500
SECCHI DEPTH	26/09/94	5.000	3.250	3.750	2.750	5.000
SECCHI DEPTH	03/10/94	4.750	5.000	3.500	3.500	5.000
SECCHI DEPTH	10/10/94	4.500	4.750	4.500	5.250	5.500
SECCHI DEPTH	17/10/94	3.000	3.000	4.250	3.250	4.750
SECCHI DEPTH	24/10/94	3.750	3.750	3.500	3.500	4.500
SECCHI DEPTH	31/10/94	4.750	4.250	3.750	3.250	3.250
SECCHI DEPTH	07/11/94	4.250	5.000	3.000	2.000	4.500
SECCHI DEPTH	14/11/94	4.250	4.000	3.000	2.750	4.250
SECCHI DEPTH	21/11/94	5.500	5.250	4.250	2.750	5.750
SECCHI DEPTH	28/11/94	5.750	6.000	4.750	3.000	5.250
SECCHI DEPTH	05/12/94	3.750	3.500	2.500	2.750	3.750
SECCHI DEPTH	12/12/94	3.500	3.500	2.500	1.750	3.750
SECCHI DEPTH	19/12/94	3.500	3.750	3.000	3.250	4.000
LIGHT	20/05/91	802.03	1771.34	1346.02		1695.62
LIGHT	28/05/91	382.6	676.32	504.38		675.36
LIGHT	03/06/91	445.16	814.12	670.12		403.87
LIGHT	10/06/91	388.5	465.06	536.13		949.6
LIGHT	17/06/91	994.52	1191.3	412.09		907.48
LIGHT	24/06/91	1036.88	895.2	1094.79		589.99
LIGHT	01/07/91	865.59	785.46	1104.68		520.94
LIGHT	08/07/91	279.95	472.92	635.63		317.84
LIGHT	15/07/91	302.95	846.59	873.58		775.99
LIGHT	25/07/91	1272.68				
LIGHT	27/07/91	1801.61	1815.73	1894.13		628.66
LIGHT	05/08/91	455.76	580.88	292.82		357.88
LIGHT	12/08/91	262.2	1732.08	1514.39		1523.09
LIGHT	20/08/91	1854.57	1760.02	1552.64		1867.56
LIGHT	27/08/91	852.9	541.67	494.85		1238.55
LIGHT	02/09/91	1055.88	1281.86	1213.4		1622.46
LIGHT	09/09/91	1534.94	1587.97	1654.63		1693.3
LIGHT	16/09/91	464.52	583.2	419.66		378.37
LIGHT	25/09/91	344.83	449.99	277.75		597.56
LIGHT	01/10/91	558.3	262.85	839.08		493.18
LIGHT	07/10/91	347.45	281.92	336.37		146.2
LIGHT	21/10/91	931.78	1101.1	814.36		990.47
LIGHT	28/10/91	123.74	101.82	128.69		119.15
LIGHT	04/11/91	350.19	719.39			
LIGHT	11/11/91	314.69	332.74	278.46		300.92
LIGHT	18/11/91	362.7	299.31	415.43		408.4
LIGHT	25/11/91	46.65	99.67	98.06		156.63
LIGHT	02/12/91	103.84	96.87	58.15		106.23
LIGHT	10/12/91	226.99	229.49	227.76		392.14
LIGHT	17/12/91	95.56	81.68	94.07		104.68
LIGHT	07/01/92	90.08	93.71	104.68		109.32
LIGHT	13/01/92	141.44	163.96	222.1		194.1
LIGHT	20/01/92	204.29	318.14	197.2		276.14
LIGHT	27/01/92	416.68	488.95	715.16		329.1
LIGHT	03/02/92	262.62	283.29	335.36		
LIGHT	10/02/92		949.72	364.43		
LIGHT	17/02/92	640.33	1048.02	310.04		709.2

DETERMINAND	DATE	NI	ST	SI2	IN	LT
LIGHT	24/02/92	601.31	887.22	456.06		
LIGHT	02/03/92	592.85	473.4	350.67		
LIGHT	09/03/92	551.68	563	1086.68		
LIGHT	16/03/92	217.81	422.28	110.04		173.61
LIGHT	23/03/92	541.55	368.25	539.47		1288.59
LIGHT	30/03/92	152.58	225.68	200.24		289.37
LIGHT	06/04/92	189.34	321.6	366.93		127.14
LIGHT	21/04/92	636.94	906.88	1010.31		377.24
LIGHT	29/04/92	928.6	461.2	1123.6		986.3
LIGHT	05/05/92	295.1				
LIGHT	11/05/92	344.12	377		629.61	763.54
LIGHT	18/05/92	1800.36	1627.17	1814.72	1639.44	1672.86
LIGHT	26/05/92	1680.91	1490.91		468.75	1262.26
LIGHT	09/06/92	1700.98	919.03	1398.69		1374.8
LIGHT	15/06/92	1940.9	1514.15	1012.21		944.12
LIGHT	22/06/92	802.74	758.06	673.99		657.37
LIGHT	29/06/92	36.64	1243.97	1067.08		977.9
LIGHT	06/07/92		89.07	1851		631.64
LIGHT	13/07/92	169.85	304.62	695.5		838.9
LIGHT	20/07/92	193.74	583.91	552.99		351.09
LIGHT	27/07/92	435.39	1475.66	1733.81		239.86
LIGHT	03/08/92	1746.98	1261.66	1484.06		864.1
LIGHT	10/08/92	834.55	657.91	648.2		1897.71
LIGHT	17/08/92	775.75	88.17			
LIGHT	24/08/92	353.95	300.98	230.62		359.01
LIGHT	01/09/92	223.71	176.17	1648.73		379.21
LIGHT	07/09/92	244.8	163.24	222.04		185.11
LIGHT	14/09/92	624.78	639.98	328.15		403.99
LIGHT	21/09/92	360.14	485.43	495.26		241.35
LIGHT	28/09/92	1096.99	1290.44	1185.22		
LIGHT	05/10/92	109.86	400.6	145.13		183.44
LIGHT	12/10/92	657.97	123.38	704.02		99.55
LIGHT	19/10/92	810.19	1039.86	799.23		810.25
LIGHT	26/10/92	944.24	698.84	678.76		602.68
LIGHT	03/11/92	130.59	680.55	1173.85		663.09
LIGHT	09/11/92	73.64	73.58	86.51		92.76
LIGHT	16/11/92	215.01	107.12	115.46		77.27
LIGHT	23/11/92	221.09				
LIGHT	03/12/92	1.91	148.58	483.82		467.38
LIGHT	07/12/92	124.81	207.09	121.6		136.73
LIGHT	14/12/92	228.78	158.65	239.86		131.61
LIGHT	21/12/92	184.15	125.53	263.03		249.27
LIGHT	04/01/93	123.62	163.9	141.91		117.01
LIGHT	01/02/93	344.41	279.12	289.6		204.11
LIGHT	08/02/93	134.11		113.08		174.98
LIGHT	15/02/93			86.86		57.02
LIGHT	22/02/93	668.33		246.05		355.97
LIGHT	01/03/93	227.05		77.75		387.31
LIGHT	08/03/93	407.98		410.49		527.55
LIGHT	15/03/93	530.12		808.22		1283.94
LIGHT	22/03/93	361.87		1430.09		1646.11
LIGHT	29/03/93	762.53		1027.76		1600.36
LIGHT	05/04/93	1548.88		499.79		405.42
LIGHT	13/04/93	197.14		57.07		479.24
LIGHT	19/04/93	611.68		537.44		745.67
LIGHT	26/04/93	623.65		517.84		400.12

DETERMINAND	DATE	NI	ST	ST2	IN	LT
LIGHT	04/05/93	1313.85		1790.11	353.17	1079.36
LIGHT	10/05/93	554.54		290.14	272.8	372.36
LIGHT	17/05/93	1111.59		1202.86	1458.8	367.89
LIGHT	24/05/93	1616.2		1768.9	1741.55	
LIGHT	07/06/93	1942.33			1558	1618.89
LIGHT	14/06/93	194.46		361.45	353.83	156.15
LIGHT	06/09/93	779.51	688.11			
LIGHT	13/09/93	189		516		340
LIGHT	20/09/93	201	210		515	280
LIGHT	27/09/93	179		153		
LIGHT	04/10/93	1204	1402	1263		1001
LIGHT	11/10/93	102	84	53	64	121
LIGHT	19/10/93	579	210	1130	1235	1280
LIGHT	25/10/93	178	176	218	237	232
LIGHT	01/11/93	205	299	466	238	197
LIGHT	08/11/93	110	100	105	137	93
LIGHT	15/11/93	183	149			
LIGHT	22/11/93	196	196	85	151	127
LIGHT	06/12/93			140.18		
LIGHT	10/01/94	78	136	183		
LIGHT	24/01/94		203			
LIGHT	07/02/94		106	106	888	152
LIGHT	21/02/94	160			25	19
LIGHT	01/03/94	523.98	258.68	217.75	326.18	225.62
LIGHT	07/03/94		248.61	230.03	510.4	801.13
LIGHT	15/03/94	765.12		770.96	775.91	782.21
LIGHT	16/05/94	291		271	839	1120
LIGHT	23/05/94	234		266	252	160
LIGHT	31/05/94	1868		1425	1908	1558
LIGHT	06/06/94	889	488	1060	1219	907
LIGHT	13/06/94	1557		1761	867	1093
LIGHT	20/06/94	813		421	204	160
LIGHT	27/06/94	1749		943	295	720
LIGHT	04/07/94	258		777	570	564
LIGHT	11/07/94	1338		336	1367	1513
LIGHT	18/07/94	669		107	103	251
LIGHT	25/07/94	473		283	1084	1296
LIGHT	01/08/94	544		711	892	839
LIGHT	08/08/94	362		591	460	737
LIGHT	15/08/94	1837		1413	983	1349
LIGHT	22/08/94	1013		661	1415	1595
LIGHT	30/08/94	443		521	353	372
LIGHT	05/09/94	215		274	183	324
LIGHT	12/09/94	0		0		
LIGHT	19/09/94	779.8		783.6	783.3	783.3
LIGHT	26/09/94	416		233	244	411
LIGHT	07/10/94	205		233	148	544
LIGHT	10/10/94	1058		1279	1220	1195
LIGHT	17/10/94	345		392	587	397
LIGHT	24/10/94	858		914	984	978
LIGHT	21/11/94	106		220	208	317
LIGHT	05/12/94	571		115	185	297
LIGHT	12/12/94	123.03		193.39	55.35	38.61
LIGHT	19/12/94	106.52		230.98	269.41	171.16
TEMPERATURE	07/04/81	7.200	7.200			7.000
TEMPERATURE	13/04/81	8.500	8.500			8.000

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TEMPERATURE	22/04/81	8.600	8.600			8.400
TEMPERATURE	30/04/81		6.800			7.500
TEMPERATURE	06/05/81	7.800	7.800			7.500
TEMPERATURE	12/05/81	9.200	9.400			9.000
TEMPERATURE	19/05/81	11.500	11.500			11.400
TEMPERATURE	25/05/81	12.000	12.500			13.000
TEMPERATURE	02/06/81	15.200	15.000			12.900
TEMPERATURE	09/06/81	13.800	13.800			13.800
TEMPERATURE	23/06/81	16.000	16.200			16.800
TEMPERATURE	30/06/81	14.000	14.000			14.200
TEMPERATURE	07/07/81	15.200	15.200			15.500
TEMPERATURE	14/07/81	16.400	16.600			17.200
TEMPERATURE	21/07/81					16.900
TEMPERATURE	04/08/81	18.600	18.600			18.200
TEMPERATURE	11/08/81	17.800	18.000			17.900
TEMPERATURE	25/08/81	17.700	17.300			18.000
TEMPERATURE	01/09/81	17.400	17.200			17.500
TEMPERATURE	08/09/81	18.100	18.300			18.000
TEMPERATURE	15/09/81	17.000	17.000			17.000
TEMPERATURE	23/09/81	15.000	15.800			16.200
TEMPERATURE	29/09/81	14.800	14.800			15.300
TEMPERATURE	06/10/81	14.000	14.000			14.000
TEMPERATURE	13/10/81	11.500	11.800			11.800
TEMPERATURE	20/10/81	10.200	10.200			10.200
TEMPERATURE	27/10/81	9.200	9.300			9.300
TEMPERATURE	10/11/81	8.200	7.800			8.200
TEMPERATURE	17/11/81	7.600	7.600			7.600
TEMPERATURE	25/11/81	7.500	7.750			7.750
TEMPERATURE	01/12/81	6.300	6.300			6.500
TEMPERATURE	09/12/81	5.500	5.500			5.800
TEMPERATURE	05/01/82					2.300
TEMPERATURE	02/02/82	2.500	2.500			2.500
TEMPERATURE	09/02/82	3.600	3.500			3.500
TEMPERATURE	16/02/82	3.800	3.800			3.500
TEMPERATURE	23/02/82	2.800	2.800			3.000
TEMPERATURE	10/03/82	4.200	4.200			4.200
TEMPERATURE	16/03/82	4.300	4.500			4.300
TEMPERATURE	23/03/82	6.600	5.800			4.700
TEMPERATURE	30/03/82	5.400	5.600			6.000
TEMPERATURE	06/04/82	7.300	7.300			6.700
TEMPERATURE	13/04/82	6.800	6.800			6.800
TEMPERATURE	21/04/82	9.200	9.200			7.800
TEMPERATURE	27/04/82	9.800	9.800			9.000
TEMPERATURE	04/05/82	8.800	8.800			9.000
TEMPERATURE	11/05/82	10.800				
TEMPERATURE	18/05/82	12.800	12.800			11.300
TEMPERATURE	27/05/82					13.200
TEMPERATURE	02/06/82	19.200	19.200			18.500
TEMPERATURE	08/06/82	21.000	21.000			20.500
TEMPERATURE	16/06/82	16.500	16.500			16.300
TEMPERATURE	29/06/82	15.800	15.800			15.800
TEMPERATURE	06/07/82	16.200	16.400			16.500
TEMPERATURE	14/07/82	18.200	18.200			17.200
TEMPERATURE	20/07/82	18.200	18.200			17.500
TEMPERATURE	27/07/82	17.200	17.200			17.200
TEMPERATURE	03/08/82	20.200	20.200			18.800

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TEMPERATURE	10/08/82	18.500	18.500			19.800
TEMPERATURE	17/08/82	17.500	17.500			18.000
TEMPERATURE	24/08/82	15.400	15.400			16.200
TEMPERATURE	07/09/82	15.000	15.000			15.700
TEMPERATURE	14/09/82	16.800	16.800			17.000
TEMPERATURE	22/09/82					16.000
TEMPERATURE	28/09/82	15.200	15.200			15.500
TEMPERATURE	12/10/82	13.200	13.200			13.400
TEMPERATURE	19/10/82	11.500	11.800			12.000
TEMPERATURE	26/10/82	10.800	11.200			11.500
TEMPERATURE	02/11/82	11.300	11.300			11.200
TEMPERATURE	09/11/82	10.200	10.200			10.200
TEMPERATURE	23/11/82	7.900	7.900			8.200
TEMPERATURE	30/11/82	6.200	6.200			6.300
TEMPERATURE	07/12/82	5.600	5.300			5.600
TEMPERATURE	14/12/82	4.500	4.800			5.000
TEMPERATURE	05/01/83	4.800	4.900			4.800
TEMPERATURE	19/01/83	4.900	4.900			4.900
TEMPERATURE	25/01/83	4.200	4.200			4.200
TEMPERATURE	02/02/83	4.200	4.200			4.200
TEMPERATURE	01/03/83	2.500	2.500			2.500
TEMPERATURE	08/03/83	3.500	3.500			3.000
TEMPERATURE	16/03/83	4.200	4.200			4.200
TEMPERATURE	19/04/83	6.200	6.000			6.500
TEMPERATURE	26/04/83	8.000	8.000			7.400
TEMPERATURE	10/05/83	9.800	9.500			10.000
TEMPERATURE	17/05/83	10.000	10.000			10.000
TEMPERATURE	31/05/83	12.800	12.000			12.000
TEMPERATURE	07/06/83	14.000	13.500			12.500
TEMPERATURE	22/06/83	17.500	17.200			15.500
TEMPERATURE	12/07/83	22.000	22.000			20.000
TEMPERATURE	19/07/83					20.600
TEMPERATURE	26/07/83	20.500	20.500			19.800
TEMPERATURE	02/08/83	18.500	19.000			19.500
TEMPERATURE	10/08/83	19.500	19.500			18.400
TEMPERATURE	16/08/83	19.200	19.500			18.500
TEMPERATURE	23/08/83	22.000	21.300			20.000
TEMPERATURE	31/08/83	19.200	18.800			19.000
TEMPERATURE	06/09/83	16.800	17.000			18.500
TEMPERATURE	10/10/83	14.000	14.200			14.500
TEMPERATURE	24/10/83					10.500
TEMPERATURE	02/04/84	4.000	4.000			4.000
TEMPERATURE	09/04/84	5.500	6.000			4.000
TEMPERATURE	16/04/84	6.000	6.000			6.000
TEMPERATURE	14/05/84	11.000	10.500			10.000
TEMPERATURE	21/05/84	12.000	12.000			11.000
TEMPERATURE	04/06/84	13.500	13.000			12.500
TEMPERATURE	11/06/84	15.000	15.000			13.500
TEMPERATURE	18/06/84		19.000			18.500
TEMPERATURE	11/07/84	19.500	20.000			16.000
TEMPERATURE	17/07/84	18.500	18.000			17.500
TEMPERATURE	23/07/84	18.500	18.000			18.000
TEMPERATURE	30/07/84	19.000	19.500			18.200
TEMPERATURE	07/08/84	17.000	17.000			18.000
TEMPERATURE	13/08/84	17.500	17.500			17.000
TEMPERATURE	29/08/84					19.500

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TEMPERATURE	19/09/84					0.000
TEMPERATURE	08/10/84		12.500			13.000
TEMPERATURE	17/10/84					12.500
TEMPERATURE	30/10/84					11.000
TEMPERATURE	05/11/84	10.000	10.000			
TEMPERATURE	13/11/84	10.000	10.000			10.000
TEMPERATURE	19/11/84	9.500	9.500			9.500
TEMPERATURE	26/11/84	7.500	7.000			8.000
TEMPERATURE	18/12/84		10.000			3.000
TEMPERATURE	18/12/84		10.000			
TEMPERATURE	18/12/84		10.000			
TEMPERATURE	04/02/85					3.000
TEMPERATURE	18/03/85	3.500	3.500			3.500
TEMPERATURE	25/03/85	4.000	4.000			4.000
TEMPERATURE	01/04/85					5.000
TEMPERATURE	09/04/85		7.500			
TEMPERATURE	15/04/85	8.000				8.000
TEMPERATURE	22/04/85	8.500	8.500			8.500
TEMPERATURE	07/05/85	10.000	10.000			9.000
TEMPERATURE	13/05/85	10.000	9.000			9.000
TEMPERATURE	28/05/85		12.000			12.500
TEMPERATURE	11/06/85		13.000			
TEMPERATURE	18/06/85	14.000	14.000			13.500
TEMPERATURE	15/07/85		17.500			17.500
TEMPERATURE	12/08/85					14.500
TEMPERATURE	20/08/85	15.000	15.500			14.500
TEMPERATURE	02/09/85					14.000
TEMPERATURE	17/09/85	13.000	12.500			13.000
TEMPERATURE	23/09/85	13.000	13.000			
TEMPERATURE	02/10/85	14.500	14.500			13.000
TEMPERATURE	08/10/85	12.000	12.500			12.500
TEMPERATURE	29/10/85	9.000	9.000			
TEMPERATURE	04/11/85	11.000	12.000			11.500
TEMPERATURE	18/11/85					8.000
TEMPERATURE	25/11/85	6.000	6.000			6.500
TEMPERATURE	02/12/85	6.000				5.000
TEMPERATURE	09/12/85					6.000
TEMPERATURE	16/12/85	7.000	7.000			7.000
TEMPERATURE	06/01/86	3.000				3.500
TEMPERATURE	20/01/86	3.500				
TEMPERATURE	27/01/86	2.000				2.000
TEMPERATURE	03/02/86					2.000
TEMPERATURE	10/03/86					1.500
TEMPERATURE	17/03/86					1.500
TEMPERATURE	01/04/86					3.000
TEMPERATURE	07/04/86					3.000
TEMPERATURE	21/04/86	4.000	3.000			5.000
TEMPERATURE	21/04/86		4.000			
TEMPERATURE	29/04/86	8.000	9.000			8.000
TEMPERATURE	06/05/86	10.000	10.000			9.000
TEMPERATURE	12/05/86	9.500	9.000			9.500
TEMPERATURE	19/05/86	12.500	10.500			10.500
TEMPERATURE	16/06/86	17.500	17.500			16.000
TEMPERATURE	23/06/86	15.500	15.500			13.000
TEMPERATURE	30/06/86		18.000			16.000
TEMPERATURE	30/06/86		18.000			16.000

DETERMINAND	DATE	NI	ST	S12	IN	LT
TEMPERATURE	11/08/86		13.500			13.500
TEMPERATURE	08/12/86	9.000	8.500			8.500
TEMPERATURE	16/12/86	7.500	7.500			8.000
TEMPERATURE	26/01/87	4.000	4.000			4.000
TEMPERATURE	23/02/87	2.500	2.500			
TEMPERATURE	10/03/87					1.500
TEMPERATURE	10/03/87					1.500
TEMPERATURE	06/04/87	8.000	8.500			8.500
TEMPERATURE	27/04/87	10.000	10.000			10.000
TEMPERATURE	05/05/87	10.000	10.000			11.000
TEMPERATURE	19/05/87	10.000	10.000			11.000
TEMPERATURE	08/06/87	12.500	12.500			
TEMPERATURE	23/06/87	14.000	14.000			14.000
TEMPERATURE	30/06/87	16.000	16.000			
TEMPERATURE	07/07/87		17.000			
TEMPERATURE	13/07/87	13.500	13.500			14.000
TEMPERATURE	28/07/87	14.000	14.000			
TEMPERATURE	11/08/87	14.500	14.500			15.000
TEMPERATURE	17/08/87	15.500	15.500			16.000
TEMPERATURE	01/09/87	16.000	16.000			
TEMPERATURE	08/09/87	15.500	15.500			
TEMPERATURE	21/09/87	15.500	15.500			16.000
TEMPERATURE	30/09/87	13.500	13.500			14.000
TEMPERATURE	14/10/87	11.500	11.500			
TEMPERATURE	28/10/87	10.000	10.500			
TEMPERATURE	04/11/87	10.500	10.500			10.000
TEMPERATURE	25/11/87	8.000	8.000			8.000
TEMPERATURE	01/12/87	5.000	5.000			
TEMPERATURE	06/04/88	6.000	6.000			6.000
TEMPERATURE	07/04/88		8.500			
TEMPERATURE	13/04/88	7.500	7.500			
TEMPERATURE	27/04/88	8.500				8.500
TEMPERATURE	04/05/88	10.000	10.000			
TEMPERATURE	11/05/88	9.000	9.000			
TEMPERATURE	17/05/88	12.000	12.000			
TEMPERATURE	25/05/88	12.000	12.000			
TEMPERATURE	01/06/88	12.000	12.000			
TEMPERATURE	07/06/88	10.000	10.000			
TEMPERATURE	14/06/88	5.500	5.500			6.000
TEMPERATURE	21/06/88	17.000	17.000			
TEMPERATURE	29/06/88		16.000			
TEMPERATURE	06/07/88	16.000	16.000			
TEMPERATURE	12/07/88	16.500	16.500			16.500
TEMPERATURE	20/07/88	16.000	16.000			
TEMPERATURE	28/07/88		16.000			15.000
TEMPERATURE	10/08/88		17.500			
TEMPERATURE	17/08/88	17.000	17.000			
TEMPERATURE	24/08/88	18.000	18.000			
TEMPERATURE	01/09/88		17.500			
TEMPERATURE	07/09/88	17.000	17.000			
TEMPERATURE	14/09/88	15.500	15.500			
TEMPERATURE	28/09/88	15.000	15.000			
TEMPERATURE	11/10/88	10.500	10.500			
TEMPERATURE	19/10/88	11.000	11.000			
TEMPERATURE	29/05/90					15
TEMPERATURE	04/06/90		14			14.37

DETERMINAND	DATE	NI	ST	ST2	IN	LT
TEMPERATURE	11/06/90			14	14	14
TEMPERATURE	18/06/90			15.7	14.9	14.8
TEMPERATURE	25/06/90			15.1	15.1	15.1
TEMPERATURE	02/07/90			15.7	15.8	16.1
TEMPERATURE	09/07/90			15.8		16.5
TEMPERATURE	16/07/90		18.7	18.7	19.3	18.4
TEMPERATURE	23/07/90		19.2	19.3	19.9	18.3
TEMPERATURE	30/07/90		18.5	18.9	18.6	18.8
TEMPERATURE	06/08/90			18.4	19.8	20.3
TEMPERATURE	13/08/90		19.7	19.7	19.7	19.9
TEMPERATURE	20/08/90			17.7		17.3
TEMPERATURE	29/08/90		19.8	19.7	19.7	20
TEMPERATURE	03/09/90		18.5	18.6	18.4	18.7
TEMPERATURE	10/09/90		16.7	16.7	17.1	17.2
TEMPERATURE	18/09/90		15.8	15.9	15.9	16.2
TEMPERATURE	24/09/90		13.2	13.7	13.5	14.3
TEMPERATURE	01/10/90			13.3	13.6	13.9
TEMPERATURE	08/10/90		12.2	12.4	12.4	12.9
TEMPERATURE	15/10/90		13.5	13.3	13.1	13.1
TEMPERATURE	22/10/90		12.3	12.6	12.7	12.5
TEMPERATURE	30/10/90		10.8	10.8	10.6	11.5
TEMPERATURE	05/11/90		8.7	9	8.9	9.9
TEMPERATURE	12/11/90		9.2	9.1	9.1	9.2
TEMPERATURE	19/11/90		8.8	8.7	8.7	8.7
TEMPERATURE	26/11/90		6.9	7		7.4
TEMPERATURE	03/12/90		6.2	6.4	6.9	6.8
TEMPERATURE	12/12/90		4.8	5.5		
TEMPERATURE	17/12/90		4.5	4.2	4.1	4.7
TEMPERATURE	07/01/91			3.8		3.9
TEMPERATURE	14/01/91		3	3.1	3	3.3
TEMPERATURE	21/01/91		3.2	3.1	3.2	3.3
TEMPERATURE	28/01/91		2.5	2.7	2.8	3
TEMPERATURE	04/02/91		1.6	1.8	2	2.6
TEMPERATURE	20/02/91		1.8	1.6	1.5	1.4
TEMPERATURE	25/02/91		4.4	3.8	4.3	2.9
TEMPERATURE	04/03/91		3.8	4	4.2	3.8
TEMPERATURE	11/03/91		6	5.8	6.1	5
TEMPERATURE	18/03/91		6.7	6.7	7.1	6.3
TEMPERATURE	16/04/91		9.6	9.4	9.2	8.9
TEMPERATURE	22/04/91		8.1	8.1	8.1	8
TEMPERATURE	03/04/91		9.7	9.5		8.6
TEMPERATURE	07/05/91		8.6	8.7	8.6	8.6
TEMPERATURE	13/05/91		9.9	10.2	10.6	11.4
TEMPERATURE	20/05/91		10.74	10.78	11.1	11.32
TEMPERATURE	28/05/91		13.77	13.68	13.78	12.78
TEMPERATURE	03/06/91		12.23	12.26	12.4	12.34
TEMPERATURE	10/06/91		12.85	12.85	12.92	12.8
TEMPERATURE	17/06/91		12.96	13.04	13.14	13.2
TEMPERATURE	24/06/91		14.45	14.68	14.46	14.14
TEMPERATURE	01/07/91		15.22	15.36	15.49	15.81
TEMPERATURE	08/07/91		20.13	20.45	19.11	17.85
TEMPERATURE	15/07/91		18.06	18.11	17.91	18.28
TEMPERATURE	29/07/91		19.91	19.92	19.5	19.59
TEMPERATURE	05/08/91		19.99	20.16	19.85	20.17
TEMPERATURE	12/08/91		19.01	19.04	18.99	19.47
TEMPERATURE	20/08/91		18.51	18.68	18.8	19.39

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TEMPERATURE	27/08/91	18.66	18.79	19.13		19.8
TEMPERATURE	02/09/91	19.55	19.47	19.33		18.74
TEMPERATURE	09/09/91	18.89	18.81	18.8		18.97
TEMPERATURE	16/09/91	17.78	17.85	17.8		17.98
TEMPERATURE	25/09/91	16.08	16.43	15.87		16.85
TEMPERATURE	01/10/91	14.21	13.8	13.13		13.64
TEMPERATURE	14/10/91	13.31	13.34	13.55		13.73
TEMPERATURE	21/10/91	10.07	10.49	10.41		11.3
TEMPERATURE	28/10/91	10.15	10.27	10.29		10.33
TEMPERATURE	04/11/91	9.4	9.56			
TEMPERATURE	11/11/91	8.08	8.14	7.97		8.48
TEMPERATURE	18/11/91	6.91	6.97	7.01		7.25
TEMPERATURE	25/11/91	6.14	6.36	6.13		6.51
TEMPERATURE	02/12/91	6.71	6.69	6.58		6.68
TEMPERATURE	10/12/91	4.58	5.1	5.2		5.98
TEMPERATURE	17/12/91	3.74	4	4.03		4.97
TEMPERATURE	07/01/92	5.76	5.78	5.79		5.79
TEMPERATURE	13/01/92	4.85	5	5.11		5.45
TEMPERATURE	20/01/92	4.85	4.85	4.73		4.83
TEMPERATURE	27/01/92	2.94	3.39	3.1		3.94
TEMPERATURE	03/02/92	3.49	3.51	3.37		
TEMPERATURE	10/02/92		4.19	4.3		
TEMPERATURE	17/02/92	4.14	4.25	4.3		4.43
TEMPERATURE	24/02/92	4.47	4.51	4.52		
TEMPERATURE	02/03/92	5.11	5.09	5.16		
TEMPERATURE	09/03/92	5.94	5.92	6.04		
TEMPERATURE	16/03/92	6.04	6.04	6.1		
TEMPERATURE	23/03/92	6.83	6.81	6.95		6.85
TEMPERATURE	30/03/92	6.57	6.6	6.54		6.64
TEMPERATURE	06/04/92	6.82	6.85	6.83		6.7
TEMPERATURE	21/04/92	8.92	9.02	9		9.04
TEMPERATURE	29/04/92	9.73	9.68	9.84		9.76
TEMPERATURE	05/05/92	10.34				10.99
TEMPERATURE	11/05/92	10.94	10.94	11.15	11.22	11.2
TEMPERATURE	18/05/92	14.08	13.96	14.32	13.76	13.22
TEMPERATURE	26/05/92	17.41	17.61			16.09
TEMPERATURE	09/06/92	16.88	16.81	16.87		16.6
TEMPERATURE	15/06/92	19.15	19.57	19.54		20.18
TEMPERATURE	22/06/92	17.46	17.49	17.49		17.14
TEMPERATURE	29/06/92	21.76	20.74	21.18		21.6
TEMPERATURE	06/07/92	17.28	17.37	17.6		17.5
TEMPERATURE	13/07/92	17.6	17.61	17.6		17.83
TEMPERATURE	20/07/92	18.7	18.67	18.46		18.79
TEMPERATURE	17/08/92	17.85	17.95			
TEMPERATURE	24/08/92	17.43	17.61	17.64		18.12
TEMPERATURE	07/09/92	15.11	15.28	15.14		15.5
TEMPERATURE	14/09/92	14.16	14.37	14.12		14.59
TEMPERATURE	21/09/92	14.82	14.77	14.81		14.74
TEMPERATURE	28/09/92	14.88	14.81	14.8		
TEMPERATURE	05/10/92	13.74	13.91	13.85		13.99
TEMPERATURE	19/10/92	10.45	10.76	10.64		11.19
TEMPERATURE	26/10/92	9.14	9.34	9.14		9.73
TEMPERATURE	03/11/92	8.41	8.46	8.22		8.66
TEMPERATURE	09/11/92	8.66	8.71	8.64		8.76
TEMPERATURE	16/11/92	7.12	7.18	7.13		7.6
TEMPERATURE	23/11/92	6.71				

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TEMPERATURE	03/12/92	6.68	6.7	6.7		6.73
TEMPERATURE	07/12/92	5.85	6.04	5.83		6.15
TEMPERATURE	14/12/92	5.87	5.88	5.84		5.92
TEMPERATURE	21/12/92	5.07	5.29	5.27		5.53
TEMPERATURE	04/01/93	2.66	2.94	2.81		3.85
TEMPERATURE	01/02/93	4.8	4.84	4.79		4.79
TEMPERATURE	08/02/93	4.98		4.95		4.94
TEMPERATURE	15/02/93	4.77				
TEMPERATURE	22/02/93	4.64	4.69			4.72
TEMPERATURE	01/03/93	2		3.88		4.1
TEMPERATURE	08/03/93	4.07		3.92		3.99
TEMPERATURE	15/03/93	5.81		5.67		4.8
TEMPERATURE	22/03/93	6.11		6.42		6.23
TEMPERATURE	29/03/93	6.17		6.3		6.24
TEMPERATURE	05/04/93	6.87		6.91		6.72
TEMPERATURE	13/04/93	8.41		7.85		7.6
TEMPERATURE	19/04/93	8.56		8.9		8.7
TEMPERATURE	26/04/93	9.93		9.93	9.96	9.62
TEMPERATURE	04/05/93	11.31		11.42	11.16	12.3
TEMPERATURE	10/05/93	12.1		11.94	11.56	11.09
TEMPERATURE	17/05/93	11.99		12.11	12.06	11.01
TEMPERATURE	24/05/93	13.3		13.12	12.99	
TEMPERATURE	01/06/93	13.29		13.37		13.3
TEMPERATURE	07/06/93	15.89		16.83	17.35	18.26
TEMPERATURE	14/06/93	15.64		15.82	15.75	15.47
TEMPERATURE	27/06/93	11		10.9		11.1
TEMPERATURE	05/07/93	13.3		13.7		13.7
TEMPERATURE	12/07/93	12		12.1		12.4
TEMPERATURE	26/07/93	17.2		17.2		17.5
TEMPERATURE	02/08/93	17.6		18.1		17.8
TEMPERATURE	09/08/93	17.3		17.3		17.5
TEMPERATURE	16/08/93	17		17.5		17.6
TEMPERATURE	23/08/93	17.5		17.8		17.7
TEMPERATURE	31/08/93	17.1		17.1		17.7
TEMPERATURE	06/09/93	16.12		16.24		16.5
TEMPERATURE	13/09/93	15.5		15.54		15.75
TEMPERATURE	20/09/93	14.94		14.97	14.7	14.82
TEMPERATURE	27/09/93	14		14		
TEMPERATURE	04/10/93	13.31	13.34	13.28		13.45
TEMPERATURE	11/10/93	12.94	12.98	12.83	12.89	13.09
TEMPERATURE	19/10/93	10.78	10.94	10.9	11.02	11.38
TEMPERATURE	25/10/93	9.52	9.64	9.49	9.74	9.86
TEMPERATURE	01/11/93	9	9.02	8.95	9.16	9.26
TEMPERATURE	08/11/93	9.04	9.04	8.86	8.91	8.89
TEMPERATURE	15/11/93	7.87	7.85	7.84		8.12
TEMPERATURE	22/11/93	5.6	6.11	6.1	6.4	6.71
TEMPERATURE	06/12/93	5.55		5.7		5.8
TEMPERATURE	13/12/93	5.2		5.1		5.2
TEMPERATURE	10/01/94	3.61	3.54	3.52		
TEMPERATURE	24/01/94		3.75			
TEMPERATURE	07/02/94		3.95	3.94	4.06	4.04
TEMPERATURE	21/02/94	2.64			2.74	2.97
TEMPERATURE	01/03/94	13.29	3.08	3.07	2.99	3.04
TEMPERATURE	07/03/94		4.15	4.27	4.14	4.09
TEMPERATURE	15/03/94	5.71		5.88	5.64	5.64
TEMPERATURE	16/05/94	12.98		12.9	12.74	5.42

DETERMINAND	DATE	NI	ST	SI2	IN	LT
TEMPERATURE	23/05/94	11.82		11.79	11.82	11.75
TEMPERATURE	31/05/94	12.06		12.35	12.5	12.74
TEMPERATURE	06/06/94	13.04	13.06	12.88	13.14	13.43
TEMPERATURE	13/06/94	14.14		15.05	15.31	15.52
TEMPERATURE	20/06/94	15.28		15.07	15.76	15.98
TEMPERATURE	27/06/94	16.48		16.58	16.87	17.09
TEMPERATURE	04/07/94	19.37		19.52	19.81	19.8
TEMPERATURE	11/07/94	19.78		19.7	19.85	20.2
TEMPERATURE	18/07/94	19.68		19.83	19.77	19.25
TEMPERATURE	25/07/94	20.76		20.87	20.79	21.02
TEMPERATURE	01/08/94	20.78		20.7	20.33	20.54
TEMPERATURE	08/08/94	19.96		20.08	19.92	19.77
TEMPERATURE	15/08/94	18.42		18.72	19.2	18.9
TEMPERATURE	22/08/94	18.18		17.93	18.01	18.12
TEMPERATURE	30/08/94	17.04		17.17	17.56	17.78
TEMPERATURE	05/09/94	16.59		16.71	16.78	16.86
TEMPERATURE	12/09/94	15.51		15.5	15.86	15.97
TEMPERATURE	19/09/94	14.16		14.13	14.16	14.25
TEMPERATURE	26/09/94	14.23		14.05	13.92	14.1
TEMPERATURE	07/10/94	10.39		10.23	10.31	10.45
TEMPERATURE	10/10/94	12.85		12.77	12.92	12.9
TEMPERATURE	17/10/94	12.04		11.96	11.93	12.07
TEMPERATURE	24/10/94	11.5		11.38	11.45	11.56
TEMPERATURE	21/11/94	10.02		10.02	10.16	10.21
TEMPERATURE	05/12/94	8.79		8.78	9.02	9.16
TEMPERATURE	12/12/94	8.36		8.36	8.46	8.53
TEMPERATURE	19/12/94	7.11		7.28	7.63	7.72

II (c) Total iron data from sites 1 - 7 in south arm of Rutland Water 1993

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
10/02/93	0.1	0.1		0.07		0.04	0.05
10/03/93	0.04	0.07	0.07	0.05		0.05	0.05
14/04/93	0.07	0.1	0.04	0.05	0.05	0.03	0.02
10/06/93	0.06	0.08	0.03	0.07	0.07	0.07	0.03
08/07/93	0.02	0.04	0.05	0.03	0.04	0.03	0.03
11/08/93	0.03	0.05	0.05		0.06	0.05	0.03
23/09/93	0.112	0.112	0.112		0.112	0.168	0.11

II (d) Chlorophyll a at sites 1 - 7 in south arm of Rutland Water 1993

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
10/03/93	7.97	8.09	7.08	8.08		9.38	10.07
14/04/93	9.48	8.39	9.12	7.76	10.26	7.76	11.36
10/06/93	9.22	7.29	7.35	6.51	4.74	5.11	4.43
08/07/93	54.83	41.28	30.86	25.96	47.95	44.2	37.1
11/08/93	30.65	22.46	29.14		19.44	23.77	23.71

II (e) Total Iron (mg/l) at depth at sites 2 and 6 in south arm of Rutland Water 1993

Date	Site	2m	4m	6m	8m	10m
10/03/93	Site 2	0.07	0.07	0.07	0.12	0.9
10/03/93	Site 6	0.05	0.05	0.05	0.08	0.09
10/06/93	Site 2	0.08	0.08	0.08	0.25	0.33
10/06/93	Site 6	0.07	0.06	0.08	0.09	0.09
11/08/93	Site 2	0.05	0.06	0.05	0.09	0.15
11/08/93	Site 6	0.05	0.05	0.05	0.06	0.05

II (f) Chlorophyll at depth at sites 2 and 6 in south arm of Rutland Water 1993

Date	Site	2m	4m	6m	8m	10m
10/03/93	Site 2	9.1	8.5	7.8	6.2	6.1
10/03/93	Site 6	10.1	9.8	9.1	6.8	7.1
10/06/93	Site 2	7.4	7.1	6.8	5.9	4.2
10/06/93	Site 6	5.8	4.9	4.5	4.5	4.2
11/08/93	Site 2	24.2	23.5	22.2	19.9	20.1
11/08/93	Site 6	24.5	24.1	23.9	21.1	20.9

II (g) Depth profile data from Rutland Water 1991 - 1994

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
LT	04/01/93	0.19	3.85	97.49	101.38	117.01	898.08	8.23
LT	04/01/93	0.57	3.85	97.36	104.52	91.75	897.07	8.23
LT	04/01/93	1.09	3.85	97.36	103.19	65.42	897.18	8.23
LT	04/01/93	1.54	3.85	97.19	97.99	47.07	896.79	8.23
LT	04/01/93	2.05	3.85	97.21	93.29	36.46	896.96	8.23
LT	04/01/93	2.61	3.85	97.21	91.88	26.51	896.53	8.23
LT	04/01/93	3.04	3.85	97.14	88.75	14.3	896.64	8.23
LT	04/01/93	3.51	3.85	97.14	89.57	12.69	896.64	8.23
LT	04/01/93	4.04	3.85	97.06	90.4	11.38	896.64	8.23
LT	04/01/93	4.53	3.85	97.06	91.72	9.59	896.32	8.23
LT	04/01/93	5.07	3.85	96.99	93.45	8.34	896.32	8.23
LT	04/01/93	5.53	3.85	97.06	94.53	7.57	896.21	8.22
LT	04/01/93	6.02	3.85	97.06	95.6	6.37	896.11	8.22
LT	04/01/93	7.02	3.85	97.06	94.61	4.47	896.11	8.21
LT	04/01/93	8.04	3.86	97.02	95.19	3.1	895.64	8.21
LT	04/01/93	9.02	3.85	97.06	99.73	2.2	895.46	8.2
LT	04/01/93	10.1	3.85	97.06	104.43	1.67	895.35	8.18
LT	04/01/93	11.11	3.85	96.97	107.32	1.25	894.86	8.16
LT	04/01/93	12.05	3.85	96.9	108.97	0.89	894.86	8.15
LT	04/01/93	13.05	3.85	96.99	106.74	0.71	894.5	8.12
LT	04/01/93	14	3.85	96.99	102.7	0.54	894.39	8.12
LT	04/01/93	14.99	3.85	96.9	98.74	0.36	894.21	8.16
LT	04/01/93	15.85	3.85	96.99	102.62	0.3	893.85	8.18
LT	04/01/93	16.96	3.85	96.99	101.46	0.06	893.64	8.19
LT	04/01/93	17.98	3.85	97.06	100.06	0.06	893.64	8.19
LT	04/01/93	18.99	3.85	96.9	100.31	0	893.03	8.17
LT	04/01/93	19.99	3.83	96.91	101.63	0	893.22	8.14
LT	04/01/93	20.97	3.84	96.8	103.11	0	892.64	8.1
LT	04/01/93	21.92	3.84	96.8	105.84	0	892.54	8.09
LT	04/01/93	22.95	3.83	96.69	114.51	0	892.25	8.09
LT	04/01/93	23.93	3.82	96.57	117.48	-0.06	892.22	8.09
LT	04/01/93	24.79	3.82	96.57	120.94	0	892.01	8.1
N1	04/01/93	0.19	2.66	110.2	99.48	123.62	886.89	7.38
N1	04/01/93	0.6	2.67	105.41	96.26	91.33	885.28	7.87
N1	04/01/93	1	2.67	104.1	97.17	72.56	885.5	7.97
N1	04/01/93	1.54	2.68	103.29	101.46	53.5	885.02	8.05
N1	04/01/93	2.04	2.68	102.6	108.48	48.73	884.8	8.1
N1	04/01/93	2.57	2.68	102.06	113.93	37.12	884.36	8.11
N1	04/01/93	3.09	2.68	101.29	123.01	30.98	884.25	8.12
N1	04/01/93	3.51	2.67	100.72	124.08	26.75	883.95	8.13
N1	04/01/93	4.02	2.66	100.53	122.43	22.34	884.32	8.13
N1	04/01/93	4.54	2.66	100.12	113.93	16.09	884.57	8.12
N1	04/01/93	5.01	2.66	99.89	111.7	13.05	883.69	8.13
N1	04/01/93	5.55	2.66	99.66	107.74	10.25	883.69	8.13
N1	04/01/93	6.03	2.66	99.51	104.52	8.58	883.58	8.14
N1	04/01/93	7.01	2.66	99.35	103.69	5.9	883.36	8.16
N1	04/01/93	8.03	2.66	99.28	106	4.11	883.14	8.17
N1	04/01/93	9.1	2.66	98.99	107.9	2.74	882.99	8.16
N1	04/01/93	10.11	2.67	98.95	110.96	2.03	884.17	8.13
N1	04/01/93	11.06	2.67	98.8	109.72	1.55	882.52	8.08
S12	04/01/93	0.21	2.81	98.81	122.35	141.91	886.56	8.27
S12	04/01/93	0.6	2.8	98.62	119.21	93.18	885.28	8.27
S12	04/01/93	1.04	2.8	98.55	119.21	38.49	885.06	8.27
S12	04/01/93	1.5	2.81	98.35	130.11	32.65	884.91	8.27
S12	04/01/93	2.06	2.85	98.31	130.93	27.29	885.03	8.27

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
S12	04/01/93	2.57	2.86	98.19	132.25	21.69	885.54	8.27
S12	04/01/93	3.05	2.87	98.25	124.33	19.48	885.36	8.26
S12	04/01/93	3.53	2.88	98.28	124.16	17.75	885.33	8.26
S12	04/01/93	4.03	2.89	98.09	126.81	13.52	885.29	8.26
S12	04/01/93	4.52	2.87	98.17	131.92	12.21	885.47	8.26
S12	04/01/93	5.03	2.89	98.09	138.28	10.19	885.29	8.26
S12	04/01/93	5.46	2.89	98.09	140.1	8.7	884.85	8.25
S12	04/01/93	6.01	2.93	98.2	149.51	8.1	884.64	8.25
S12	04/01/93	6.99	2.95	98.14	149.26	5.48	884.86	8.24
S12	04/01/93	8.01	2.97	98.07	156.69	3.93	885.08	8.22
S12	04/01/93	9.08	3.1	98.23	159.5	2.68	885.45	8.2
S12	04/01/93	10.1	3.11	97.98	175.43	2.03	885.93	8.16
S12	04/01/93	11.09	3.18	97.96	176.17	1.49	886.03	8.16
S12	04/01/93	12.09	3.19	97.92	171.47	1.07	886.21	8.16
S12	04/01/93	13.02	3.19	97.94	175.93	0.77	885.74	8.18
S12	04/01/93	14	3.23	97.86	181.71	0.66	885.9	8.2
S12	04/01/93	15.03	3.24	97.76	194.17	0.48	885.94	8.21
ST	04/01/93	0.26	2.94	98.77	105.67	163.9	888.33	8.2
ST	04/01/93	0.62	2.92	98.54	104.68	12.21	887.2	8.21
ST	04/01/93	0.96	2.92	98.24	106.99	76.62	887.52	8.23
ST	04/01/93	1.54	2.92	98.24	110.87	53.2	886.87	8.26
ST	04/01/93	2.02	2.93	98.27	110.13	46.29	886.72	8.27
ST	04/01/93	2.54	2.93	98.2	113.35	29.91	886.83	8.27
ST	04/01/93	3.05	2.93	98.2	117.56	28.12	886.83	8.27
ST	04/01/93	3.53	2.94	98.18	125.98	21.98	886.87	8.26
ST	04/01/93	4.03	2.94	98.1	131.59	23.47	886.87	8.23
ST	04/01/93	4.52	2.96	98.1	121.03	15.97	886.69	8.2
ST	04/01/93	5.05	2.98	98.11	130.03	14.36	886.58	8.18
ST	04/01/93	5.55	3.01	98.08	142.08	12.75	886.65	8.15
ST	04/01/93	6.04	3.07	98.04	140.68	11.56	887.01	8.14
ST	04/01/93	7.01	3.08	98.07	134.4	7.86	886.97	8.14
ST	04/01/93	8.05	3.16	97.95	131.1	5.3	887.44	8.15
ST	04/01/93	9.07	3.22	97.96	133.99	3.75	887.06	8.15
ST	04/01/93	10.07	3.26	97.9	137.29	2.74	887.61	8.16
ST	04/01/93	11.06	3.31	97.97	133.58	2.09	887.55	8.16
ST	04/01/93	12.07	3.32	97.85	123.83	1.37	887.62	8.16
ST	04/01/93	13.01	3.32	97.85	122.76	1.01	887.51	8.16
ST	04/01/93	13.99	3.33	97.73	128.29	0.77	887.37	8.16
LT	15/03/93	0.18	4.8	118.35	1499.13	1283.94	344.18	8.81
LT	15/03/93	0.53	4.8	118.35	1540.16	695.56	343.8	8.8
LT	15/03/93	0.95	4.79	118.4	1657.56	184.87	343.59	8.78
LT	15/03/93	1.6	4.79	118.38	1723.11	95.56	343.41	8.74
LT	15/03/93	2.06	4.78	118.29	1658.3	66.43	343.23	8.73
LT	15/03/93	2.61	4.77	118.25	1648.64	77.81	342.92	8.69
LT	15/03/93	3.09	4.75	118.36	1743.5	103.25	342.73	8.67
LT	15/03/93	3.56	4.77	118.25	1774.13	146.74	342.83	8.65
LT	15/03/93	4.01	4.75	118.28	1750.35	112.66	342.56	8.65
LT	15/03/93	4.54	4.75	118.19	1751.51	101.22	342.34	8.65
LT	15/03/93	5.04	4.75	118.19	1745.65	77.15	342.39	8.65
LT	15/03/93	5.51	4.75	118.19	1745.73	56.72	342.3	8.66
LT	15/03/93	6.07	4.74	118.17	1757.86	48.2	341.84	8.69
LT	15/03/93	8.07	4.71	117.91	1718.48	20.32	341.32	8.72
LT	15/03/93	10.06	4.7	117.89	1743.58	8.82	341.15	8.74
LT	15/03/93	12.02	4.71	117.83	1753.41	4.05	341.03	8.75
LT	15/03/93	14.03	4.71	117.83	1764.3	1.97	341.74	8.74
LT	15/03/93	16.01	4.66	117.4	1755.39	1.01	339.93	8.68

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
LT	15/03/93	18.01	4.65	116.98	1719.06	0.6	339.37	8.63
LT	15/03/93	19.97	4.62	116.64	1672.25	0.3	338.7	8.58
LT	15/03/93	21.92	4.56	116.07	1663.91	0.06	337.44	8.57
LT	15/03/93	23.98	4.51	115.24	1701.4	0.06	336.68	8.6
LT	15/03/93	25.77	4.47	114.95	1701.73	0.06	335.91	8.62
LT	15/03/93	27.87	4.43	103.8	1595.15	0	335.06	8.24
N1	15/03/93	0.24	5.81	145.17	460.58	530.12	356.05	9.1
N1	15/03/93	0.65	5.79	143.09	431.77	210.07	355.15	9.05
N1	15/03/93	1	5.79	141.95	438.37	31.34	355.08	9.08
N1	15/03/93	1.53	5.74	141.3	437.13	99.14	354.3	9.11
N1	15/03/93	2	5.7	140.84	468.34	52.43	353.69	9.14
N1	15/03/93	2.55	5.64	139.01	422.69	48.2	352.52	9.13
N1	15/03/93	3.07	5.64	138.69	433.83	25.08	352.34	9.11
N1	15/03/93	3.54	5.44	135.11	419.88	17.87	349.16	8.96
N1	15/03/93	4.06	5.35	134.01	745.89	35.57	347.99	8.88
N1	15/03/93	4.55	5.23	131.18	685.87	23.95	345.67	8.89
N1	15/03/93	5.04	5.18	130.75	685.05	20.91	345.06	8.89
N1	15/03/93	5.53	5.17	130.26	675.97	13.82	344.74	8.89
N1	15/03/93	6.04	5.12	129.35	707.42	10.66	344.03	8.89
N1	15/03/93	8.03	4.88	124.7	556.84	3.87	339.82	8.83
N1	15/03/93	10.11	4.71	122.5	526.21	1.79	337.04	8.8
S12	15/03/93	0.11	5.67	138.67	571.2	808.22	356.88	9.18
S12	15/03/93	0.61	5.66	138.5	471.89	287.1	355.59	9.15
S12	15/03/93	0.94	5.59	138.42	485.1	234.61	354.4	9.13
S12	15/03/93	1.57	5.47	137.54	532.24	90.26	352.5	9.03
S12	15/03/93	2.04	5.35	136.24	517.46	66.61	350.88	9.01
S12	15/03/93	2.58	5.29	134.67	527.2	45.99	349.98	9.06
S12	15/03/93	3.07	5.13	131.38	509.37	37	347.84	9.02
S12	15/03/93	3.53	5.1	129.88	560.72	35.09	347.15	9
S12	15/03/93	4.04	5.07	129.78	530.59	22.22	346.9	8.99
S12	15/03/93	4.54	5.07	129.23	523.9	16.86	346.72	8.97
S12	15/03/93	5.07	5.05	128.98	947.16	24.72	346.57	8.96
S12	15/03/93	5.56	5.03	128.56	909.85	15.79	346.24	8.94
S12	15/03/93	6.05	5.03	128.41	962.93	12.03	346.2	8.9
S12	15/03/93	8.08	4.87	125.14	629.49	3.04	344.5	8.75
S12	15/03/93	10.09	4.84	123.68	598.94	1.25	344.61	8.69
S12	15/03/93	12.09	4.8	121.77	566.99	0.6	345.13	8.66
S12	15/03/93	14.02	4.75	119.42	579.79	0.24	345.09	8.66
IN	14/06/93	0.13	15.75	10.17	152.89	353.83	557	8.22
IN	14/06/93	0.45	15.78	10.18	319	272.21	558.24	8.24
IN	14/06/93	0.92	15.79	10.2	305.54	91.27	558.62	8.25
IN	14/06/93	1.48	15.81	10.2	300.34	56.42	559.21	8.26
IN	14/06/93	2	15.76	10.15	292.74	48.61	559.32	8.26
IN	14/06/93	2.47	15.57	9.95	261.7	37.65	557.16	8.26
IN	14/06/93	2.97	15.42	9.85	265.83	33.48	553	8.26
IN	14/06/93	3.44	15.38	10.01	279.78	19.18	554.95	8.28
IN	14/06/93	3.94	15.3	10.02	271.11	13.94	555.45	8.29
IN	14/06/93	4.46	15.27	9.88	265.17	11.2	554.14	8.27
IN	14/06/93	4.95	15.27	9.79	268.55	10.6	553.19	8.26
IN	14/06/93	5.45	15.24	9.61	305.37	10.31	551.67	8.24
IN	14/06/93	5.92	15.05	9.37	332.87	8.16	549.13	8.21
IN	14/06/93	6.93	14.97	9.25	330.55	4.77	547.25	8.19
IN	14/06/93	7.98	14.77	9.16	312.39	2.86	543.95	8.17
IN	14/06/93	8.95	14.7	9.1	360.85	2.26	542.04	8.14
IN	14/06/93	9.99	14.62	8.96	373.9	1.43	540.04	8.11
IN	14/06/93	10.98	14.56	8.83	365.31	0.83	538.38	8.06

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
IN	14/06/93	11.93	14.51	8.7	434.16	0.66	536.72	7.98
IN	14/06/93	12.95	14.5	8.7	452.24	0.42	536.07	7.97
IN	14/06/93	13.88	14.35	8.53	467.35	0.12	531.78	7.96
IN	14/06/93	14.86	14.26	8.42	463.06	0.06	530.04	7.96
IN	14/06/93	15.87	14	8.18	455.63	0.06	526.79	7.97
IN	14/06/93	16.89	13.89	8.19	469.99	0	527.52	7.98
IN	14/06/93	17.86	13.82	8.12	460.58	0	525.77	7.99
IN	14/06/93	18.88	13.58	7.97	446.88	0	522	7.99
IN	14/06/93	19.95	13.45	7.5	418.97	0	519.17	7.98
LT	14/06/93	0.15	15.47	10.42	169.16	156.15	559.76	8.28
LT	14/06/93	0.52	15.48	10.42	165.85	107.95	559.32	8.29
LT	14/06/93	1	15.48	10.43	162.8	88.77	559.26	8.29
LT	14/06/93	1.46	15.48	10.41	156.44	43.73	559.4	8.29
LT	14/06/93	2.04	15.48	10.41	156.61	22.88	559.35	8.28
LT	14/06/93	2.5	15.48	10.41	158.42	26.51	559.3	8.28
LT	14/06/93	3	15.46	10.38	158.26	22.88	558.89	8.28
LT	14/06/93	3.48	15.46	10.38	156.36	17.4	558.83	8.28
LT	14/06/93	4	15.46	10.37	152.48	12.69	558.78	8.27
LT	14/06/93	4.48	15.45	10.29	145.55	9.23	558.24	8.27
LT	14/06/93	5.01	15.37	10.2	139.52	7.03	556.76	8.26
LT	14/06/93	5.47	15.35	10.16	134.9	5.3	556.14	8.25
LT	14/06/93	6	15.28	10.09	131.76	4.11	555.04	8.25
LT	14/06/93	6.94	15.21	9.96	125.65	2.5	553.98	8.23
LT	14/06/93	7.93	15.15	9.9	123.59	1.67	553.31	8.22
LT	14/06/93	9.04	15.09	9.85	124.25	1.13	552.74	8.21
LT	14/06/93	10.02	14.84	9.49	127.05	0.89	549.65	8.17
LT	14/06/93	11.03	14.57	9.18	128.29	0.66	544.87	8.13
LT	14/06/93	12.01	14.41	8.93	129.78	0.54	541.21	8.11
LT	14/06/93	13.03	14.17	8.69	135.89	0.42	536.66	8.05
LT	14/06/93	13.84	14.13	8.53	144.47	0.36	535.3	8.01
LT	14/06/93	14.97	13.96	8.31	150.17	0.12	531.42	8.01
LT	14/06/93	15.98	13.89	8.42	174.52	0.18	529.81	8.05
LT	14/06/93	16.9	13.76	8.23	181.62	0.12	526.79	8.05
LT	14/06/93	17.94	13.52	7.86	186.58	0.06	521.75	8.02
LT	14/06/93	18.94	13.41	7.63	198.96	0.06	518.91	7.98
LT	14/06/93	20.09	13.29	7.46	212.33	0	515.89	7.95
LT	14/06/93	20.98	13.26	7.43	219.1	0	515.25	7.94
LT	14/06/93	21.92	13.25	7.42	223.23	0.06	514.92	7.94
LT	14/06/93	22.91	13.25	7.43	226.37	0	514.87	7.94
LT	14/06/93	23.9	13.24	7.33	229.42	0	514.21	7.94
LT	14/06/93	24.76	13.23	7.29	226.12	0	514.34	7.94
LT	14/06/93	25.81	13.2	7.13	217.62	0	513.47	7.94
LT	14/06/93	26.8	13.19	7.02	213.74	0	513.22	7.94
N1	14/06/93	0.14	15.64	10.45	209.61	194.46	559.03	8.15
N1	14/06/93	0.51	15.65	10.45	200.28	88.77	558.69	8.17
N1	14/06/93	0.93	15.65	10.43	192.93	114.15	558.32	8.19
N1	14/06/93	1.48	15.65	10.42	186.16	67.38	558.48	8.2
N1	14/06/93	1.86	15.64	10.4	171.14	28.48	558.24	8.28
N1	14/06/93	2.56	15.6	10.34	164.53	26.69	557.74	8.3
N1	14/06/93	2.99	15.58	10.31	173.2	25.14	557.35	8.3
N1	14/06/93	3.51	15.54	10.26	188.64	22.4	556.93	8.29
N1	14/06/93	4	15.45	10.17	187.24	14.95	555.29	8.24
N1	14/06/93	4.47	15.38	10.1	29.06	10.66	554.53	8.18
N1	14/06/93	5.02	15.36	10.08	27.57	8.04	554.36	8.14
N1	14/06/93	5.53	15.32	10.05	28.07	7.03	553.65	8.12
N1	14/06/93	6.03	15.27	10.03	29.72	6.43	552.77	8.06

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
N1	14/06/93	6.99	15.21	9.99	29.22	3.99	551.55	8.04
N1	14/06/93	8.01	15.01	9.82	28.56	2.62	547.97	8.03
N1	14/06/93	9.06	14.95	9.72	28.48	1.97	546.66	8.04
N1	14/06/93	10.06	14.94	9.7	30.55	1.49	546.42	8.04
N1	14/06/93	11.03	14.93	9.68	31.04	1.19	546.13	8.05
S12	14/06/93	0.13	15.82	10.14	72.32	361.45	557.89	8.2
S12	14/06/93	0.44	15.83	10.15	349.38	262.73	558.13	8.21
S12	14/06/93	0.88	15.84	10.16	344.34	205.84	563.09	8.29
S12	14/06/93	1.48	15.84	10.17	299.35	107.36	558.88	8.31
S12	14/06/93	1.98	15.85	10.16	286.39	73.58	560.08	8.32
S12	14/06/93	2.48	15.84	10.15	252.79	37.12	560.96	8.33
S12	14/06/93	2.96	15.85	10.15	269.96	23.83	559.58	8.38
S12	14/06/93	3.48	15.85	10.15	244.7	20.26	560.06	8.36
S12	14/06/93	3.97	15.85	10.15	242.14	14.78	560.86	8.35
S12	14/06/93	4.5	15.85	10.14	245.19	11.56	560.75	8.3
S12	14/06/93	5.01	15.83	10.1	276.07	10.01	561.38	8.26
S12	14/06/93	5.43	15.85	10.12	284.82	8.88	560.78	8.25
S12	14/06/93	5.98	15.77	10.04	277.06	6.67	561.03	8.22
S12	14/06/93	6.97	15.52	9.65	285.23	4.35	559.72	8.13
S12	14/06/93	8.02	15.34	9.55	276.07	2.56	558.45	8.08
S12	14/06/93	9.01	15.25	9.46	279.53	1.85	557.56	8.07
S12	14/06/93	10.02	14.96	9.02	287.05	1.37	552.93	8.03
S12	14/06/93	11.05	14.9	8.95	311.24	0.95	552.03	8
S12	14/06/93	12.05	14.86	8.94	313.71	0.77	551.28	7.97
S12	14/06/93	12.96	14.84	8.92	309.75	0.6	550.88	7.95
S12	14/06/93	13.91	14.74	8.83	305.13	0.48	548.78	7.93
S12	14/06/93	14.96	14.45	8.33	306.03	0.3	544.18	7.91
LT	13/09/93	0.21	15.75	87.5	311	340	830	8.8
LT	13/09/93	0.66	15.77	87.3	313	207	829.7	8.73
LT	13/09/93	1.63	15.78	87.3	318	129	829.5	8.69
LT	13/09/93	1.98	15.79	87.1	318	107	829.8	8.7
LT	13/09/93	2.44	15.79	87.1	319	79	829.3	8.7
LT	13/09/93	3.03	15.78	87.4	319	52	829.8	8.71
LT	13/09/93	3.47	15.78	87.3	319	36	829.5	8.71
LT	13/09/93	4.02	15.79	87.1	319	31	828.8	8.72
LT	13/09/93	4.49	15.79	87	318	26	828.9	8.72
LT	13/09/93	4.97	15.79	87	317	21	828.9	8.71
LT	13/09/93	5.57	15.79	86.9	315	15	828.6	8.71
LT	13/09/93	6.11	15.79	86.8	314	11	828.7	8.7
LT	13/09/93	7.07	15.79	86.8	311	7	828.8	8.69
LT	13/09/93	8.03	15.79	86.7	306	5	829	8.66
LT	13/09/93	9.12	15.79	86.7	303	3	828.7	8.64
LT	13/09/93	10.09	15.8	86.6	296	2	828.2	8.6
LT	13/09/93	11.02	15.79	86.6	291	1	828.1	8.56
LT	13/09/93	11.98	15.79	86.5	286	1	828	8.52
LT	13/09/93	13.02	15.79	86.7	283	1	827.8	8.5
LT	13/09/93	13.95	15.79	86.8	278	1	827.6	8.49
N1	13/09/93	0.1	15.5	90.6	181	189	820.2	7.83
N1	13/09/93	0.54	15.5	90.5	179	88	819.1	7.92
N1	13/09/93	0.96	15.5	90.2	177	76	818.7	7.98
N1	13/09/93	1.53	15.5	90.1	177	51	818.9	8.05
N1	13/09/93	1.97	15.5	89.9	178	36	818.4	8.08
N1	13/09/93	2.52	15.5	89.9	179	24	818.6	8.12
N1	13/09/93	3.04	15.5	90	179	20	818.9	8.15
N1	13/09/93	3.56	15.5	89.9	181	17	818	8.17
N1	13/09/93	4.46	15.5	89.9	182	13	817.9	8.19

SITE	DATE	DEPTH (M)	TEMP	D_OXYGE	SURFACE L	LIGHT	Conductivity	pH
N1	13/09/93	5.53	15.49	89.7	183	8	817.5	8.19
N1	13/09/93	6.9	15.49	89.5	182	4	817.5	8.19
N1	13/09/93	7.99	15.48	89.3	183	2	817.4	8.18
N1	13/09/93	9.03	15.39	89	185	1	815.9	8.17
N1	13/09/93	10.04	15.36	88.6	184	1	816	8.16
S12	13/09/93	0.05	15.54	91.6	480	516	824.4	8.81
S12	13/09/93	0.53	15.56	91.4	482	377	823.1	8.81
S12	13/09/93	0.93	15.56	91.3	467	246	822.9	8.81
S12	13/09/93	1.48	15.56	91.2	453	177	823.3	8.81
S12	13/09/93	1.94	15.56	91.2	455	135	823.4	8.81
S12	13/09/93	2.51	15.57	91.3	461	99	822.9	8.82
S12	13/09/93	3.01	15.57	91.2	469	67	823.1	8.82
S12	13/09/93	3.45	15.56	91.1	462	48	823.2	8.82
S12	13/09/93	4.01	15.55	91.1	451	30	823.1	8.82
S12	13/09/93	4.46	15.55	91	443	28	822.8	8.81
S12	13/09/93	5.03	15.55	91.1	446	19	822.8	8.8
S12	13/09/93	5.57	15.54	91	430	13	823	8.8
S12	13/09/93	6.01	15.55	91	419	10	822.8	8.78
S12	13/09/93	7.02	15.54	91.1	412	6	822.6	8.78
S12	13/09/93	8.07	15.55	90.9	405	3	822.3	8.77
S12	13/09/93	9.05	15.54	91.1	400	2	822.1	8.76
S12	13/09/93	9.98	15.54	91	394	1	821.7	8.76
S12	13/09/93	11.03	15.54	91	387	1	821.5	8.75
S12	13/09/93	12.04	15.54	91	380	1	821.4	8.76
S12	13/09/93	12.86	15.51	90.7	368	0	820.9	8.75
S12	13/09/93	14.01	15.51	90.7	361	0	821	8.74

These data are those shown in Chapter Three graphs. Other profile data are not presented

II (h) Total iron measured from sediment transects in Rutland Water

Secondary Tower	A	B
Feb-92	60.50	60.30
Mar-92	46.30	53.10
May-92	48.10	48.30
Jul-92	54.60	51.50
Sep-92	56.50	58.10
Nov-92	56.20	56.70
Jan-93	53.10	56.30
Mar-93	50.30	53.60
Apr-93	57.40	60.20
Jun-93	66.50	55.60

	Outlet
Jan-92	128.00
Apr-92	75.30
Jun-92	114.00
Aug-92	35.60
Jan-93	128.00
Mar-93	64.00
May-93	47.90
Jul-93	61.20
Sep-93	55.50
Nov-93	59.20
Dec-93	49.70

S3 Transect	1	2	3	4	5	6
Jan-92	63.50	61.40	66.70	82.70	63.60	51.70
Apr-92	83.60	144.00	136.00	152.00	112.00	83.20
Jun-92	87.10	159.00	141.00	182.00	131.00	63.30
Aug-92	80.70	107.00	181.00	124.00	96.10	53.80
Oct-92	97.00	118.00	119.00	85.30	138.00	98.80
Dec-92	100.00	96.70	70.50	112.00	146.00	85.30
Jan-93	77.70	79.10	90.30	186.00	153.00	86.70
Mar-93	66.50	105.00	147.00	230.00	190.00	99.90
May-93	115.00	163.00	163.00	223.00	168.00	82.10
Jul-93	87.90	132.00	111.00	203.00	181.00	108.00
Sep-93	79.10	84.70	98.60	161.00	162.00	133.00
Nov-93	58.30	186.00	196.00	200.00	116.00	111.00
Dec-93	65.00	81.50	167.00	147.00	184.00	115.00

Howells Inlet	1A	1B	2A	2B	3A	3B
Feb-92	66.70	72.70	81.70		75.40	77.60
Mar-92	73.50	61.10	62.50	73.20	60.50	59.50
May-92	57.70	63.40	72.90	56.10	69.10	57.00
Jul-92	57.50	81.00	92.30	78.00	60.40	52.50
Sep-92	93.40	54.40	90.00	95.70	74.50	68.10
Nov-92	81.10	81.20	72.00	67.60	74.80	63.00
Jan-93	88.90	70.60	53.90	66.20	60.10	60.90
Mar-93	63.10	58.50	75.80	95.10	72.70	57.10
Apr-93	63.10	92.60	87.30	90.90	63.60	70.40
Jun-93	60.40	76.50	97.80	91.90	66.30	51.80
Sep-93	56.50	57.60	85.00	73.50	54.30	51.10
Oct-93	66.40	69.80	71.20	59.10	57.00	62.10
Dec-93	69.50	50.50	81.80	73.80	55.30	54.50

Inlet	A	B
Feb-92	570.00	537.00
May-92	402.00	455.00
Jul-92	371.00	515.00
Sep-92	361.00	215.00
Nov-92	196.00	211.00
Jan-93	272.00	275.00
Mar-93	232.00	197.00
Apr-93	540.00	496.00
Jun-93	475.00	465.00
Sep-93	521.00	451.00
Oct-93	371.00	328.00
Dec-93	32.60	401.00

North Buoy	A	B
Feb-92	56.20	56.90
Mar-92	58.70	53.80
May-92	50.80	46.10
Jul-92	54.10	58.30
Sep-92	59.40	60.20
Nov-92	61.30	67.60
Jan-93	53.60	50.30
Mar-93	58.40	55.90
Apr-93	57.00	58.80
Jun-93	56.70	56.70

Lodge Farm	1A	1B	2A	2B	3A	3B
Feb-92	71.50	61.80	60.00	80.60	89.80	60.90
Mar-92	58.00	56.70	60.50	60.80	52.60	69.80
May-92	74.70	57.50	76.90	78.30	51.40	64.60
Jul-92	82.40	96.10	86.30	67.90	64.30	58.10
Sep-92	95.20	67.80	78.10	74.00	69.80	61.80
Nov-92	63.20	56.70	40.60	63.70	45.00	56.40
Jan-93	69.30	57.00	65.60	76.90	71.40	64.70
Mar-93	69.10	54.10	71.00	80.60	65.00	59.90
Apr-93	66.40	63.20	110.00	60.30	64.20	65.90
Jun-93	57.00	59.30	77.80	75.70	70.90	59.50
Sep-93	60.10	56.40	72.40	58.60	61.60	53.60
Oct-93	60.30	62.20	56.70	59.40	57.50	54.40
Dec-93	51.20	54.40	74.70	54.70	58.90	49.70

Slipway	1A	1B	2A	2B	3A	3B
Feb-92	90.80	62.20	453.00	305.00	158.00	242.00
Mar-92	290.00	272.00	473.00	434.00	253.00	357.00
May-92	399.00	386.00	378.00	320.00	188.00	158.00
Jun-92	191.00	271.00	379.00	397.00	254.00	244.00
Jul-92	289.00		419.00	400.00	122.00	68.70
Sep-92	353.00	414.00	377.00	337.00	66.50	133.00
Nov-92	433.00	453.00	355.00	449.00	309.00	265.00
Jan-93	365.00	310.00	370.00	345.00	245.00	216.00
Mar-93	324.00	309.00	357.00	285.00	195.00	214.00
Apr-93	352.00	332.00	309.00	353.00	275.00	312.00
Jun-93	331.00	360.00	238.00	313.00	252.00	280.00
Sep-93	253.00	266.00	331.00	239.00	205.00	224.00
Oct-93	281.00	265.00	229.00	247.00	216.00	201.00
Dec-93	253.00	247.00	143.00	314.00	215.00	127.00

Littoral	Carrot Creek	Golden p/s	Normanton Ch	Nature Res	Sykes Lane
Sep-92	46.30	108.00			
Dec-92	86.80	37.20			33.00
Feb-93	46.90	57.90	73.40	42.00	93.00
May-93	57.00	79.60	82.60	35.10	32.30
Aug-93	32.00	42.50	48.40	65.20	48.90
Nov-93	44.40	41.80	53.50	43.70	18.80

II (j) Total P measured from sediment transects in Rutland Water

S3 transect	1	2	3	4	5	6
Jan-93	3.470	4.940	5.670	7.550	7.160	4.810
Mar-93	3.290	6.010	6.840	7.210	7.480	5.810
May-93	6.070	7.440	7.730	8.080	7.650	4.670
Jul-93	2.260	4.760	6.090	17.200	4.650	4.030
Sep-93	4.330	5.180	6.750	9.990	7.960	7.320
Nov-93	3.370	8.210	8.370	7.640	5.340	5.470
Dec-93	3.060	4.750	8.710	6.680	7.310	5.230

Howells inlet	1A	1B	2A	2B	3A	3B
Jan-93	5.850	3.490	1.730	3.330	3.330	3.540
Mar-93	2.870	2.890	5.130	5.690	5.690	2.700
Apr-93	4.130	6.640	4.090	5.170	5.170	4.840
Jun-93	2.440	3.730	5.320	5.310	5.310	3.190
Sep-93	2.800	3.120	5.030	4.140	4.140	2.740
Oct-93	3.730	4.280	3.630	2.440	2.440	3.610
Dec-93	3.800	2.900	1.580	3.940	3.940	4.160

Inlet	A	B
Jan-93	6.860	2.820
Mar-93	8.370	7.160
Apr-93	9.220	6.410
Jun-93	5.440	5.930
Sep-93	6.500	6.040
Oct-93	2.600	5.620
Dec-93	6.650	6.930

North buoy	A	B
Jan-93	3.380	2.430
Mar-93	3.420	2.640
Apr-93	3.200	3.160
Jun-93	3.610	3.850

Lodge Farm	1A	1B	2A	2B	3A	3B
Jan-93	3.820	3.050	3.870	5.190	4.310	3.800
Mar-93	3.960	3.390	4.490	5.400	4.290	3.110
Apr-93	3.870	3.510	7.690	2.470	4.210	3.990
Jun-93	3.470	3.730	4.530	4.600	4.340	3.090
Sep-93	3.410	4.190	5.470	3.740	3.710	2.980
Oct-93	3.500	3.560	3.070	3.080	3.530	3.380
Dec-93	3.000	3.110	4.880	3.740	3.900	3.780

Slipway	1A	1B	2A	2B	3A
Jan-93	7.960	8.430	4.840	8.580	7.860
Mar-93	8.790	8.240	9.520	8.140	7.000
Apr-93	8.910	8.400	9.850	11.100	8.020
Jun-93	7.350	11.000	6.310	12.700	8.870
Sep-93	7.780	8.520	6.600	10.500	8.900
Oct-93	8.220	6.500	10.300	7.500	6.330
Dec-93	9.250	9.080	6.710	7.740	7.710

Littoral	Carrot Creek	Golden p/s	Normanton Ch	Nature Res	Sykes Lane
Feb-93	0.957	1.920	1.660	1.090	1.530
May-93	0.801	1.340	1.950	1.110	0.805
Aug-93	0.297	3.150	1.080	1.070	0.787
Nov-93	0.406	1.050	1.730	0.567	0.823

II (k) Chlorophyll a measurements in Rutland Water 1976 - 1994

MONTH	LT
Jan-76	
Feb-76	
Mar-76	
Apr-76	
May-76	
Jun-76	
Jul-76	5.00
Aug-76	4.00
Sep-76	21.00
Oct-76	14.00
Nov-76	17.00
Dec-76	1.00
Jan-77	1.00
Feb-77	2.00
Mar-77	0.50
Apr-77	19.00
May-77	15.00
Jun-77	2.50
Jul-77	23.00
Aug-77	6.00
Sep-77	110.50
Oct-77	26.00
Nov-77	6.00
Dec-77	4.00
Jan-78	125.10
Feb-78	4.50
Mar-78	11.00
Apr-78	22.00
May-78	4.00
Jun-78	10.00
Jul-78	4.00
Aug-78	10.00
Sep-78	6.00
Oct-78	4.50
Nov-78	8.00
Dec-78	10.00
Jan-79	9.00
Feb-79	15.00
Mar-79	20.00
Apr-79	16.00
May-79	10.00
Jun-79	25.00
Jul-79	1.00
Aug-79	10.00
Sep-79	9.00
Oct-79	22.00
Nov-79	21.00
Dec-79	11.00
Jan-80	16.00
Feb-80	13.00
Mar-80	6.00
Apr-80	8.00
May-80	14.00
Jun-80	6.00
Jul-80	18.00

DATE	NI	ST	ST2	IN	LT
29/05/90	28.000				33.000
04/06/90		2.140	19.500		15.200
11/06/90		1.360	0.973		0.778
18/06/90	6.420	10.500	6.810		3.890
25/06/90	9.150	13.400	20.000		15.600
02/07/90	28.000	26.900	44.600		25.100
09/07/90	9.930	23.400	8.760		19.100
16/07/90	24.900	29.600	22.600		25.100
23/07/90	23.900	28.600	25.700		36.200
30/07/90	36.200	39.700	26.500		41.300
06/08/90	20.200	19.200	13.100		18.600
13/08/90	7.010	6.230	10.900		16.000
20/08/90	8.270	6.230	12.800		9.730
29/08/90	7.980	5.640	3.500		11.900
03/09/90	7.590	6.420	8.950		6.620
10/09/90	60.700	1.750	62.100		7.390
18/09/90	5.640	10.500	14.000		18.100
24/09/90	3.890	6.030	5.250		9.150
01/10/90	4.870	7.200	7.980		3.700
08/10/90	4.280	4.670	4.870		6.230
15/10/90	2.330	3.500	5.060		4.870
22/10/90	6.810	4.870	3.700		2.330
29/10/90	3.310	2.720	2.140		1.170
05/11/90		3.890	5.450		1.360
12/11/90	165.000	5.450	4.870		1.750
19/11/90	6.620	3.890	5.060		3.700
26/11/90	4.870	5.060	4.670		
03/12/90	3.310	3.310	4.670		1.560
12/12/90	3.890	3.500			
17/12/90	4.870	4.280	7.590		5.840
07/01/91	3.310	4.870			4.670
14/01/91	4.280	5.060	4.480		4.280
21/01/91	5.060	4.280	5.250		3.500
28/01/91	7.980	7.980	8.760		5.840
04/02/91	12.500	14.000	16.300		7.390
20/02/91	15.400	17.500	22.600		17.900
25/02/91	24.900	23.500	38.900		37.400
04/03/91	24.900	27.000	34.600		19.300
11/03/91	29.000	29.000	29.800		20.600
18/03/91	11.500	18.500	23.400		20.600
26/03/91	28.200	14.400	28.200		19.100
03/04/91	23.000	24.900			27.200
08/04/91	23.400	27.400			24.500
16/04/91	42.800		44.200		21.400
22/04/91	20.900	25.100	29.200		12.000
30/04/91	5.200	7.800	11.500		10.900
07/05/91	7.300	5.200	3.600		5.200
13/05/91	10.900	8.300	13.000		18.200
20/05/91	3.600	2.600	5.200		6.800
28/05/91	5.200	4.700	7.300		2.100
03/06/91	2.600	2.100	1.600		1.600
10/06/91	5.200	5.200	5.700		4.200
17/06/91	25.500	14.100	13.000		8.300
24/06/91	15.100	15.600	17.200		13.000
01/07/91	4.200	4.700	15.100		27.100

MONTH	LT
Aug-80	11.00
Sep-80	18.00
Oct-80	25.00
Nov-80	6.00
Dec-80	19.00
Jan-81	14.00
Feb-81	20.00
Mar-81	12.00
Apr-81	11.00
May-81	7.00
Jun-81	22.00
Jul-81	2.00
Aug-81	11.00
Sep-81	12.00
Oct-81	9.00
Nov-81	11.00
Dec-81	8.00
Jan-82	
Feb-82	7.50
Mar-82	7.00
Apr-82	11.00
May-82	16.00
Jun-82	10.00
Jul-82	18.00
Aug-82	5.00
Sep-82	6.00
Oct-82	4.00
Nov-82	18.00
Dec-82	4.00
Jan-83	5.00
Feb-83	7.70
Mar-83	20.00
Apr-83	11.00
May-83	5.00
Jun-83	8.00
Jul-83	15.00
Aug-83	3.00
Sep-83	9.00
Oct-83	12.00
Nov-83	20.00
Dec-83	6.00
Jan-84	5.00
Feb-84	7.50
Mar-84	7.00
Apr-84	9.00
May-84	16.00
Jun-84	6.00
Jul-84	20.50
Aug-84	5.00
Sep-84	14.00
Oct-84	25.00
Nov-84	12.00
Dec-84	4.00
Jan-85	6.00
Feb-85	5.00
Mar-85	42.00

DATE	NI	ST	SI2	IN	LT
08/07/91	6.800	7.800	6.800		7.800
15/07/91	6.300	7.300	8.300		12.000
22/07/91	6.800	8.300	13.600		17.700
29/07/91	58.400	52.100	12.500		29.100
05/08/91	16.200	15.100	11.500		18.200
12/08/91	8.900	10.900	10.900		35.400
19/08/91	13.000	19.300	13.000		33.400
27/08/91	12.500	14.600	25.000		31.300
02/09/91	48.000	35.400	48.000		9.900
09/09/91	31.300	27.100	31.300		12.500
16/09/91	17.200	20.300	25.500		12.000
25/09/91	5.640	8.760			6.810
01/10/91	5.200	3.100	9.400		2.600
07/10/91	5.700	5.700	21.400		2.600
14/10/91	5.200	8.900	11.500		15.600
21/10/91	3.600	7.300	6.800		4.200
28/10/91	5.200	4.700	3.600		2.100
04/11/91	3.100	2.100	1.600		2.100
11/11/91	1.000	0.500	1.000		1.000
18/11/91	2.600	2.600	2.100		1.600
25/11/91	2.600	1.600	2.600		1.000
02/12/91	2.100	1.000	1.600		1.000
10/12/91	1.600	1.600	1.000		0.300
17/12/91	3.600	3.100	3.100		2.100
30/12/91	1.400	2.100	1.800		2.500
07/01/92	1.000	1.600	1.000		2.100
13/01/92	2.600	2.600	3.100		2.100
20/01/92	2.100	2.100	2.100		2.100
27/01/92	2.600	2.600	3.100		2.100
03/02/92	2.100	2.100	2.600		2.100
10/02/92	2.100	2.100	2.100		1.600
17/02/92	2.600	2.100	3.100		2.600
24/02/92	3.100	3.100	4.700		3.100
02/03/92	6.300	6.300	10.400		5.200
09/03/92	10.400	9.900	15.000		7.300
16/03/92	12.000	9.400	15.600		10.400
23/03/92	9.900	9.400	12.000		10.400
30/03/92	11.500	12.000	15.100		8.900
06/04/92	8.560	12.100	11.900		8.370
21/04/92	7.300	9.400	20.300		8.300
29/04/92	6.300	6.800	8.900		5.200
05/05/92	2.100	3.100	4.700	3.600	1.600
11/05/92	3.100	4.200	2.600		2.100
18/05/92	15.600	14.100	24.000	5.700	5.200
26/05/92	3.100	2.100	2.100	4.200	2.100
01/06/92	3.500	2.330	2.920	2.330	1.750
09/06/92	7.300	5.700	6.300	4.300	5.700
15/06/92	8.900	10.400	12.000		15.600
22/06/92	2.100	1.600	6.300		3.100
29/06/92	3.100	2.600	4.200		3.600
06/07/92	3.600	3.100	3.600	4.600	3.100
13/07/92	12.000	17.200	6.300	5.200	8.900
20/07/92	7.800	7.300	8.300	6.300	12.000
27/07/92	8.860	8.340	8.340	10.400	11.500
03/08/92	7.300	5.200	5.200	5.200	7.800
10/08/92	15.100	6.800	8.300	7.800	6.800

MONTH	LT
Apr-85	60.00
May-85	10.00
Jun-85	5.00
Jul-85	12.00
Aug-85	3.00
Sep-85	21.00
Oct-85	25.00
Nov-85	12.00
Dec-85	8.00
Jan-86	3.00
Feb-86	0.50
Mar-86	4.00
Apr-86	23.00
May-86	45.00
Jun-86	4.00
Jul-86	5.00
Aug-86	10.00
Sep-86	19.00
Oct-86	25.00
Nov-86	5.00
Dec-86	4.00
Jan-87	5.00
Feb-87	5.00
Mar-87	7.50
Apr-87	55.00
May-87	22.00
Jun-87	3.00
Jul-87	17.00
Aug-87	4.00
Sep-87	8.00
Oct-87	2.00
Nov-87	7.00
Apr-88	12.00
May-88	4.00
Jun-88	5.00
Jul-88	4.00
Aug-88	34.00
Sep-88	18.00
Oct-88	47.00
Nov-88	5.00
Dec-88	10.00
Aug-89	10.00
Sep-89	52.00
Oct-89	62.00
Nov-89	8.00

DATE	NI	ST	SI2	IN	LT
17/08/92	9.400	7.300	10.900	10.400	7.800
24/08/92	8.900	8.300	10.400	13.500	8.900
01/09/92	12.000	14.100	12.500	8.300	6.800
07/09/92	12.500	13.000		11.500	7.800
14/09/92	9.900	10.900	17.200	9.900	8.300
21/09/92	3.100	4.200	11.500	7.800	8.300
28/09/92	4.200	5.200	3.600	2.600	3.100
05/10/92	1.600	1.600	3.100	2.100	2.600
12/10/92	3.100	2.100	3.600	2.100	1.600
19/10/92	3.100	2.600	4.700	3.100	2.100
26/10/92	1.360	1.170	1.560		0.584
03/11/92	1.600	1.600	1.600	1.600	0.500
09/11/92	1.600	1.000	2.100	1.600	1.600
16/11/92	1.600	2.100	2.100		
23/11/92	1.600	1.000	1.600	1.600	1.600
03/12/92	2.100	2.100	3.100		2.100
07/12/92	1.600	1.000	2.100	1.000	1.600
14/12/92	1.600	0.500	1.600	1.000	1.000
04/01/93	1.600	1.600	2.100	0.500	0.500
18/01/93	2.100	2.100	2.100	2.600	3.600
25/01/93	1.600		1.600	2.100	0.900
01/02/93	2.600	2.100	3.100	2.300	2.100
08/02/93	3.100		5.700	3.100	2.600
15/02/93	2.600		2.300	3.600	2.300
22/02/93	2.600		3.600	3.100	2.600
01/03/93	3.600		6.800	5.700	3.600
08/03/93	4.700		5.200	4.700	3.100
15/03/93	18.800		19.800	10.900	7.800
22/03/93	13.600		16.200	13.600	12.000
29/03/93	8.900		14.600	9.900	7.300
05/04/93	6.800		10.900	12.500	5.700
13/04/93	7.300		9.400	6.300	5.700
19/04/93	5.700		11.500	7.800	7.300
26/04/93	10.900		10.400	7.300	3.100
04/05/93	4.200		6.800	7.300	2.600
10/05/93	3.100		16.200	8.300	3.000
17/05/93	5.700		17.200	12.500	7.800
24/05/93	6.800		10.900	6.300	4.200
01/06/93	2.600		5.200	7.300	2.600
07/06/93	7.300		6.300	10.900	12.500
14/06/93	7.800		6.300	4.700	16.700
21/06/93	5.700		8.900	12.500	13.600
28/06/93	10.400		19.800	26.600	20.900
05/07/93	19.800		31.800	40.100	32.300
12/07/93	25.000		37.500	43.800	113.000
19/07/93	22.900		39.600	31.300	79.200
26/07/93	13.600	15.100	15.600	16.200	26.600
02/08/93	27.600	29.800	29.200	20.300	
09/08/93	15.100	17.700	20.300	20.900	26.100
16/08/93	8.300	9.900	25.000	43.800	21.400
23/08/93	19.800	16.200	25.000	21.900	15.100
31/08/93	15.100	14.600	24.500	30.800	17.200
06/09/93	10.400	10.900	18.200	10.900	7.800
13/09/93	7.490	5.630	13.500	7.550	5.190
20/09/93	3.000	5.600		3.100	3.600
27/09/93	3.600		4.200		

MONTH	LT

DATE	NI	ST	ST2	IN	LT
04/10/93	1.600	1.600	2.100	1.600	1.600
11/10/93	1.600	2.100	2.100	1.600	2.100
19/10/93	2.100	2.600	2.600	2.100	2.100
25/10/93	3.600	3.100	3.100	2.100	2.100
01/11/93	2.100	2.100	3.100	1.600	1.000
08/11/93	2.100	1.600	2.100	1.600	1.600
15/11/93	2.100	2.100	2.600	2.600	1.600
22/11/93	2.600	3.100	3.100	1.600	1.600
29/11/93	2.600		3.100		1.000
06/12/93	1.600	1.600	2.100	1.600	1.000
13/12/93	1.600	2.500	1.600	1.000	0.500
20/12/93	1.000	1.000	1.000	1.000	0.500
10/01/94	1.600	1.600	1.600	1.000	1.000
24/01/94		1.000	1.000	1.600	1.000
31/01/94		1.600	1.000	1.000	1.000
07/02/94		1.600	2.100	1.000	1.600
21/02/94		2.600	3.600	2.100	1.600
01/03/94		3.100	4.700	3.100	2.600
07/03/94		4.200	7.800	5.700	4.200
15/03/94		6.800	8.900	7.800	6.800
21/03/94		7.300	7.800	6.800	6.800
28/03/94	10.300	11.600	13.500	9.400	9.900
05/04/94	9.800	11.400	14.100	10.200	11.400
11/04/94	7.300	6.300	7.300	6.300	6.300
18/04/94	5.700	5.200	5.200	3.600	3.100
25/04/94	3.600	3.100	4.200	3.100	2.100
03/05/94	2.600	3.600	4.700	4.700	
09/05/94	4.200	3.600	4.200	2.600	3.100
16/05/94	4.200	4.700	4.200	4.200	5.700
23/05/94	3.100	3.600	4.200	4.700	3.600
31/05/94	3.100	2.600	5.700	5.200	4.700
06/06/94	2.100	1.700	1.900	3.600	2.700
20/06/94	2.600	3.100	4.200	6.300	5.700
27/06/94	2.100	2.600	2.600	2.600	2.600
04/07/94	1.300	3.100	3.600	5.700	5.700
11/07/94	4.000	4.600	3.100	5.100	6.200
18/07/94	5.700	5.200	5.200	6.800	4.700
25/07/94	7.400	7.800	9.500	10.500	11.600
01/08/94	3.300	4.500	5.700	4.400	5.000
15/08/94	7.800	5.700	8.900	14.000	7.800
22/08/94	9.400	8.300	12.500	7.800	6.300
30/08/94	7.800	142.000	220.000	17.200	26.600
12/09/94	5.200	4.200	6.800	19.000	4.700
19/09/94	6.300	4.200	4.700	4.200	4.200
26/09/94	4.700	7.200	9.500	3.600	3.100
03/10/94	2.600	2.600	5.700	5.200	3.600
10/10/94	10.900	8.340	5.730	4.690	3.120
17/10/94	15.100	10.400	7.820	3.120	2.600
31/10/94	3.650	4.170	8.860	9.380	8.860
07/11/94	6.780	4.170	9.900	4.170	5.210
14/11/94	2.610	2.610	2.090	2.090	1.040
21/11/94	1.110	0.520	1.040	1.040	1.040
05/12/94	2.220	4.100	2.130	1.670	1.110
12/12/94	1.670	1.560	1.560	1.680	1.110
19/12/94	2.800	1.560	1.610	1.680	1.110

II (I) ANOVA results for water chemistry data

Within and between sites

DETERMINAND	N1	ST	S12	IN	LT	ALL
Light profile	F=0.576;n=3	F=0.799;n=19	F=0.433;n=27	F=0.119;n=1	F=0.827;n=26	F=0.194;n=11
Temp profile	F=3.588;n=3	F=5.013;n=19	F=3.261;n=27	F=1.115;n=1	F=2.626;n=26	F=0.211;n=11
Diss Ox profile	F=2.679;n=3	F=1.784;n=19	F=2.079;n=27	F=3.936;n=1	F=2.206;n=26	F=0.693;n=11
Conductivity prof	F=1035;n=29	F=218.8;n=19	F=386.2;n=25	F=27.13;n=9	F=1160;n=25	F=6.345;n=10
pH profile	F=3.588;n=2	F=5.013;n=18	F=3.26;n=25	F=1.11;n=9	F=2.625;n=25	F=0.21;n=110
Secchi depth	F=7.661;n=3	F=7.803;n=38	F=7.505;n=36	F=29.61;n=1	F=22.81;n=36	F=1.104;n=15
Alkalinity	F=-1120;n=4	F=39.3;n=42	F=24.99;n=41	F=202.6;n=2	F=1.11;n=42	F=-0.5;n=194
pH	F=2.742;n=4	F=16.87;n=42	F=6.47;n=41	F=5.644;n=2	F=8.57;n=42	F=-46.1;n=194
TON	F=65.29;n=4	F=129.3;n=42	F=163.1;n=41	F=1.683;n=2	F=193.4;n=42	F=1.149;n=19
Sulphur	F=-0.001;n=1	F=3.295;n=17	F=0.101;n=17	F=2.249;n=2	F=4.15;n=17	F=-1.63;n=86
Total Fe	F=0.092;n=4	F=0.825;n=42	F=-0.61;n=41	F=1.465;n=2	F=2.055;n=42	F=4.328;n=19
Total P	F=0.02;n=24	F=45.12;n=24	F=44.0;n=24	F=0.078;n=1	F=46.67;n=23	F=0.02;n=94

DETERMINAND	1991	1992	1993	1994
Light profile	F=0.221;n=3	F=0.028;n=33	F=0.319;n=10	F=0.057;n=36
Temp profile	F=0.113;n=3	F=0.108;n=33	F=0.276;n=10	F=0.052;n=36
Diss Ox profile	F=0.245;n=3	F=0.206;n=33	F=4.903;n=10	F=1.002;n=36
Conductivity prof	F=0.356;n=3	F=0.6;n=30	F=0.97;n=11	F=3.08;n=30
pH profile	F=0.249;n=3	F=0.114;n=30	F=0.381;n=10	F=0.164;n=30
Secchi depth	F=0.23;n=30	F=1.1;n=38	F=1.505;n=36	F=0.89;n=29
Alkalinity	F=0.103;n=3	F=1.12;n=44	F=1.09;n=40	F=1.58;n=29
pH	F=0.71;n=30	F=0.89;n=44	F=0.43;n=30	F=0.25;n=29
TON	F=0.04;n=30	F=4.65;n=44	F=0.35;n=40	F=2.67;n=29
Sulphur			F=0.101;n=40	F=0.42;n=44
Total Fe	F=1.18;n=30	F=2.22;n=43	F=0.53;n=40	F=0.25;n=39
Total P	F=2.13;n=30	F=7.04;n=44	F=0.37;n=40	F=1.34;n=29

II (m) Daphnid population measurements 1985 and 1992-1993 in Rutland Water

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
15/03/85	LT	0-5M	91	19	90	4.737	0.989	3.50	11.90	0.058	0.050	0.008
22/03/85	LT	0-5M	163	23	121	5.261	0.742	3.50	11.90	0.047	0.060	-0.013
29/03/85	LT	0-5M	211	43	273	6.349	1.294	4.00	11.40	0.073	0.150	-0.077
16/04/85	LT	0-5M	339	72	648	9.000	1.912	8.00	8.10	0.132	-0.190	0.322
19/04/85	LT	0-5M	360	11	96	8.727	0.267	8.50	7.75	0.031	0.090	-0.059
10/05/85	LT	0-5M	3941	427	200	0.468	0.051	9.00	7.30	0.007	0.080	-0.073
17/05/85	LT	0-5M	2212	165	611	3.703	0.276	10.10	6.55	0.037	-0.002	0.039
23/05/85	LT	0-5M	1984	27	55	2.037	0.028	10.80	6.10	0.004	-0.270	0.274
31/05/85	LT	0-5M	162	7	16	2.286	0.099	12.00	5.30	0.018	0.090	-0.072
07/06/85	LT	0-5M	1702	77	364	4.727	0.214	12.40	5.10	0.038	0.210	-0.172
17/06/85	LT	0-5M	3711	140	224	1.600	0.060	13.60	4.50	0.013	-0.180	0.193
21/06/85	LT	0-5M	2800	8	8	1.000	0.003	14.20	4.20	0.001	-0.090	0.091
28/06/85	LT	0-5M	1417	17	25	1.471	0.018	14.80	4.05	0.004	-0.015	0.019
05/07/85	LT	0-5M	361	72	176	2.444	0.488	18.20	3.00	0.132	0.040	0.092
22/07/85	LT	0-5M	746	20	27	1.350	0.036	17.00	3.35	0.011	-0.380	0.391
26/07/85	LT	0-5M	185	28	72	2.571	0.389	16.90	3.35	0.098	0.160	-0.062
09/08/85	LT	0-5M	3013	28	28	1.000	0.009	16.60	3.45	0.003	0.110	-0.107
23/08/85	LT	0-5M	455	60	270	4.500	0.593	16.40	3.55	0.131	-0.050	0.181
06/09/85	LT	0-5M	191	26	274	10.538	1.435	15.50	3.85	0.231	0.230	0.001
07/10/85	LT	0-5M	1305	107	232	2.168	0.178	14.40	4.15	0.039	0.010	0.029
18/10/85	LT	0-5M	301	25	29	1.160	0.096	13.80	4.40	0.021	-0.140	0.161
08/11/85	LT	0-5M	232	37	48	1.297	0.207	9.80	6.70	0.028	-0.008	0.036
28/07/92	1	2M	182	12	48	4.000	0.264	18.39	2.95	0.079		
28/07/92	1	4M	184	2	6	3.000	0.033	18.32	3.00	0.011		
28/07/92	1	8M	342	8	28	3.500	0.082	18.28	3.00	0.026		
28/07/92	2	2M	186	2	12	6.000	0.065	18.39	2.95	0.021		
28/07/92	2	4M	210	2	6	3.000	0.029	18.32	3.00	0.009		
28/07/92	2	8M	174	14	72	5.143	0.414	18.28	3.00	0.115		
28/07/92	3	2M	74	0	0		0.000	18.39	2.95	0.000		
28/07/92	3	4M	134	0	0		0.000	18.32	3.00	0.000		

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
28/07/92	3	8M	163	34	148	4.353	0.908	18.28	3.20	0.202		
28/07/92	4	2M	210	21	8	0.381	0.038	18.39	2.95	0.013		
28/07/92	4	4M	392	24	106	4.417	0.270	18.32	2.95	0.081		
28/07/92	4	8M	103	19	73	3.842	0.709	18.28	3.05	0.176		
28/07/92	5	2M	148	14	56	4.000	0.378	18.39	2.95	0.109		
28/07/92	5	4M	200	29	86	2.966	0.430	18.32	2.95	0.121		
28/07/92	5	8M	61	6	32	5.333	0.525	18.28	3.00	0.141		
28/07/92	6	2M	158	2	4	2.000	0.025	18.39	2.95	0.008		
28/07/92	6	4M	108	2	6	3.000	0.056	18.32	2.95	0.018		
28/07/92	6	8M	88	16	65	4.063	0.739	18.28	3.00	0.184		
28/07/92	7	2M	300	14	50	3.571	0.167	18.39	2.95	0.052		
28/07/92	7	4M	100	2	6	3.000	0.060	18.32	2.95	0.020		
28/07/92	7	8M	89	23	103	4.478	1.157	18.28	3.00	0.256		
05/08/92	2	2M	193	7	21	3.000	0.109	17.97	3.10	0.033	0.004	0.029
05/08/92	6	2M	186	14	36	2.571	0.194	17.97	3.10	0.057	0.020	0.037
05/08/92	6	4M	115	6	22	3.667	0.191	17.96	3.10	0.056	0.007	0.049
05/08/92	6	8M	99	4	8	2.000	0.081	17.95	3.10	0.025	0.014	0.011
11/08/92	2	2M	120	17	45	2.647	0.375	17.97	3.10	0.103	-0.079	0.182
11/08/92	2	4M	392	34	76	2.235	0.194	17.96	3.10	0.057	0.044	0.013
11/08/92	2	8M	146	24	54	2.250	0.370	17.95	3.10	0.102	-0.012	0.114
11/08/92	6	2M	186	10	32	3.200	0.172	17.97	3.10	0.051	0.000	0.051
11/08/92	6	4M	116	3	5	1.667	0.043	17.96	3.10	0.014	0.001	0.013
11/08/92	6	8M	132	14	33	2.357	0.250	17.95	3.10	0.072	0.048	0.024
18/08/92	2	2M	108	19	58	3.053	0.537	17.97	3.10	0.139	-0.015	0.154
18/08/92	2	4M	40	6	20	3.333	0.500	17.96	3.10	0.131	-0.326	0.457
18/08/92	2	8M	81	5	10	2.000	0.123	17.95	3.10	0.038	-0.084	0.122
18/08/92	6	2M	42	0	0		0.000	17.97	3.10	0.000	-0.212	0.212
18/08/92	6	4M	102	5	15	3.000	0.147	17.96	3.10	0.044	-0.018	0.062
18/08/92	6	8M	62	13	41	3.154	0.661	17.95	3.10	0.164	-0.108	0.272
08/09/92	1	2M	22	1	4	4.000	0.182	15.14	3.95	0.042	-0.050	0.092
08/09/92	1	4M	37	4	13	3.250	0.351	15.14	3.95	0.076	0.000	0.076

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
08/09/92	1	8M	31	3	11	3.667	0.355	15.11	3.95	0.077	-0.057	0.134
08/09/92	2	2M	44	6	20	3.333	0.455	15.14	3.95	0.095	-0.075	0.170
08/09/92	2	4M	22	2	10	5.000	0.455	15.14	3.95	0.095	-0.006	0.101
08/09/92	2	8M	36	7	27	3.857	0.750	15.11	3.95	0.142	-0.025	0.167
08/09/92	3	2M	59	6	26	4.333	0.441	15.14	3.95	0.092	-0.220	0.312
08/09/92	3	4M	35	2	8	4.000	0.229	15.14	3.95	0.052	-1.342	1.394
08/09/92	3	8M	40	6	29	4.833	0.725	15.11	3.95	0.138	-0.033	0.171
08/09/92	4	2M	37	3	15	5.000	0.405	15.14	3.95	0.086	-0.041	0.127
08/09/92	4	4M	29	4	22	5.500	0.759	15.14	3.95	0.143	-0.062	0.205
08/09/92	4	8M	25	2	6	3.000	0.240	15.11	3.95	0.054	-0.033	0.087
08/09/92	5	2M	43	3	12	4.000	0.279	15.14	3.95	0.062	-0.029	0.091
08/09/92	5	4M	36	7	28	4.000	0.778	15.14	3.95	0.146	-0.041	0.187
08/09/92	5	8M	29	6	24	4.000	0.828	15.11	3.95	0.153	-0.017	0.170
08/09/92	6	2M	29	7	28	4.000	0.966	15.14	3.95	0.171	-0.017	0.188
08/09/92	6	4M	46	8	32	4.000	0.696	15.14	3.95	0.134	-0.038	0.172
08/09/92	6	8M	26	4	20	5.000	0.769	15.11	3.95	0.144	-0.041	0.185
08/09/92	7	2M	65	16	68	4.250	1.046	15.14	3.95	0.181	-0.036	0.217
08/09/92	7	4M	52	14	43	3.071	0.827	15.14	3.95	0.153	-0.015	0.168
08/09/92	7	8M	45	15	60	4.000	1.333	15.11	3.95	0.215	-0.016	0.231
23/09/92	2	2M	137	10	47	4.700	0.343	14.80	4.05	0.073	0.121	-0.048
23/09/92	2	4M	79	6	26	4.333	0.329	14.70	4.05	0.070	0.052	0.018
23/09/92	2	8M	117	9	30	3.333	0.256	14.58	4.10	0.056	0.059	-0.003
23/09/92	4	2M	105	3	10	3.333	0.095	14.80	4.05	0.022	0.068	-0.046
23/09/92	4	4M	145	9	41	4.556	0.283	14.70	4.05	0.061	0.107	-0.046
23/09/92	4	8M	99	6	17	2.833	0.172	14.58	4.10	0.039	0.091	-0.052
23/09/92	6	2M	73	1	5	5.000	0.068	14.80	4.05	0.016	0.061	-0.045
23/09/92	6	4M	71	6	22	3.667	0.310	14.70	4.05	0.067	0.028	0.039
23/09/92	6	8M	130	21	71	3.381	0.546	14.58	4.10	0.106	0.107	-0.001
01/10/92	1	2M	152	9	23	2.556	0.151	13.86	4.40	0.032	0.065	-0.033
01/10/92	1	4M	98	5	13	2.600	0.133	13.87	4.40	0.028	-0.030	0.058
01/10/92	1	8M	26	0	0		0.000	13.86	4.40	0.000	0.000	0.000

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
01/10/92	2	2M	450	42	82	1.952	0.182	13.86	4.40	0.038	0.148	-0.110
01/10/92	2	4M	72	7	16	2.286	0.222	13.87	4.40	0.046	-0.011	0.057
01/10/92	2	8M	72	2	3	1.500	0.042	13.86	4.40	0.009	-0.060	0.069
01/10/92	3	2M	57	2	7	3.500	0.123	13.86	4.40	0.026	-0.001	0.027
01/10/92	3	4M	40	0	0		0.000	13.87	4.40	0.000	0.005	-0.005
01/10/92	3	8M	56	1	5	5.000	0.089	13.86	4.40	0.019	0.014	0.005
01/10/92	4	2M	87	5	7	1.400	0.080	13.86	4.40	0.018	-0.022	0.040
01/10/92	4	4M	61	5	11	2.200	0.180	13.87	4.40	0.038	-0.108	0.146
01/10/92	4	8M	59	1	2	2.000	0.034	13.86	4.40	0.008	-0.064	0.072
01/10/92	5	2M	144	20	61	3.050	0.424	13.86	4.40	0.080	-0.064	0.144
01/10/92	5	4M	10	2	50	25.000	5.000	13.87	4.40	0.407	-0.055	0.462
01/10/92	5	8M	64	16	1	0.063	0.016	13.86	4.40	0.004	0.034	-0.030
01/10/92	6	2M	164	16	19	1.188	0.116	13.86	4.40	0.025	0.101	-0.076
01/10/92	6	4M	210	22	52	2.364	0.248	13.87	4.40	0.050	0.135	-0.085
01/10/92	6	8M	81	5	8	1.600	0.099	13.86	4.40	0.021	-0.059	0.080
01/10/92	7	2M	184	75	105	1.400	0.571	13.86	4.40	0.103	0.045	0.058
01/10/92	7	4M	290	14	42	3.000	0.145	13.87	4.40	0.031	0.074	-0.043
01/10/92	7	8M	75	15	8	0.533	0.107	13.86	4.40	0.023	0.022	0.001
21/10/92	1	2M	14	0	0		0.000	10.54	6.25	0.000	-0.097	0.097
21/10/92	1	4M	15	0	0		0.000	10.51	6.25	0.000	-0.027	0.027
21/10/92	1	8M	14	1	1	1.000	0.071	10.27	6.40	0.011	-0.018	0.029
21/10/92	2	2M	14	0	0		0.000	10.54	6.25	0.000	-0.173	0.173
21/10/92	2	4M	17	0	0		0.000	10.51	6.25	0.000	-0.072	0.072
21/10/92	2	8M	10	0	0		0.000	10.27	6.40	0.000	-0.098	0.098
21/10/92	3	2M	1	0	0		0.000	10.54	6.25	0.000	-0.202	0.202
21/10/92	3	4M	8	0	0		0.000	10.51	6.25	0.000	-0.080	0.080
21/10/92	3	8M	8	1	1	1.000	0.125	10.27	6.40	0.018	-0.097	0.115
21/10/92	4	2M	24	0	0		0.000	10.54	6.25	0.000	-0.064	0.064
21/10/92	4	4M	18	0	0		0.000	10.51	6.25	0.000	-0.061	0.061
21/10/92	4	8M	13	1	2	2.000	0.154	10.27	6.40	0.022	-0.075	0.097
21/10/92	5	2M	47	3	4	1.333	0.085	10.54	6.25	0.013	-0.055	0.068

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
21/10/92	5	4M	20	1	1	1.000	0.050	10.51	6.25	0.008	0.034	-0.026
21/10/92	5	8M	30	1	1	1.000	0.033	10.27	6.40	0.005	-0.037	0.042
21/10/92	6	2M	42	2	4	2.000	0.095	10.54	6.25	0.015	-0.068	0.083
21/10/92	6	4M	68	7	15	2.143	0.221	10.51	6.25	0.032	-0.056	0.088
21/10/92	6	8M	65	9	15	1.667	0.231	10.27	6.40	0.032	-0.011	0.043
21/10/92	7	2M	101	3	9	3.000	0.089	10.54	6.25	0.014	-0.029	0.043
21/10/92	7	4M	90	7	10	1.429	0.111	10.51	6.25	0.017	-0.058	0.075
21/10/92	7	8M	54	0	0		0.000	10.27	6.40	0.000	-0.016	0.016
04/11/92	1	2M	82	12	25	2.083	0.305	8.22	8.00	0.033	0.126	-0.093
04/11/92	1	4M	91	1	1	1.000	0.011	8.21	8.00	0.001	0.131	-0.130
04/11/92	1	8M	40	1	2	2.000	0.050	8.18	8.00	0.006	0.175	-0.169
04/11/92	2	2M	34	3	7	2.333	0.206	8.22	8.00	0.023	0.063	-0.040
04/11/92	2	4M	46	2	6	3.000	0.130	8.21	8.00	0.015	0.071	-0.056
04/11/92	2	8M	26	0	0		0.000	8.18	8.00	0.000	0.068	-0.068
04/11/92	3	2M	24	0	0		0.000	8.22	8.00	0.000	0.227	-0.227
04/11/92	3	4M	15	1	1	1.000	0.067	8.21	8.00	0.008	0.045	-0.037
04/11/92	3	8M	17	0	0		0.000	8.18	8.00	0.000	0.053	-0.053
04/11/92	4	2M	16	1	4	4.000	0.250	8.22	8.00	0.028	-0.028	0.056
04/11/92	4	4M	25	1	4	4.000	0.160	8.21	8.00	0.019	0.023	-0.004
04/11/92	4	8M	10	1	4	4.000	0.400	8.18	8.00	0.042	-0.018	0.060
04/11/92	5	2M	13	0	0		0.000	8.22	8.00	0.000	-0.091	0.091
04/11/92	5	4M	14	0	0		0.000	8.21	8.00	0.000	-0.025	0.025
04/11/92	5	8M	2	0	0		0.000	8.18	8.00	0.000	-0.193	0.193
04/11/92	6	2M	12	0	0		0.000	8.22	8.00	0.000	-0.089	0.089
04/11/92	6	4M	24	2	3	1.500	0.125	8.21	8.00	0.015	-0.074	0.089
04/11/92	6	8M	25	1	2	2.000	0.080	8.18	8.00	0.010	-0.068	0.078
04/11/92	7	2M	65	13	24	1.846	0.369	8.22	8.00	0.039	-0.441	0.480
04/11/92	7	4M	82	9	20	2.222	0.244	8.21	8.00	0.027	-0.006	0.033
04/11/92	7	8M	55	13	31	2.385	0.564	8.18	8.00	0.056	0.001	0.055
05/02/93	2	2M	3	0	0		0.000	4.91	10.55	0.000		
05/02/93	2	4M	3	0	0		0.000	4.81	10.60	0.000		

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
05/02/93	2	6M	11	4	11	2.750	1.000	4.81	10.60	0.065		
05/02/93	2	8M	2	0	0		0.000	4.83	10.60	0.000		
05/02/93	2	10M	4	2	4	2.000	1.000	8.78	10.60	0.065		
05/02/93	6	2M	15	2	8	4.000	0.533	4.91	10.55	0.049		
05/02/93	6	4M	16	7	23	3.286	1.438	4.81	10.60	0.084		
05/02/93	6	6M	11	2	4	2.000	0.364	4.81	10.60	0.029		
05/02/93	6	8M	9	1	2	2.000	0.222	4.83	10.60	0.019		
05/02/93	6	10M	5	0	0		0.000	4.78	10.60	0.000		
10/02/93	1	2M	25	9	34	3.778	1.360	4.91	10.55	0.081		
10/02/93	1	4M	36	5	17	3.400	0.472	4.81	10.60	0.036		
10/02/93	1	6M	21	2	6	3.000	0.286	4.81	10.60	0.024		
10/02/93	1	8M	28	4	16	4.000	0.571	4.83	10.60	0.043		
10/02/93	1	10M	11	0	0		0.000	4.78	10.60	0.000		
10/02/93	2	2M	39	13	46	3.538	1.179	4.91	10.55	0.074	0.510	-0.436
10/02/93	2	4M	26	9	26	2.889	1.000	4.81	10.60	0.065	0.430	-0.365
10/02/93	2	6M	41	17	56	3.294	1.366	4.81	10.60	0.081	0.370	-0.289
10/02/93	2	8M	18	1	4	4.000	0.222	4.83	10.60	0.190	0.430	-0.240
10/02/93	2	10M	30	4	12	3.000	0.400	4.78	10.60	0.032	0.400	-0.368
10/02/93	4	2M	75	19	53	2.789	0.707	4.91	10.55	0.081		
10/02/93	4	4M	39	17	47	2.765	1.205	4.81	10.60	0.075		
10/02/93	4	6M	32	10	31	3.100	0.969	4.81	10.60	0.064		
10/02/93	4	8M	22	3	9	3.000	0.409	4.83	10.60	0.032		
10/02/93	4	10M	21	6	17	2.833	0.810	4.78	10.60	0.056		
10/02/93	6	2M	23	5	15	3.000	0.652	4.91	10.55	0.048	0.080	-0.032
10/02/93	6	4M	54	8	29	3.625	0.537	4.81	10.60	0.041	0.170	-0.129
10/02/93	6	6M	24	5	17	3.400	0.708	4.81	10.60	0.051	0.150	-0.099
10/02/93	6	8M	10	5	17	3.400	1.700	4.83	10.60	0.094	0.020	0.074
10/02/93	6	10M	13	1	4	4.000	0.308	4.78	10.60	0.025	0.190	-0.165
10/02/93	7	2M	23	2	8	4.000	0.348	4.91	10.55	0.028		
10/02/93	7	4M	26	6	25	4.167	0.962	4.81	10.60	0.064		
10/02/93	7	6M	15	4	19	4.750	1.267	4.81	10.60	0.077		

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
10/02/93	7	8M	12	4	12	3.000	1.000	4.83	10.60	0.065		
10/02/93	7	10M	6	0	0		0.000	4.78	10.60	0.000		
17/02/93	1	2M	16	0	0		0.000	4.73	10.60	0.000	0.000	0.000
17/02/93	1	4M	12	0	0		0.000	4.52	10.90	0.000	0.000	0.000
17/02/93	1	6M	18	1	3	3.000	0.167	4.71	10.70	0.014	-0.010	0.024
17/02/93	1	8M	20	2	6	3.000	0.300	4.71	10.70	0.025	-0.040	0.065
17/02/93	1	10M	10	2	6	3.000	0.600	4.71	10.70	0.044	-0.010	0.054
17/02/93	2	2M	27	2	9	4.500	0.333	4.73	10.70	0.027	-0.050	0.077
17/02/93	2	4M	6	0	0		0.000	4.52	11.10	0.000	0.000	0.000
17/02/93	2	6M	14	1	4	4.000	0.286	4.71	10.70	0.023	-0.150	0.173
17/02/93	2	8M	7	0	0		0.000	4.71	10.70	0.000	0.000	0.000
17/02/93	2	10M	4	0	0		0.000	4.71	10.70	0.000	0.000	0.000
17/02/93	3	2M	15	1	4	4.000	0.267	4.73	10.70	0.022		
17/02/93	3	4M	20	3	21	7.000	1.050	4.52	11.10	0.065		
17/02/93	3	6M	13	3	14	4.667	1.077	4.71	10.70	0.068		
17/02/93	3	8M	13	1	3	3.000	0.231	4.71	10.70	0.019		
17/02/93	3	10M	14	0	0		0.000	4.71	10.70	0.000		
17/02/93	4	2M	25	3	15	5.000	0.600	4.73	10.70	0.044	-0.150	0.194
17/02/93	4	4M	29	4	13	3.250	0.448	4.52	11.10	0.033	-0.040	0.073
17/02/93	4	6M	26	0	0		0.000	4.71	10.70	0.000	0.000	0.000
17/02/93	4	8M	13	2	5	2.500	0.385	4.71	10.70	0.030	-0.520	0.550
17/02/93	4	10M	9	0	0		0.000	4.71	10.70	0.000	0.000	0.000
17/02/93	6	2M	28	6	28	4.667	1.000	4.73	10.70	0.065	0.020	0.045
17/02/93	6	4M	25	4	13	3.250	0.520	4.52	11.10	0.038	0.050	-0.012
17/02/93	6	6M	14	5	19	3.800	1.357	4.71	10.70	0.080	-0.530	0.610
17/02/93	6	8M	11	1	6	6.000	0.545	4.71	10.70	0.041	0.010	0.031
17/02/93	6	10M	13	5	15	3.000	1.154	4.71	10.70	0.072	0.000	0.072
17/02/93	7	2M	46	7	36	5.143	0.783	4.73	10.70	0.054	0.090	-0.036
17/02/93	7	4M	25	6	24	4.000	0.960	4.52	11.10	0.061	-0.003	0.064
17/02/93	7	6M	33	5	25	5.000	0.758	4.71	10.70	0.053	0.780	-0.727
17/02/93	7	8M	29	6	33	5.500	1.138	4.71	10.70	0.071	0.880	-0.809

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
17/02/93	7	10M	24	2	11	5.500	0.458	4.71	10.70	0.035	0.190	-0.155
03/03/93	1	2M	25	2	10	5.000	0.400	4.11	11.30	0.030	0.030	0.000
03/03/93	1	4M	28	2	9	4.500	0.321	4.11	11.30	0.025	0.060	-0.035
03/03/93	1	6M	14	0	0		0.000	4.12	11.30	0.000	0.000	0.000
03/03/93	1	8M	28	2	9	4.500	0.321	4.12	11.30	0.250	0.020	0.230
03/03/93	1	10M	17	1	6	6.000	0.353	4.11	11.30	0.027	0.030	-0.003
03/03/93	2	2M	58	11	61	5.545	1.052	4.11	11.30	0.064	0.050	0.014
03/03/93	2	4M	26	5	25	5.000	0.962	4.11	11.30	0.060	0.100	-0.040
03/03/93	2	6M	12	2	4	2.000	0.333	4.12	11.30	0.025	-0.010	0.035
03/03/93	2	8M	26	3	17	5.667	0.654	4.12	11.30	0.045	0.090	-0.045
03/03/93	2	10M	14	0	0		0.000	4.11	11.30	0.000	0.000	0.000
03/03/93	3	2M	26	0	0		0.000	4.11	11.30	0.000	0.000	0.000
03/03/93	3	4M	17	1	4	4.000	0.235	4.11	11.30	0.019	-0.010	0.029
03/03/93	3	6M	13	2	9	4.500	0.692	4.12	11.30	0.047	0.000	0.047
03/03/93	3	8M	25	2	11	5.500	0.440	4.12	11.30	0.032	0.040	-0.008
03/03/93	3	10M	17	2	7	3.500	0.412	4.11	11.30	0.031	0.010	0.021
03/03/93	4	2M	28	2	12	6.000	0.429	4.11	11.30	0.032	0.002	0.030
03/03/93	4	4M	35	1	6	6.000	0.171	4.11	11.30	0.014	0.010	0.004
03/03/93	4	6M	29	3	17	5.667	0.586	4.12	11.30	0.041	0.000	0.041
03/03/93	4	8M	13	2	11	5.500	0.846	4.12	11.30	0.054	0.000	0.054
03/03/93	4	10M	31	1	9	9.000	0.290	4.11	11.30	0.023	0.050	-0.027
03/03/93	6	2M	16	1	7	7.000	0.438	4.11	11.30	0.032	-0.030	0.062
03/03/93	6	4M	35	2	6	3.000	0.171	4.11	11.30	0.014	0.020	-0.006
03/03/93	6	6M	24	3	21	7.000	0.875	4.12	11.30	0.056	0.030	0.026
03/03/93	6	8M	20	0	0		0.000	4.12	11.30	0.000	0.000	0.000
03/03/93	6	10M	21	2	12	6.000	0.571	4.11	11.30	0.040	0.030	0.010
03/03/93	7	2M	28	5	24	4.800	0.857	4.11	11.30	0.055	-0.030	0.085
03/03/93	7	4M	21	1	7	7.000	0.333	4.11	11.30	0.025	-0.010	0.035
03/03/93	7	6M	40	5	21	4.200	0.525	4.12	11.30	0.037	0.010	0.027
03/03/93	7	8M	28	2	14	7.000	0.500	4.12	11.30	0.036	-0.002	0.038
03/03/93	7	10M	11	1	6	6.000	0.545	4.11	11.30	0.039	-0.050	0.089

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
10/03/93	1	2M	12	1	5	5.000	0.417	3.98	11.40	0.031	-0.100	0.131
10/03/93	1	4M	12	1	6	6.000	0.500	3.95	11.40	0.036	-0.120	0.156
10/03/93	1	6M	13	1	7	7.000	0.538	3.94	11.40	0.038	-0.070	0.108
10/03/93	1	8M	5	1	3	3.000	0.600	3.93	11.50	0.041	-0.240	0.281
10/03/93	1	10M	7	0	0		0.000	3.92	11.50	0.000	0.000	0.000
10/03/93	2	2M	23	2	11	5.500	0.478	3.98	11.40	0.034	-0.130	0.164
10/03/93	2	4M	13	2	18	9.000	1.385	3.95	11.40	0.076	-0.090	0.166
10/03/93	2	6M	18	2	7	3.500	0.389	3.94	11.50	0.029	-0.110	0.139
10/03/93	2	8M	8	0	0		0.000	3.93	11.50	0.000	0.000	0.000
10/03/93	2	10M	19	1	4	4.000	0.211	3.92	11.50	0.017	0.000	0.017
10/03/93	3	2M	24	1	5	5.000	0.208	3.98	11.40	0.017	0.000	0.017
10/03/93	3	4M	20	1	5	5.000	0.250	3.95	11.50	0.019	0.020	-0.001
10/03/93	3	6M	18	2	9	4.500	0.500	3.94	11.50	0.035	0.040	-0.005
10/03/93	3	8M	9	1	4	4.000	0.444	3.93	11.50	0.032	-0.140	0.172
10/03/93	3	10M	13	1	7	7.000	0.538	3.92	11.50	0.037	-0.030	0.067
10/03/93	4	2M	9	0	0		0.000	3.98	11.40	0.000	0.000	0.000
10/03/93	4	4M	29	0	0		0.000	3.95	11.40	0.000	0.000	0.000
10/03/93	4	6M	29	0	0		0.000	3.94	11.50	0.000	0.000	0.000
10/03/93	4	8M	43	2	11	5.500	0.256	3.93	11.50	0.020	0.170	-0.150
10/03/93	4	10M	20	0	0		0.000	3.92	11.50	0.000	0.000	0.000
10/03/93	6	2M	60	13	84	6.462	1.400	3.98	11.40	0.077	0.180	-0.103
10/03/93	6	4M	52	6	35	5.833	0.673	3.95	11.40	0.045	0.050	-0.005
10/03/93	6	6M	25	0	0		0.000	3.94	11.50	0.000	0.000	0.000
10/03/93	6	8M	16	0	0		0.000	3.93	11.50	0.000	0.000	0.000
10/03/93	6	10M	23	2	12	6.000	0.522	3.92	11.50	0.037	0.010	0.027
10/03/93	7	2M	12	1	5	5.000	0.417	3.98	11.40	0.031	-0.120	0.151
10/03/93	7	4M	56	3	11	3.667	0.196	3.95	11.40	0.016	0.140	-0.124
10/03/93	7	6M	40	1	6	6.000	0.150	3.94	11.50	0.012	0.000	0.012
10/03/93	7	8M	28	2	12	6.000	0.429	3.93	11.50	0.031	0.000	0.031
10/03/93	7	10M	31	0	0		0.000	3.92	11.50	0.000	0.000	0.000
01/04/93	1	2M	11	0	0		0.000	6.22	9.50	0.000	0.000	0.000

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
01/04/93	1	4M	20	2	14	7.000	0.700	6.22	9.50	0.056	0.023	0.033
01/04/93	1	6M	7	4	37	9.250	5.286	6.21	9.50	0.194	-0.020	0.214
01/04/93	1	8M	6	1	10	10.000	1.667	6.18	9.50	0.130	0.008	0.122
01/04/93	1	10M	18	4	25	6.250	1.389	6.17	9.50	0.092	0.040	0.052
01/04/93	2	2M	14	6	36	6.000	2.571	6.22	9.50	0.134	-0.020	0.154
01/04/93	2	4M	14	4	28	7.000	2.000	6.22	9.50	0.116	0.003	0.113
01/04/93	2	6M	9	2	11	5.500	1.222	6.21	9.50	0.084	-0.030	0.114
01/04/93	2	8M	6	0	0		0.000	6.18	9.50	0.000	0.000	0.000
01/04/93	2	10M	7	1	2	2.000	0.286	6.17	9.50	0.026	-0.040	0.066
01/04/93	3	2M	23	2	9	4.500	0.391	6.22	9.50	0.035	-0.002	0.037
01/04/93	3	4M	30	3	24	8.000	0.800	6.22	9.50	0.062	0.018	0.044
01/04/93	3	6M	27	8	53	6.625	1.963	6.21	9.50	0.114	0.018	0.096
01/04/93	3	8M	11	0	0		0.000	6.18	9.50	0.000	0.000	0.000
01/04/93	3	10M	17	3	17	5.667	1.000	6.17	9.50	0.073	0.012	0.061
01/04/93	4	2M	49	8	73	9.125	1.490	6.22	9.50	0.096	0.070	0.026
01/04/93	4	4M	24	2	8	4.000	0.333	6.22	9.50	0.030	-0.008	0.038
01/04/93	4	6M	26	3	20	6.667	0.769	6.21	9.50	0.060	-0.004	0.064
01/04/93	4	8M	20	1	8	8.000	0.400	6.18	9.50	0.035	-0.030	0.065
01/04/93	4	10M	23	6	50	8.333	2.174	6.17	9.50	0.122	0.006	0.116
01/04/93	5	2M	13	0	0		0.000	6.22	9.50	0.000		
01/04/93	5	4M	22	0	0		0.000	6.22	9.50	0.000		
01/04/93	5	6M	33	2	12	6.000	0.364	6.21	9.50	0.033		
01/04/93	5	8M	20	2	14	7.000	0.700	6.18	9.50	0.056		
01/04/93	5	10M	34	4	34	8.500	1.000	6.17	9.50	0.073		
01/04/93	6	2M	27	3	22	7.333	0.815	6.22	9.50	0.063	-0.030	0.093
01/04/93	6	4M	29	3	24	8.000	0.828	6.22	9.50	0.063	-0.020	0.083
01/04/93	6	6M	24	2	15	7.500	0.625	6.21	9.50	0.051	-0.002	0.053
01/04/93	6	8M	31	4	37	9.250	1.194	6.18	9.50	0.083	0.030	0.053
01/04/93	6	10M	28	4	29	7.250	1.036	6.17	9.50	0.075	0.009	0.066
01/04/93	7	2M	37	5	37	7.400	1.000	6.22	9.50	0.073	0.050	0.023
01/04/93	7	4M	45	9	75	8.333	1.667	6.22	9.50	0.103	-0.009	0.112

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
01/04/93	7	6M	42	8	81	10.125	1.929	6.21	9.50	0.113	0.002	0.111
01/04/93	7	8M	54	15	100	6.667	1.852	6.18	9.50	0.110	0.029	0.081
01/04/93	7	10M	54	14	97	6.929	1.796	6.17	9.50	0.108	0.025	0.083
14/04/93	1	2M	42	5	34	6.800	0.810	7.59	8.50	0.070	0.100	-0.030
14/04/93	1	4M	58	2	15	7.500	0.259	7.59	8.50	0.027	0.080	-0.053
14/04/93	1	6M	51	2	8	4.000	0.157	7.47	8.55	0.017	0.140	-0.123
14/04/93	1	8M	51	4	24	6.000	0.471	7.38	8.60	0.045	0.160	-0.115
14/04/93	1	10M	30	0	0		0.000	7.36	8.60	0.000	0.000	0.000
14/04/93	2	2M	39	1	8	8.000	0.205	7.59	8.50	0.022	0.070	-0.048
14/04/93	2	4M	41	2	14	7.000	0.341	7.59	8.50	0.035	0.080	-0.045
14/04/93	2	6M	45	1	5	5.000	0.111	7.47	8.55	0.012	0.120	-0.108
14/04/93	2	8M	34	2	10	5.000	0.294	7.38	8.60	0.030	0.130	-0.100
14/04/93	2	10M	48	0	0		0.000	7.36	8.60	0.000	0.000	0.000
14/04/93	3	2M	62	4	33	8.250	0.532	7.59	8.50	0.050	0.070	-0.020
14/04/93	3	4M	33	1	4	4.000	0.121	7.59	8.50	0.013	0.007	0.006
14/04/93	3	6M	52	3	18	6.000	0.346	7.47	8.55	0.035	0.050	-0.015
14/04/93	3	8M	44	4	28	7.000	0.636	7.38	8.60	0.057	0.100	-0.043
14/04/93	3	10M	50	8	47	5.875	0.940	7.36	8.60	0.077	0.080	-0.003
14/04/93	4	2M	25	0	0		0.000	7.59	8.50	0.000	0.000	0.000
14/04/93	4	4M	44	3	22	7.333	0.500	7.59	8.50	0.048	0.040	0.008
14/04/93	4	6M	62	6	34	5.667	0.548	7.47	8.55	0.051	0.060	-0.009
14/04/93	4	8M	41	3	19	6.333	0.463	7.38	8.60	0.044	0.050	-0.006
14/04/93	4	10M	38	3	27	9.000	0.711	7.36	8.60	0.062	0.040	0.022
14/04/93	5	2M	54	1	5	5.000	0.093	7.59	8.50	0.010	0.110	-0.100
14/04/93	5	4M	69	1	8	8.000	0.116	7.59	8.50	0.013	0.080	-0.067
14/04/93	5	6M	69	2	17	8.500	0.246	7.47	8.55	0.026	0.050	-0.024
14/04/93	5	8M	78	1	8	8.000	0.103	7.38	8.60	0.011	0.100	-0.089
14/04/93	5	10M	75	2	14	7.000	0.187	7.36	8.60	0.020	0.060	-0.040
14/04/93	6	2M	75	0	0		0.000	7.59	8.50	0.000	0.000	0.000
14/04/93	6	4M	100	5	26	5.200	0.260	7.59	8.50	0.027	0.900	-0.873
14/04/93	6	6M	78	5	35	7.000	0.449	7.47	8.55	0.043	0.900	-0.857

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
14/04/93	6	8M	93	7	49	7.000	0.527	7.38	8.60	0.049	0.080	-0.031
14/04/93	6	10M	55	8	56	7.000	1.018	7.36	8.60	0.082	0.050	0.032
14/04/93	7	2M	300	2	6	3.000	0.020	7.59	8.50	0.002	0.160	-0.158
14/04/93	7	4M	200	4	24	6.000	0.120	7.59	8.50	0.013	0.110	-0.097
14/04/93	7	6M	262	22	166	7.545	0.634	7.47	8.55	0.057	0.140	-0.083
14/04/93	7	8M	224	14	86	6.143	0.384	7.38	8.60	0.038	0.110	-0.072
14/04/93	7	10M	174	4	28	7.000	0.161	7.36	8.60	0.017	0.090	-0.073
06/05/93	3	2M	314	38	176	4.632	0.561	11.20	5.80	0.077	0.070	0.007
06/05/93	3	4M	94	3	10	3.333	0.106	10.82	6.10	0.017	0.040	-0.023
06/05/93	3	6M	198	10	46	4.600	0.232	10.76	6.10	0.034	0.060	-0.026
06/05/93	3	8M	116	4	14	3.500	0.121	10.70	6.15	0.019	0.040	-0.021
06/05/93	4	2M	160	0	0		0.000	11.20	5.80	0.000	0.000	0.000
06/05/93	4	4M	121	4	16	4.000	0.132	10.82	6.10	0.020	0.040	-0.020
06/05/93	4	6M	69	2	12	6.000	0.174	10.76	6.10	0.026	0.005	0.021
06/05/93	4	8M	150	0	0		0.000	10.70	6.15	0.000	0.000	0.000
06/05/93	4	10M	57	2	6	3.000	0.105	10.58	6.20	0.016	0.020	-0.004
06/05/93	5	2M	83	0	0		0.000	11.20	5.80	0.000	0.000	0.000
06/05/93	5	4M	280	38	180	4.737	0.643	10.82	6.10	0.081	0.060	0.021
06/05/93	5	6M	298	26	90	3.462	0.302	10.76	6.10	0.043	0.060	-0.017
06/05/93	5	8M	206	14	54	3.857	0.262	10.70	6.15	0.038	0.040	-0.002
06/05/93	5	10M	188	12	46	3.833	0.245	10.58	6.20	0.035	0.050	-0.015
06/05/93	6	2M	300	18	96	5.333	0.320	11.20	5.80	0.048	0.060	-0.012
06/05/93	6	4M	300	12	55	4.583	0.183	10.82	6.10	0.028	0.050	-0.022
06/05/93	6	6M	104	6	28	4.667	0.269	10.76	6.10	0.039	0.010	0.029
06/05/93	6	8M	192	10	26	2.600	0.135	10.70	6.15	0.021	0.030	-0.009
06/05/93	6	10M	318	8	30	3.750	0.094	10.58	6.20	0.015	0.080	-0.065
06/05/93	7	2M	238	22	86	3.909	0.361	11.20	5.80	0.053	-0.010	0.063
06/05/93	7	4M	250	12	34	2.833	0.136	10.82	6.20	0.021	0.010	0.011
06/05/93	7	6M	288	10	37	3.700	0.128	10.76	6.20	0.019	0.004	0.015
06/05/93	7	8M	204	14	94	6.714	0.461	10.70	6.15	0.062	-0.004	0.066
06/05/93	7	10M	57	8	30	3.750	0.526	10.58	6.20	0.068	-0.050	0.118

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
27/05/93	1	2M	112	3	13	4.333	0.116	13.08	4.75	0.023	0.020	0.003
27/05/93	1	4M	106	2	14	7.000	0.132	13.01	4.80	0.026	0.010	0.016
27/05/93	1	6M	56	1	1	1.000	0.018	13.00	4.80	0.040	0.002	0.038
27/05/93	1	8M	144	8	16	2.000	0.111	13.00	4.80	0.022	0.020	0.002
27/05/93	1	10M	232	14	35	2.500	0.151	12.96	4.80	0.029	0.040	-0.011
27/05/93	2	2M	236	14	58	4.143	0.246	13.08	4.75	0.046	0.040	0.006
27/05/93	2	4M	236	12	54	4.500	0.229	13.01	4.80	0.043	0.040	0.003
27/05/93	2	6M	300	14	33	2.357	0.110	13.00	4.80	0.022	0.040	-0.018
27/05/93	2	8M	236	22	96	4.364	0.407	13.00	4.80	0.071	0.040	0.031
27/05/93	2	10M	292	20	60	3.000	0.205	12.96	4.80	0.039	0.040	-0.001
27/05/93	4	2M	268	8	38	4.750	0.142	13.08	4.75	0.028	-0.008	0.036
27/05/93	4	4M	404	28	128	4.571	0.317	13.01	4.80	0.057	0.050	0.007
27/05/93	4	6M	488	4	24	6.000	0.049	13.00	4.80	0.010	0.090	-0.080
27/05/93	4	8M	488	8	16	2.000	0.033	13.00	4.80	0.007	0.020	-0.013
27/05/93	4	10M	388	16	76	4.750	0.196	12.96	4.80	0.038	0.090	-0.052
27/05/93	5	2M	416	68	368	5.412	0.885	13.08	4.75	0.133	0.070	0.063
27/05/93	5	4M	208	32	240	7.500	1.154	13.01	4.80	0.160	-0.010	0.170
27/05/93	5	6M	236	52	312	6.000	1.322	13.00	4.80	0.176	-0.010	0.186
27/05/93	5	8M	264	64	468	7.313	1.773	13.00	4.80	0.212	0.010	0.202
27/05/93	5	10M	180	16	76	4.750	0.422	12.96	4.80	0.073	-0.002	0.075
27/05/93	6	2M	428	18	184	10.222	0.430	13.08	4.75	0.075	0.016	0.059
27/05/93	6	4M	380	12	224	18.667	0.589	13.01	4.80	0.097	0.010	0.087
27/05/93	6	6M	524	6	280	46.667	0.534	13.00	4.80	0.089	0.070	0.019
27/05/93	6	8M	212	10	0	0.000	0.000	13.00	4.80	0.000	0.000	0.000
27/05/93	6	10M	234	8	248	31.000	1.060	12.96	4.80	0.151	-0.010	0.161
27/05/93	7	2M	476	76	400	5.263	0.840	13.08	4.75	0.128	0.030	0.098
27/05/93	7	4M	316	48	296	6.167	0.937	13.01	4.80	0.138	0.008	0.130
27/05/93	7	6M	428	28	176	6.286	0.411	13.00	4.80	0.072	0.010	0.062
27/05/93	7	8M	380	12	88	7.333	0.232	13.00	4.80	0.043	0.020	0.023
27/05/93	7	10M	336	20	116	5.800	0.345	12.96	4.80	0.062	0.060	0.002
10/06/93	1	2M	746	12	64	5.333	0.086	16.41	3.65	0.023	0.130	-0.107

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
10/06/93	1	4M	328	48	168	3.500	0.512	15.22	3.95	0.105	0.080	0.025
10/06/93	1	6M	27	6	22	3.667	0.815	14.00	4.50	0.139	-0.050	0.189
10/06/93	1	8M	82	9	38	4.222	0.463	13.59	4.50	0.085	-0.040	0.125
10/06/93	1	10M	52	1	2	2.000	0.038	13.44	4.60	0.008	-0.010	0.018
10/06/93	2	2M	284	2	8	4.000	0.028	16.41	3.55	0.008	0.010	-0.002
10/06/93	2	4M	226	8	22	2.750	0.097	15.22	3.95	0.024	-0.003	0.027
10/06/93	2	6M	244	6	24	4.000	0.098	14.00	4.30	0.022	-0.010	0.032
10/06/93	2	8M	43	1	5	5.000	0.116	13.59	4.50	0.024	-0.120	0.144
10/06/93	2	10M	36	0	0		0.000	13.44	4.60	0.000	0.000	0.000
10/06/93	3	2M	118	0	0		0.000	16.41	3.40	0.000	0.000	0.000
10/06/93	3	4M	216	8	40	5.000	0.185	15.22	3.95	0.043	0.020	0.023
10/06/93	3	6M	156	2	8	4.000	0.051	14.00	4.30	0.012	-0.006	0.018
10/06/93	3	8M	60	1	4	4.000	0.067	13.59	4.50	0.014	-0.010	0.024
10/06/93	3	10M	43	1	5	5.000	0.116	13.44	4.60	0.024	-0.003	0.027
10/06/93	4	2M	294	6	24	4.000	0.082	16.41	3.55	0.022	0.030	-0.008
10/06/93	4	4M	150	4	14	3.500	0.093	15.22	3.95	0.023	-0.040	0.063
10/06/93	4	6M	18	2	8	4.000	0.444	14.00	4.30	0.086	-0.150	0.236
10/06/93	4	8M	13	0	0		0.000	13.59	4.50	0.000	0.000	0.000
10/06/93	4	10M	8	0	0		0.000	13.44	4.60	0.000	0.000	0.000
10/06/93	5	2M	540	8	20	2.500	0.037	16.41	3.55	0.010	0.020	-0.010
10/06/93	5	4M	100	2	10	5.000	0.100	15.22	3.95	0.024	-0.050	0.074
10/06/93	5	6M	320	16	76	4.750	0.238	14.00	4.30	0.050	0.010	0.040
10/06/93	5	8M	142	4	8	2.000	0.056	13.59	4.50	0.012	-0.040	0.052
10/06/93	5	10M	62	0	0		0.000	13.44	4.60	0.000	0.000	0.000
10/06/93	6	2M	191	1	6	6.000	0.031	16.41	3.50	0.009	-0.050	0.059
10/06/93	6	4M	450	6	24	4.000	0.053	15.22	3.95	0.013	0.010	0.003
10/06/93	6	6M	55	3	11	3.667	0.200	14.00	4.30	0.042	-0.160	0.202
10/06/93	6	8M	328	10	46	4.600	0.140	13.59	4.50	0.029	0.030	-0.001
10/06/93	6	10M	33	4	14	3.500	0.424	13.44	4.60	0.077	-0.130	0.207
10/06/93	7	2M	448	6	16	2.667	0.036	16.41	3.55	0.010	0.004	0.006
10/06/93	7	4M	338	8	16	2.000	0.047	15.22	3.95	0.012	0.004	0.008

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
10/06/93	7	6M	204	2	14	7.000	0.069	14.00	4.30	0.015	-0.050	0.065
10/06/93	7	8M	33	3	13	4.333	0.394	13.59	4.50	0.074	-0.170	0.244
10/06/93	7	10M	53	7	36	5.143	0.679	13.44	4.60	0.113	-0.130	0.243
29/06/93	1	2M	174	18	52	2.889	0.299	10.90	6.00	0.044	-0.070	0.114
29/06/93	1	4M	123	4	5	1.250	0.041	10.80	6.10	0.007	-0.050	0.057
29/06/93	1	6M	39	0	0		0.000	10.80	6.10	0.000	0.000	0.000
29/06/93	1	8M	20	0	0		0.000	10.80	6.10	0.000	0.000	0.000
29/06/93	1	10M	14	1	3	3.000	0.214	10.80	6.10	0.032	-0.070	0.102
29/06/93	2	2M	28	0	0		0.000	10.90	6.00	0.000	0.000	0.000
29/06/93	2	4M	142	14	32	2.286	0.225	10.80	6.10	0.033	-0.020	0.053
29/06/93	2	6M	20	4	12	3.000	0.600	10.80	6.10	0.077	-0.130	0.207
29/06/93	2	8M	20	1	2	2.000	0.100	10.80	6.10	0.016	-0.040	0.056
29/06/93	2	10M	33	6	12	2.000	0.364	10.80	6.10	0.051	-0.004	0.055
29/06/93	3	2M	113	6	16	2.667	0.142	10.90	6.00	0.022	-0.002	0.024
29/06/93	3	4M	117	10	36	3.600	0.308	10.80	6.10	0.044	-0.030	0.074
29/06/93	3	6M	24	0	0		0.000	10.80	6.10	0.000	0.000	0.000
29/06/93	3	8M	14	1	1	1.000	0.071	10.80	6.10	0.011	-0.070	0.081
29/06/93	3	10M	106	4	11	2.750	0.104	10.80	6.10	0.016	0.040	-0.024
29/06/93	4	2M	246	44	120	2.727	0.488	10.90	6.00	0.066	-0.007	0.073
29/06/93	4	4M	99	11	28	2.545	0.283	10.80	6.10	0.041	-0.020	0.061
29/06/93	4	6M	44	8	27	3.375	0.614	10.80	6.10	0.078	0.040	0.038
29/06/93	4	8M	20	1	1	1.000	0.050	10.80	6.10	0.008	0.020	-0.012
29/06/93	4	10M	13	1	4	4.000	0.308	10.80	6.10	0.044	0.020	0.024
29/06/93	5	2M	135	6	19	3.167	0.141	10.90	6.00	0.022	-0.070	0.092
29/06/93	5	4M	226	12	40	3.333	0.177	10.80	6.10	0.027	0.040	-0.013
29/06/93	5	6M	29	2	4	2.000	0.138	10.80	6.10	0.021	-0.120	0.141
29/06/93	5	8M	23	1	1	1.000	0.043	10.80	6.10	0.007	-0.090	0.097
29/06/93	5	10M	39	1	3	3.000	0.077	10.80	6.10	0.012	-0.020	0.032
29/06/93	6	2M	133	6	12	2.000	0.090	10.90	6.00	0.014	-0.020	0.034
29/06/93	6	4M	159	27	105	3.889	0.660	10.80	6.10	0.083	-0.050	0.133
29/06/93	6	6M	203	17	27	1.588	0.133	10.80	6.10	0.020	0.060	-0.040

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
29/06/93	6	8M	134	15	48	3.200	0.358	10.80	6.10	0.050	-0.040	0.090
29/06/93	6	10M	172	38	88	2.316	0.512	10.80	6.10	0.068	0.080	-0.012
29/06/93	7	2M	186	18	58	3.222	0.312	10.90	6.00	0.045	-0.040	0.085
29/06/93	7	4M	198	4	4	1.000	0.020	10.80	6.10	0.003	-0.020	0.023
29/06/93	7	6M	127	40	128	3.200	1.008	10.80	6.10	0.114	-0.020	0.134
29/06/93	7	8M	49	6	18	3.000	0.367	10.80	6.10	0.051	0.020	0.031
29/06/93	7	10M	44	6	17	2.833	0.386	10.80	6.10	0.054	-0.009	0.063
14/07/93	1	2M	189	4	12	3.000	0.063	12.10	5.25	0.012	0.005	0.007
14/07/93	1	4M	87	0	0		0.000	12.10	5.25	0.000	0.000	0.000
14/07/93	1	6M	63	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	1	8M	58	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	1	10M	35	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	2	2M	129	3	10	3.333	0.078	12.10	5.25	0.014	0.090	-0.076
14/07/93	2	4M	107	0	0		0.000	12.10	5.25	0.000	0.000	0.000
14/07/93	2	6M	145	3	15	5.000	0.103	12.00	5.30	0.019	0.130	-0.111
14/07/93	2	8M	200	1	1	1.000	0.005	12.00	5.30	0.001	0.150	-0.149
14/07/93	2	10M	82	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	3	2M	161	6	21	3.500	0.130	12.10	5.25	0.023	0.020	0.003
14/07/93	3	4M	112	0	1		0.009	12.10	5.25	0.002	0.040	-0.038
14/07/93	3	6M	170	4	10	2.500	0.059	12.00	5.30	0.011	0.130	-0.119
14/07/93	3	8M	85	4	11	2.750	0.129	12.00	5.30	0.023	0.120	-0.097
14/07/93	3	10M	75	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	4	2M	101	0	0		0.000	12.10	5.25	0.000	0.000	0.000
14/07/93	4	4M	107	4	13	3.250	0.121	12.10	5.25	0.022	0.005	0.017
14/07/93	4	6M	90	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	4	8M	65	0	0		0.000	12.00	5.30	0.000	0.000	0.000
14/07/93	4	10M	56	3	7	2.333	0.125	12.00	5.30	0.022	0.090	-0.068
14/07/93	5	2M	137	4	12	3.000	0.088	12.10	5.25	0.016	0.001	0.015
14/07/93	5	4M	143	1	1	1.000	0.007	12.10	5.25	0.001	-0.030	0.031
14/07/93	5	6M	144	2	2	1.000	0.014	12.00	5.30	0.003	0.100	-0.097
14/07/93	5	8M	122	1	3	3.000	0.025	12.00	5.30	0.005	0.110	-0.105

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
14/07/93	5	10M	74	1	2	2.000	0.027	12.00	5.30	0.005	0.040	-0.035
14/07/93	6	2M	146	4	11	2.750	0.075	12.10	5.25	0.014	0.006	0.008
14/07/93	6	4M	104	1	1	1.000	0.010	12.10	5.25	0.002	-0.027	0.029
14/07/93	6	6M	118	3	4	1.333	0.034	12.00	5.30	0.006	-0.030	0.036
14/07/93	6	8M	90	1	2	2.000	0.022	12.00	5.30	0.004	-0.020	0.024
14/07/93	7	2M	95	1	2	2.000	0.021	12.10	5.25	0.004	-0.040	0.044
14/07/93	7	4M	106	4	0	0.000	0.000	12.10	5.25	0.000	0.000	0.000
14/07/93	7	6M	68	1	4	4.000	0.059	12.00	5.30	0.011	-0.040	0.051
14/07/93	7	8M	72	7	8	1.143	0.111	12.00	5.30	0.020	0.020	0.000
14/07/93	7	10M	69	3	5	1.667	0.072	12.00	5.30	0.013	0.030	-0.017
29/07/93	1	2M	14	2	9	4.500	0.643	17.20	3.30	0.150	-0.170	0.320
29/07/93	1	4M	22	0	0		0.000	17.20	3.30	0.000	0.000	0.000
29/07/93	1	6M	13	0	0		0.000	17.20	3.30	0.000	0.000	0.000
29/07/93	1	8M	12	1	5	5.000	0.417	17.10	3.35	0.104	0.000	0.104
29/07/93	1	10M	6	0	0		0.000	17.10	3.35	0.000	0.000	0.000
29/07/93	2	2M	27	3	13	4.333	0.481	17.20	3.30	0.119	-0.104	0.223
29/07/93	2	4M	15	0	0		0.000	17.20	3.30	0.000	0.000	0.000
29/07/93	2	6M	20	1	4	4.000	0.200	17.20	3.30	0.055	-0.130	0.185
29/07/93	2	8M	29	3	6	2.000	0.207	17.10	3.35	0.056	-0.130	0.186
29/07/93	2	10M	16	1	1	1.000	0.063	17.10	3.35	0.018	-0.110	0.128
29/07/93	3	2M	22	3	14	4.667	0.636	17.20	3.30	0.149	-0.130	0.279
29/07/93	3	4M	26	3	15	5.000	0.577	17.20	3.30	0.138	-0.160	0.298
29/07/93	3	6M	16	2	8	4.000	0.500	17.20	3.30	0.123	-0.150	0.273
29/07/93	3	8M	13	3	17	5.667	1.308	17.10	3.35	0.250	-0.120	0.370
29/07/93	3	10M	42	2	7	3.500	0.167	17.10	3.35	0.046	-0.090	0.136
29/07/93	4	2M	42	4	22	5.500	0.524	17.20	3.30	0.128	-0.060	0.188
29/07/93	4	4M	26	2	8	4.000	0.308	17.20	3.30	0.081	-0.090	0.171
29/07/93	4	6M	35	9	45	5.000	1.286	17.20	3.30	0.236	-0.060	0.296
29/07/93	4	8M	9	3	16	5.333	1.778	17.10	3.35	0.305	-0.130	0.435
29/07/93	4	10M	14	3	3	1.000	0.214	17.10	3.35	0.058	-0.090	0.148
29/07/93	5	2M	40	4	16	4.000	0.400	17.20	3.30	0.102	-0.080	0.182

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
29/07/93	5	4M	40	8	48	6.000	1.200	17.20	3.30	0.239	-0.080	0.319
29/07/93	5	6M	30	2	6	3.000	0.200	17.20	3.30	0.055	-0.140	0.195
29/07/93	5	8M	37	5	25	5.000	0.676	17.10	3.35	0.154	-0.080	0.234
29/07/93	5	10M	25	5	23	4.600	0.920	17.10	3.35	0.195	-0.070	0.265
29/07/93	6	2M	29	2	7	3.500	0.241	17.20	3.30	0.066	-0.110	0.176
29/07/93	6	4M	20	1	6	6.000	0.300	17.20	3.30	0.080	-0.110	0.190
29/07/93	6	6M	24	4	24	6.000	1.000	17.20	3.30	0.210	-0.106	0.316
29/07/93	6	8M	19	4	20	5.000	1.053	17.10	3.35	0.215	-0.103	0.318
29/07/93	6	10M	27	8	41	5.125	1.519	17.10	3.35	0.276	-0.060	0.336
29/07/93	7	2M	23	1	4	4.000	0.174	17.20	3.30	0.049	-0.090	0.139
29/07/93	7	4M	19	4	19	4.750	1.000	17.20	3.30	0.210	-0.110	0.320
29/07/93	7	6M	21	1	4	4.000	0.190	17.20	3.30	0.053	-0.080	0.133
29/07/93	7	8M	20	7	31	4.429	1.550	17.10	3.35	0.279	-0.080	0.359
29/07/93	7	10M	13	3	14	4.667	1.077	17.10	3.35	0.218	-0.110	0.328
11/08/93	1	2M	26	3	11	3.667	0.423	17.30	3.25	0.109	0.040	0.069
11/08/93	1	4M	49	4	18	4.500	0.367	17.30	3.25	0.096	0.060	0.036
11/08/93	1	6M	72	10	39	3.900	0.542	17.30	3.25	0.133	0.130	0.003
11/08/93	1	8M	51	5	16	3.200	0.314	17.30	3.25	0.084	0.110	-0.026
11/08/93	1	10M	51	6	17	2.833	0.333	17.40	3.25	0.089	0.160	-0.071
11/08/93	2	2M	46	5	17	3.400	0.370	17.30	3.25	0.097	4.000	-3.903
11/08/93	2	4M	45	8	26	3.250	0.578	17.30	3.25	0.140	0.080	0.060
11/08/93	2	6M	41	11	34	3.091	0.829	17.30	3.25	0.186	0.050	0.136
11/08/93	2	8M	56	2	7	3.500	0.125	17.30	3.25	0.036	0.050	-0.014
11/08/93	2	10M	55	7	30	4.286	0.545	17.40	3.25	0.134	0.090	0.044
11/08/93	3	2M	51	9	23	2.556	0.451	17.30	3.25	0.115	0.060	0.055
11/08/93	3	4M	59	7	23	3.286	0.390	17.30	3.25	0.101	0.060	0.041
11/08/93	3	6M	66	13	60	4.615	0.909	17.30	3.25	0.199	0.110	0.089
11/08/93	3	8M	38	3	9	3.000	0.237	17.30	3.25	0.065	0.080	-0.015
11/08/93	3	10M	37	3	8	2.667	0.216	17.40	3.25	0.060	0.050	0.010
11/08/93	5	2M	56	1	6	6.000	0.107	17.30	3.25	0.031	0.020	0.011
11/08/93	5	4M	67	6	19	3.167	0.284	17.30	3.25	0.077	0.040	0.037

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
11/08/93	5	6M	49	9	25	2.778	0.510	17.30	3.25	0.127	0.070	0.057
11/08/93	5	8M	50	10	36	3.600	0.720	17.30	3.25	0.167	0.020	0.147
11/08/93	5	10M	55	9	38	4.222	0.691	17.40	3.25	0.162	0.060	0.102
11/08/93	6	2M	56	3	10	3.333	0.179	17.30	3.25	0.051	0.050	0.001
11/08/93	6	4M	38	5	17	3.400	0.447	17.30	3.25	0.114	0.050	0.064
11/08/93	6	6M	30	4	14	3.500	0.467	17.30	3.25	0.118	0.010	0.108
11/08/93	6	8M	46	5	19	3.800	0.413	17.30	3.25	0.106	0.070	0.036
11/08/93	6	10M	31	7	31	4.429	1.000	17.40	3.25	0.213	0.010	0.203
11/08/93	7	2M	42	1	2	2.000	0.048	17.30	3.25	0.014	0.040	-0.026
11/08/93	7	4M	58	3	8	2.667	0.138	17.30	3.25	0.040	0.080	-0.040
11/08/93	7	6M	32	3	12	4.000	0.375	17.30	3.25	0.098	0.030	0.068
11/08/93	7	8M	42	4	15	3.750	0.357	17.30	3.25	0.094	0.050	0.044
11/08/93	7	10M	27	2	8	4.000	0.296	17.40	3.25	0.080	0.050	0.030
25/08/93	1	2M	52	10	47	4.700	0.904	17.70	3.15	0.204	0.050	0.154
25/08/93	1	4M	40	3	3	1.000	0.075	17.70	3.15	0.023	-0.010	0.033
25/08/93	1	6M	45	6	27	4.500	0.600	17.60	3.20	0.147	-0.030	0.177
25/08/93	1	8M	58	7	21	3.000	0.362	17.60	3.20	0.097	0.009	0.088
25/08/93	1	10M	44	6	23	3.833	0.523	17.60	3.20	0.131	-0.010	0.141
25/08/93	2	2M	53	9	33	3.667	0.623	17.70	3.15	0.154	0.010	0.144
25/08/93	2	4M	69	11	51	4.636	0.739	17.70	3.15	0.176	0.030	0.146
25/08/93	2	6M	61	11	41	3.727	0.672	17.60	3.20	0.161	0.030	0.131
25/08/93	2	8M	73	9	32	3.556	0.438	17.60	3.20	0.114	0.020	0.094
25/08/93	2	10M	51	5	19	3.800	0.373	17.60	3.20	0.099	-0.005	0.104
25/08/93	3	2M	62	4	15	3.750	0.242	17.70	3.15	0.069	0.010	0.059
25/08/93	3	4M	70	6	22	3.667	0.314	17.60	3.20	0.085	0.010	0.075
25/08/93	3	8M	66	11	42	3.818	0.636	17.60	3.20	0.154	0.040	0.114
25/08/93	3	10M	63	8	35	4.375	0.556	17.60	3.20	0.138	0.040	0.098
25/08/93	5	2M	62	0	0		0.000	17.70	3.15	0.000	0.000	0.000
25/08/93	5	4M	47	6	25	4.167	0.532	17.70	3.15	0.135	-0.002	0.137
25/08/93	5	6M	53	6	29	4.833	0.547	17.60	3.20	0.136	0.005	0.131
25/08/93	5	8M	40	2	7	3.500	0.175	17.60	3.20	0.050	-0.010	0.060

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
25/08/93	5	10M	46	3	12	4.000	0.261	17.60	3.20	0.072	-0.010	0.082
25/08/93	6	2M	56	5	14	2.800	0.250	17.70	3.15	0.070	0.000	0.070
25/08/93	6	4M	80	10	40	4.000	0.500	17.70	3.15	0.129	0.050	0.079
25/08/93	6	6M	57	8	31	3.875	0.544	17.60	3.20	0.136	0.040	0.096
25/08/93	6	8M	47	5	17	3.400	0.362	17.60	3.20	0.096	0.001	0.095
25/08/93	6	10M	30	4	15	3.750	0.500	17.60	3.20	0.127	-0.002	0.129
25/08/93	7	2M	72	8	25	3.125	0.347	17.70	3.15	0.095	0.040	0.055
25/08/93	7	4M	74	18	81	4.500	1.095	17.70	3.15	0.235	0.010	0.225
25/08/93	7	6M	52	11	42	3.818	0.808	17.60	3.20	0.185	0.030	0.155
25/08/93	7	8M	50	8	29	3.625	0.580	17.60	3.20	0.143	0.010	0.133
25/08/93	7	10M	84	20	72	3.600	0.857	17.60	3.20	0.193	0.080	0.113
23/09/93	1	2M	114	9	23	2.556	0.202	14.95	4.00	0.046	0.030	0.016
23/09/93	1	4M	174	4	16	4.000	0.092	14.93	4.00	0.022	0.050	-0.028
23/09/93	1	6M	186	22	42	1.909	0.226	14.91	4.00	0.058	0.050	0.008
23/09/93	1	8M	230	16	30	1.875	0.130	14.89	4.05	0.030	0.050	-0.020
23/09/93	1	10M	92	2	4	2.000	0.043	14.89	4.05	0.110	0.030	0.080
23/09/93	2	2M	332	36	100	2.778	0.301	14.95	4.00	0.066	0.060	0.006
23/09/93	2	4M	428	52	144	2.769	0.336	14.93	4.00	0.073	0.060	0.013
23/09/93	2	6M	198	40	46	1.150	0.232	14.91	4.00	0.052	0.040	0.012
23/09/93	2	8M	130	13	29	2.231	0.223	14.89	4.05	0.050	0.020	0.030
23/09/93	2	10M	192	11	54	4.909	0.281	14.89	4.05	0.061	0.040	0.021
23/09/93	3	2M	248	2	4	2.000	0.016	14.95	4.00	0.004	0.050	-0.046
23/09/93	3	4M	254	42	92	2.190	0.362	14.93	4.00	0.077	0.030	0.047
23/09/93	3	6M	115	10	27	2.700	0.235	14.91	4.00	0.053	0.020	0.033
23/09/93	3	8M	92	13	27	2.077	0.293	14.89	4.05	0.064	0.010	0.054
23/09/93	3	10M	80	2	5	2.500	0.063	14.89	4.05	0.015	0.008	0.007
23/09/93	5	2M	284	40	112	2.800	0.394	14.95	4.00	0.083	0.050	0.033
23/09/93	5	4M	282	44	100	2.273	0.355	14.93	4.00	0.076	0.060	0.016
23/09/93	5	6M	468	84	164	1.952	0.350	14.91	4.00	0.075	0.080	-0.005
23/09/93	5	8M	274	44	84	1.909	0.307	14.89	4.05	0.066	0.070	-0.004
23/09/93	5	10M	236	12	24	2.000	0.102	14.89	4.05	0.024	0.060	-0.036

DATE	SITE	DEPTH	COUNT	GRAVID	NO. EGGS	FECUNDITY	EGG RATIO	T°C	DEVELOPMENT TIME	BIRTH RATE	R	DEATH RATE
23/09/93	6	2M	294	18	34	1.889	0.116	14.95	4.00	0.027	0.060	-0.033
23/09/93	6	4M	264	30	72	2.400	0.273	14.93	4.00	0.060	0.040	0.020
23/09/93	6	6M	272	24	48	2.000	0.176	14.91	4.00	0.041	0.050	-0.009
23/09/93	6	8M	121	8	18	2.250	0.149	14.89	4.05	0.034	0.030	0.004
23/09/93	6	10M	130	7	17	2.429	0.131	14.89	4.05	0.030	0.050	-0.020
23/09/93	7	2M	196	7	30	4.286	0.153	14.95	4.00	0.036	0.040	-0.004
23/09/93	7	4M	180	32	110	3.438	0.611	14.93	4.00	0.119	0.030	0.089
23/09/93	7	6M	140	22	66	3.000	0.471	14.91	4.00	0.097	0.030	0.067
23/09/93	7	8M	122	18	48	2.667	0.393	14.89	4.05	0.082	0.030	0.052
23/09/93	7	10M	74	10	34	3.400	0.459	14.89	4.05	0.093	-0.004	0.097

II (n) Length distribution of *Daphnia longispina* (expressed as percentage of population)
1992-1993

Date	Site	I	II	III	IV	V
28/7/92	Site 1 2m	48.3	36.3	14.3	1.1	
	Site 1 4m	69.6	26.1	4.3		
	Site 1 8m	42.7	49.1	7.6	0.6	
8/9/92	Site 1 2m	63.7	31.8	4.5		
	Site 1 4m	64.8	27	8.1		
	Site 1 8m	64.5	32.2	3.2		
1/10/92	Site 1 2m	57.2	30.2	11.2	1.3	
	Site 1 4m	57.1	25.5	17.3		
	Site 1 8m	80.7	19.2			
21/10/92	Site 1 2m	50	28.6	14.3	7.1	
	Site 1 4m	53.3	33.3	13.3		
	Site 1 8m	49.9	35.7	14.3		
4/11/92	Site 1 2m	54.9	17.1	23.2	4.8	
	Site 1 4m	70.1	19.1	8.5	2.1	
	Site 1 8m	77.5	12.5	10		
10/2/93	Site 1 2m	52	8	24	16	
	Site 1 4m	58.1	15.4	28	15.4	
	Site 1 6m	47.7	23.8	19	9.5	
	Site 1 8m	60.7	17.8	14.3	7.1	
	Site 1 10m	90.9		9.1		
17/2/93	Site 1 2m	100				
	Site 1 4m	91.6		8.3		
	Site 1 6m	88.8	5.5	5.5		
	Site 1 8m	80	15	5		
	Site 1 10m	80		20		
3/3/93	Site 1 2m	48	48	4		
	Site 1 4m	67.8	25	7.1		
	Site 1 6m	64.2	42.8	28.6	7.1	
	Site 1 8m	57.1	42.8	32.1	10.7	
	Site 1 10m	82.3	5.8	5.8		
10/3/93	Site 1 2m	58.3	16.6	25		
	Site 1 4m	58.3	25	16.6		
	Site 1 6m	69.2	30.7			
	Site 1 8m	60	20	20		
	Site 1 10m	85.7		14.3		
1/4/93	Site 1 2m	81.7	9.1	9.1		
	Site 1 4m	60	20	20		
	Site 1 6m	25	25	50		
	Site 1 8m	66.6	16.6	16.6		16.6
	Site 1 10m	77.7	11.1	5.5	5.5	
14/4/93	Site 1 2m	64.3	26.2	9.5		
	Site 1 4m	74.1	17.2	8.6		
	Site 1 6m	64.6	19.6	15.7		
	Site 1 8m	76.6	11.7	7.8	3.9	
	Site 1 10m	93.2	6.6			
27/5/93	Site 1 2m	57.3	31.2	11.6		
	Site 1 4m	83.4	11.7	4.4		
	Site 1 6m	69.6	19.6	10.7		
	Site 1 8m	58.3	29.1	12.5		
	Site 1 10m	46.5	38.8	12.9	0.8	

Date	Site	I	II	III	IV	V
10/6/93	Site 1 2m	73	22.7	4.1		
	Site 1 4m	32.5	43.9	18.3	6.1	
	Site 1 6m	51.8	25.9	18.5	3.7	
	Site 1 8m	43.9	34.1	18.3	3.6	
	Site 1 10m	46.1	48.1	5.7		
29/6/93	Site 1 2m	26.7	56.3	14.9	1.1	
	Site 1 4m	36.5	52	11.4		
	Site 1 6m	41	51.3	7.7		
	Site 1 8m	70	25	5		
	Site 1 10m	42.8	42.8	14.3		
14/7/93	Site 1 2m	54.8	41.2	5.3		
	Site 1 4m	80.4	19.5			
	Site 1 6m	54	38.1	7.9		
	Site 1 8m	79.2	17.2	3.4		
	Site 1 10m	77.1	20	2.8		
29/7/93	Site 1 2m	42.9	42.8	14.3		
	Site 1 4m	81.8	13.6	4.5		
	Site 1 6m	61.5	38.4			
	Site 1 8m	58.3	41.7			
	Site 1 10m	83.3	16.6			
11/8/93	Site 1 2m	57.6	11.5	30.7		
	Site 1 4m	61.2	26.5	8.1	4.1	
	Site 1 6m	44.4	30.5	23.6	1.4	
	Site 1 8m	54.8	19.6	19.6	5.9	
	Site 1 10m	60.8	19.6	15.7	3.9	
25/8/93	Site 1 2m	63.4	15.4	15.4	3.8	1.9
	Site 1 4m	55	25	17.5	2.5	
	Site 1 6m	60	17.8	20	2.2	
	Site 1 8m	63.7	25.8	10.3		
	Site 1 10m	65.9	25	9.1		
23/9/93	Site 1 2m	56.9	32.4	9.6	0.9	
	Site 1 4m	37.9	43.7	16.1	2.3	
	Site 1 6m	47.3	23.6	22.6	5.4	
	Site 1 8m	40	42.6	15.6	1.7	
	Site 1 10m	77.1	16.3	6.5		
28/7/92	Site 2 2m	72.2	21.5	1.2		
	Site 2 4m	75.9	18.5	5.5		
	Site 2 8m	36.3	30.7	27.3	5.7	
5/8/92	Site 2 2m	68.8	21.5	9.7		
	Site 2 4m	72.2	20	6.9	0.8	
	Site 2 8m	79.8	13.1	5.1	2	
11/8/92	Site 2 2m	61.3	34.4	4.3		
	Site 2 4m	68.1	25.8	6		
	Site 2 8m	43.9	50	4.5	1.5	
18/8/92	Site 2 2m	92.8	7.1			
	Site 2 4m	92.1	5.9	1.9		
	Site 2 8m	61.3	29	9.7		
8/9/92	Site 2 2m	68.9	24.1	6.9		
	Site 2 4m	71.7	21.7	6.5		
	Site 2 8m	88.4	11.5			
23/9/92	Site 2 2m	80.8	19.2			
	Site 2 4m	81.7	15.5	2.8		

Date	Site	I	II	III	IV	V
	Site 2 8m	60.8	30.7	8.4		
1/10/92	Site 2 2m	56.1	30.5	13.4		
	Site 2 4m	54.2	31.4	14.3		
	Site 2 8m	64.2	23.4	11.1	1.2	
21/10/92	Site 2 2m	38.1	26.2	35.7		
	Site 2 4m	19.1	39.7	32.3	8.8	
	Site 2 8m	26.1	29.2	36.9	7.7	
4/11/92	Site 2 2m	91.6		8.3		
	Site 2 4m	54.1	25	16.6	4.2	
	Site 2 8m	68	4	20	8	
5/2/93	Site 2 2m	33.3	6.6	60		
	Site 2 4m	43.7	10	30	5	
	Site 2 6m	45.5	27.3	18.2	9.1	
	Site 2 8m	55.5	22.2	11.1	11.1	
	Site 2 10m	80		20		
10/2/93	Site 2 2m	39.1	21.7	30.4	8.7	
	Site 2 4m	55.3	15.8	26.3	2.6	
	Site 2 6m	62.5	8.3	20.8	8.3	
	Site 2 8m	50		50		
	Site 2 10m	76.8		23.1		
17/2/93	Site 2 2m	67.8	14.3	7.1	7.1	3.6
	Site 2 4m	52	8	36	4	
	Site 2 6m	35.7	28.6	21.4	7.1	7.1
	Site 2 8m	54.5	18.2	18.2	9.1	
	Site 2 10m	38.5	23.1	38.4		
3/3/93	Site 2 2m	68.7	12.5	12.5	6.3	
	Site 2 4m	77.1	8.6	14.3		
	Site 2 6m	45.8	33.3	12.5	8.3	
	Site 2 8m	70	20	10		
	Site 2 10m	52.4	14.3	28.6	4.7	
10/3/93	Site 2 2m	31.6	31.6	30	6.6	
	Site 2 4m	46.1	34.6	19.2		
	Site 2 6m	56	28	16		
	Site 2 8m	81.2	18.7			
	Site 2 10m	56.5	30.4	13		
1/4/93	Site 2 2m	44.4	25.9	25.9	3.7	
	Site 2 4m	51.7	31	17.2		
	Site 2 6m	87.4	12.5			
	Site 2 8m	67.7	19.3	12.9		
	Site 2 10m	60.7	25	14.3		
14/4/93	Site 2 2m	84	14.6	1.3		
	Site 2 4m	87	10	3		
	Site 2 6m	88.3	7.7	8.9		
	Site 2 8m	72	18.3	9.7		
	Site 2 10m	70.9	18.2	10.9		
6/5/93	Site 2 2m	78.6	10	10	0.6	0.6
	Site 2 4m	61.9	22.6	15.3		
	Site 2 6m	82.7	7.7	9.6		
	Site 2 8m	77.1	16.6	5.2	1	
	Site 2 10m	88.6	7.5	3.8		
27/5/93	Site 2 2m	63.5	22.4	11.2	2.8	
	Site 2 4m	62.1	17.9	15.8	4.2	

Date	Site	I	II	III	IV	V
	Site 2 6m	61.8	13.7	20.6	3.8	
	Site 2 8m	75.5	16.9	5.6	1.9	
	Site 2 10m	80.3	10.2	7.7	1.7	
10/6/93	Site 2 2m	95.2	3.1	1.6		
	Site 2 4m	70.1	25.8	3.1	0.9	
	Site 2 6m	67.3	23.6	9.1		
	Site 2 8m	70.1	22.5	7.3		
	Site 2 10m	66.7	24.2	6	3	
29/6/93	Site 2 2m	66.2	25.5	8.3		
	Site 2 4m	25.2	47.8	25.8	1.2	
	Site 2 6m	44.8	37.4	17.7		
	Site 2 8m	25.9	24.4	57.4	16.4	0.7
	Site 2 10m	18.8	50	31.4		
14/7/93	Site 2 2m	64.1	30	6.4	0.7	
	Site 2 4m	64.4	28.8	6.7		
	Site 2 6m	73.7	22.9	3.4		
	Site 2 8m	57.7	32.2	8.9		
29/7/93	Site 2 2m	79.3	20.7			
	Site 2 4m	75	20	5		
	Site 2 6m	62.4	16.6	16.6	4.2	
	Site 2 8m	52.6	26.3	21.1		
	Site 2 10m	40.7	44.4	14.8		
11/8/93	Site 2 2m	64.3	30.3	5.4		
	Site 2 4m	81.5	15.8	2.6		
	Site 2 6m	76.6	13.3	6.6	6.6	
	Site 2 8m	69.5	15.2	13	2.2	
	Site 2 10m	77.4	16.1	6.4		
25/8/93	Site 2 2m	60.6	28.6	7.1	3.6	
	Site 2 4m	57.5	33.7	7.5	1.2	
	Site 2 6m	57.9	21.1	21.1	1.7	
	Site 2 8m	61.7	29.8	12.7		
	Site 2 10m	49.9	33.3	16.6		
23/9/93	Site 2 2m	51.3	30.6	13.6	4.1	
	Site 2 4m	42.4	22.7	27.3	7.6	
	Site 2 6m	60.7	22.8	11.7	2.2	2.2
	Site 2 8m	62.5	15.8	13.2	7.5	0.8
	Site 2 10m	61.6	19.2	14.7	2.4	0.8
28/7/92	Site 3 2m	72.9	16.2	10.8		
	Site 3 4m	59.7	35.1	4.5	0.7	
	Site 3 8m	26.3	41.1	30.1	2.4	
8/9/92	Site 3 2m	67.7	23.7	8.5		
	Site 3 4m	71.4	28.6			
	Site 3 8m	75	15	10		
1/10/92	Site 3 2m	64.5	31.6	3.5		
	Site 3 4m	90	7.5	2.5		
	Site 3 8m	78.2	14.3	7.1		
21/10/92	Site 3 2m		100			
	Site 3 4m	50	50			
	Site 3 8m	50	37.5	12.5		
4/11/92	Site 3 2m	87.5	12.5			
	Site 3 4m	73.2	13.3	13.3		
	Site 3 8m	82.3	11.7	1.8		

Date	Site	I	II	III	IV	V
17/2/93	Site 3 2m	80	13.3	6.6		
	Site 3 4m	65	5	5	20	5
	Site 3 6m	76.9			23.1	
	Site 3 8m	76.8	23.1			
	Site 3 10m	71.4	21.4	7.1		
3/3/93	Site 3 2m	53.8	34.6	7.7	3.8	
	Site 3 4m	23.5	29.4	5.9	5.9	
	Site 3 6m	69.2	7.7	23.1		
	Site 3 8m	72	20	4	4	
	Site 3 10m	70.5	11.7	17.6		
10/3/93	Site 3 2m	41.6	45.8	12.5		
	Site 3 4m	45	35	20		
	Site 3 6m	61	16.6	22.2		
	Site 3 8m	33.3	66.6			
	Site 3 10m	53.8	23.1	23.1		
1/4/93	Site 3 2m	69.5	30.4			
	Site 3 4m	66.6	13.3	16.6	3.3	
	Site 3 6m	29.6	44.4	18.5	3.7	3.7
	Site 3 8m	54.5	18.2	27.3		
	Site 3 10m	58.8	23.5	17.6		
14/4/93	Site 3 2m	69.3	24.2	6.4		
	Site 3 4m	94	3	3		
	Site 3 6m	78.8	17.3	3.8		
	Site 3 8m	63.6	25	11.4		
	Site 3 10m	56	26	18		
6/5/93	Site 3 2m	44.6	22.3	29.3	3.8	
	Site 3 4m	70.2	15.9	13.8		
	Site 3 6m	63.6	19.2	15.1	2	
	Site 3 8m	86.2	10.3	3.4		
10/6/93	Site 3 2m	72.9	20.3	6.8		
	Site 3 4m	42.9	41.6	12.9	1.8	
	Site 3 6m	52.5	38.4	6.5		
	Site 3 8m	54.9	41.6	3.3		
	Site 3 10m	76.7	18.6	2.3	2.3	
29/6/93	Site 3 2m	48.6	46	4.4	0.9	
	Site 3 4m	23	50.4	26.5		
	Site 3 6m	30.4	69.5			
	Site 3 8m	64.2	35.7			
	Site 3 10m	55.6	40.5	2.8	0.9	
14/7/93	Site 3 2m	66.4	24.8	8.7		
	Site 3 4m	49.1	41.9	8.9		
	Site 3 6m	59.9	30.6	9.4		
	Site 3 8m	67.1	23.5	9.4		
	Site 3 10m	66.6	30.6	2.6		
29/7/93	Site 3 2m	54.5	40.9	4.5		
	Site 3 4m	49.9	38.4	7.7	3.8	
	Site 3 6m	37.4	43.7	18.7		
	Site 3 8m	38.4	38.4	23.1		
	Site 3 10m	73.6	36.8			
11/8/93	Site 3 2m	61.7	27.4	13.7	3.9	
	Site 3 4m	71.1	18.6	10.1		
	Site 3 6m	50	21.2	21.2	7.6	

Date	Site	I	II	III	IV	V
	Site 3 8m	65.8	21	13.2		
	Site 3 10m	64.8	24.3	10.8		
25/8/93	Site 3 2m	74.6	13.6	10.6		
	Site 3 6m	62.8	25.7	7.1	4.3	
	Site 3 8m	30.4	42.4	27.2		
	Site 3 10m	58.7	29.9	11.1	3.2	
23/9/93	Site 3 2m	86.3	10.5	3.2		
	Site 3 4m	36.8	18.1	37.8	5.5	0.8
	Site 3 6m	58.2	23.5	13.9	4.3	
	Site 3 8m	51	21.7	20.6	6.5	
	Site 3 10m	76.2	27.5	8.7		
28/7/92	Site 4 2m	87.6	10.5	1.9		
	Site 4 4m	68.3	23.9	6.6	1	
	Site 4 8m	39.7	37.8	20.4	1.9	
8/9/92	Site 4 2m	72.9	21.6	5.4		
	Site 4 4m	82.7	10.3	6.9		
	Site 4 8m	83.8	15.2	1		
23/9/92	Site 4 2m	84.7	13.3	1.9		
	Site 4 4m	81.4	11.7	6.2	0.7	
	Site 4 8m	83.8	15.2	1		
1/10/92	Site 4 2m	63.6	19.5	16.1		
	Site 4 4m	73.7	16.4	9.8		
	Site 4 8m	86.4	10.1	3.4		
21/10/92	Site 4 2m	41.6	41.6	12.5	4.1	
	Site 4 4m	49.9	38.9	5.5	5.5	
	Site 4 8m	53.8	15.4	15.4	15.4	
4/11/92	Site 4 2m	68.7	6.2	6.2	18.7	
	Site 4 4m	72	12	8	8	
	Site 4 8m	60	20	20		
10/2/93	Site 4 2m	32	18.6	34.6	12	2.6
	Site 4 4m	20.5	7.7	58.9	12.8	
	Site 4 8m	59	4.5	27.3	9.1	
	Site 4 10m	38.1	19	28.6	14.3	
17/2/93	Site 4 2m	76	4	20		
	Site 4 4m	55.1	20.7	24.1		
	Site 4 8m	53.8		38.5	7.7	
	Site 4 10m	66.6	22.2	11.1		
3/3/93	Site 4 2m	53.5	39.3	3.6	3.6	
	Site 4 4m	74.3	14.3	11.4		
	Site 4 6m	58.6	27.6	6.9	6.9	
	Site 4 8m	69.2	7.7	15.4	7.7	
	Site 4 10m	64.5	29	3.2	3.2	
10/3/93	Site 4 2m	44.4	55.5			
	Site 4 4m	58.6	37.9	3.4		
	Site 4 6m	55.1	37.9	6.9		
	Site 4 8m	62.8	30.2	4.6	2.3	
	Site 4 10m	56	25	5		
1/4/93	Site 4 2m	63.2	12.2	16.3	8.1	
	Site 4 4m	39.8	29.1	12.5		
	Site 4 6m	57.6	19.2	19.2		3.8
	Site 4 8m	65	20	15		
	Site 4 10m	47.8	13	30.4	8.7	

Date	Site	I	II	III	IV	V
14/4/93	Site 4 2m	92	8			
	Site 4 4m	84	9.1	6.8		
	Site 4 6m	61.3	29	9.7		
	Site 4 8m	82.8	12.2	4.9		
	Site 4 10m	81.6	10.5	7.9		
6/5/93	Site 4 2m	96.2	3.7			
	Site 4 4m	80.1	16.5	2.5	0.8	
	Site 4 6m	81.1	14.5	4.3		
	Site 4 8m	94.6	5.3			
	Site 4 10m	77.1	14.1	7	1.7	
27/5/93	Site 4 2m	76.8	20.9	2.2		
	Site 4 4m	63.8	27.7	7.9	0.5	
	Site 4 6m	70.5	36.9	22.9	5.7	0.8
	Site 4 8m	69.5	25.4	4.1		
	Site 4 10m	57.7	30.9	10.3		
10/6/93	Site 4 2m	64.3	48.6	28.6	6.1	0.7
	Site 4 4m	33.3	50.6	14.6	1.3	
	Site 4 6m	44.4	38.9	11.1	5.5	
	Site 4 8m	23.1	46.1	15.3	15.3	
	Site 4 10m	50	37.5	12.5		
29/6/93	Site 4 2m	32.2	44.1	22.8	0.8	
	Site 4 4m	32.3	46.5	17.2	4	
	Site 4 6m	24.9	59.1	11.4	4.5	
	Site 4 8m	35	45	20		
	Site 4 10m	23.1	46.1	30.7		
14/7/93	Site 4 2m	70.2	27.7	1.9		
	Site 4 4m	60.7	34.6	4.7		
	Site 4 6m	74.1	23.3	2.2		
	Site 4 8m	70.3	29.2			
	Site 4 10m	46.9	36.7	12.2		
29/7/93	Site 4 2m	63.3	23.8	11.9		
	Site 4 4m	76.9	15.4	7.7		
	Site 4 6m	36.1	45.7	14.3	2.8	
	Site 4 8m	55.5	11.1	33.3		
	Site 4 10m	21.4	42.8	35.7		
28/7/92	Site 5 2m	59.4	24.3	16.2		
	Site 5 4m	38.6	42.6	16.6	20	
	Site 5 8m	55.7	32.8	8.2	3.3	
8/9/92	Site 5 2m	16.3	27.9	4.6		
	Site 5 4m	41.5	41.5	16.5		
	Site 5 8m	62.1	27.6	10.3		
1/10/92	Site 5 2m	46.4	29.8	21.5	2.1	
	Site 5 8m	79.6	9.4	10.9		
21/10/92	Site 5 2m	34	27.6	25.5	12.7	
	Site 5 4m	35	30	35		
	Site 5 8m	46.6	26.6	26.6		
4/11/92	Site 5 2m	69.2	15.4	15.4		
	Site 5 4m	57.1	21.4	21.4		
	Site 5 8m	50		50		
1/4/93	Site 5 2m	92.3	7.7			
	Site 5 4m	95.5		4.5		
	Site 5 6m	69.7	24.2	6.1		

Date	Site	I	II	III	IV	V
	Site 5 8m	60	30	10		
	Site 5 10m	64.7	17.6	14.7		2.9
14/4/93	Site 5 2m	94.5	5.5			
	Site 5 4m	82.6		11.6	5.8	
	Site 5 6m	71.0	23.2	5.8		
	Site 5 8m	80.7	15.4	2.5	1.3	
	Site 5 10m	86.6	6.6	6.6		
6/5/93	Site 5 2m	98.5	1.2			
	Site 5 4m	58.5	25	15	1.4	
	Site 5 6m	61.2	25.2	12.9	0.7	
	Site 5 8m	76.7	15.5	7.7		
	Site 5 10m	70.1	18.1	11.7		
27/5/93	Site 5 2m	35.5	26.9	31.7	4.8	0.9
	Site 5 4m	54.7	19.2	17.3	9.6	
	Site 5 6m	47.4	25.4	23.7	3.4	
	Site 5 8m	30.2	34.8	21.2	13.6	
	Site 5 10m	49.9	28.9	20		
10/6/93	Site 5 2m	55.2	37	6.6		0.7
	Site 5 4m	58	26	14	2	
	Site 5 6m	53.4	30	16.3		
	Site 5 8m	50.6	38	9.8	1.4	
	Site 5 10m	64.4	24.2	11.3		
29/6/93	Site 5 2m	56.2	33.3	10.4		
	Site 5 4m	18.5	64.6	15.8	0.8	0.8
Site 5 6m	48.3	41.4	10.3			
	Site 5 8m	52.2	39.1	6.9		
	Site 5 10m	35.9	48.7	15.4		
14/7/93	Site 5 2m	40.1	41.6	19.7	0.7	
	Site 5 4m	42	47.5	10.5		
	Site 5 6m	61.8	29.8	7.6	0.7	
	Site 5 8m	63.2	27.8	9		
	Site 5 10m	48.6	40.5	9.4	1.3	
29/7/93	Site 5 2m	60	30	10		
	Site 5 4m	42.5	30	22.5	5	
	Site 5 6m	33.3	50	16.6		
	Site 5 8m	48.6	29.7	21.6		
	Site 5 10m	60	36	4		
11/8/93	Site 5 2m	82.1	10.7	5.3	1.8	
	Site 5 4m	63.6	19.4	16.4		
	Site 5 6m	57.2	14.3	26.5	2	
	Site 5 8m	56	22	22		
	Site 5 10m	59.2	27.2	12.7		
25/8/93	Site 5 2m	71	22.6	6.4		
	Site 5 4m	57.4	21.3	19.1	2.1	
	Site 5 6m	60.4	24.5	13.2	1.9	
	Site 5 8m	65	30	5		
	Site 5 10m	49.9	34.8	15.2		
23/9/93	Site 5 2m	25.3	33.8	28.9	10.5	1.4
	Site 5 4m	32.6	19.1	41.1	7.1	
	Site 5 6m	29	22.2	34.2	11.9	2.5
	Site 5 8m	41.9	23.3	27	6.5	0.7
	Site 5 10m	41.5	33	19.5	1.7	

Date	Site	I	II	III	IV	V
28/7/92	Site 6 2m	60.2	34.4	5.4		
	Site 6 4m	53.3	41.9	4.7		
	Site 6 8m	29.8	57.5	10.3	2.3	
5/8/93	Site 6 2m	58.5	19.7	21.2	0.5	
11/8/93	Site 6 2m	63.3	26.6	7.5	2.5	
	Site 6 4m	37.2	51.5	10.7	0.5	
	Site 6 8m	56.1	32.9	10.9		
18/8/92	Site 6 2m	52.8	31.5	15.7		
	Site 6 4m	37.5	50	12.5		
	Site 6 8m	61.7	29.6	8.6		
8/9/92	Site 6 2m	63.6	29.5	6.8		
	Site 6 4m	72.7	27.3			
	Site 6 8m	55.5	38.9	5.5		
23/9/93	Site 6 2m	84.6	8.7	6.5		
	Site 6 4m	78.5	15.2	6.3		
	Site 6 8m	83.8	34.2	11.9	4.3	
1/10/92	Site 6 2m	43.5	36	18.6	1.8	
	Site 6 4m	52.7	23.6	22.2	1.4	
	Site 6 8m	59.7	29.2	9.7	1.4	
21/10/92	Site 6 2m	64.2	28.6	7.1		
	Site 6 4m	23.4	47.1	29.4		
	Site 6 8m	70	30			
4/11/92	Site 6 2m	64.7	5.9	23.5	5.9	
	Site 6 4m	56.5	19.5	19.5	4.3	
	Site 6 8m	73	11.5	11.5	3.8	
5/2/93	Site 6 2m		33.3	66.6		
	Site 6 4m			100		
	Site 6 6m	9.1	18.2	45.4	27.3	
	Site 6 8m	50	50			
	Site 6 10m		25	75		
10/2/93	Site 6 2m	38.4	12.8	43.6	2.5	2.5
	Site 6 4m	38.5	15.4	38.4	7.7	
	Site 6 6m	34.2	19.5	41.4	4.9	
	Site 6 8m	72.2	16.6	11.1		
	Site 6 10m	63.3	10	20	6.6	
17/2/93	Site 6 2m	70.3	7.4	18.5		3.7
	Site 6 4m	83.2	16.6			
	Site 6 6m	71.4	14.3	14.3		
	Site 6 8m	85.6		14.3		
	Site 6 10m	100				
3/3/93	Site 6 2m	51.8	22.2	18.5	7.4	
	Site 6 4m	50	15.4	23.1	11.5	
	Site 6 6m	83.4	8.3	8.3		
	Site 6 8m	69.2	7.7	50		
	Site 6 10m	64.3	11.5	7.7		
10/3/93	Site 6 2m	56.5	26.1	17.4		
	Site 6 4m	61.5	15.4	15.4	7.7	
	Site 6 6m	55.5	27.8	16.6		
	Site 6 8m	75	25			
	Site 6 10m	42.1	47.3	10.5		
1/4/93	Site 6 2m	42.8	35.7	21.4		
	Site 6 4m	42.9	35.7	21.4		

Date	Site	I	II	III	IV	V
	Site 6 6m	44.4	44.4	11.1		
	Site 6 8m	83.2	16.6			
	Site 6 10m	57.1	42.8			
14/4/93	Site 6 2m	92.2	7.7			
	Site 6 4m	82.9	12.2	4.9		
	Site 6 6m	88.9	8.9	2.2		
	Site 6 8m	91.2	2.9	5.9		
	Site 6 10m	93.7	4.1	2.1		
27/5/93	Site 6 2m	39.8	41.5	17.8	0.8	
	Site 6 4m	64.4	29.6	4.2	1.7	
	Site 6 6m	59.7	29.3	9.3	1.3	
	Site 6 8m	49.1	30.5	19.5	0.8	
	Site 6 10m	49.9	29.4	19.2	1.3	
10/6/93	Site 6 2m	62.6	33.8	3.5		
	Site 6 4m	59.3	30.1	7.1	3.5	
	Site 6 6m	46.7	41.8	10.6	0.8	
	Site 6 8m	53.4	32.5	11.6	2.3	
	Site 6 10m	47.2	41.6	11.1		
29/6/93	Site 6 2m	53.6	42.8	3.6		
	Site 6 4m	35.2	49.3	15.5		
	Site 6 6m	30	50	20		
	Site 6 8m	60	40			
	Site 6 10m	42.4	48.5	9.1		
14/7/93	Site 6 2m	75.9	21.7	2.3		
	Site 6 4m	66.4	28.9	4.7		
	Site 6 6m	60.7	29.6	9.6		
	Site 6 8m	58.6	36	5.3		
	Site 6 10m	76.8	18.3	4.9		
29/7/93	Site 6 2m	59.2	25.9	14.8		
	Site 6 4m	39.9	60			
	Site 6 6m	55	40	5		
	Site 6 8m	62.1	27.6	10.3		
	Site 6 10m	50	31.2	18.7		
11/8/93	Site 6 2m	54.3	26.1	13	6.5	
	Site 6 4m	53.3	24.4	17.8	4.4	
	Site 6 6m	31.7	24.4	31.7	9.7	2.4
	Site 6 8m	51.5	19.6	19.6		
	Site 6 10m	52.7	16.3	30.9		
25/8/93	Site 6 2m	54.7	24.5	20.7		
	Site 6 4m	52.2	30.4	11.6	5.8	
	Site 6 6m	49.2	31.1	19.7		
	Site 6 8m	57.5	28.7	12.3	1.3	
	Site 6 10m	56.8	31.4	1.9	1.9	
23/9/93	Site 6 2m	24.7	23.6	40.8	9.7	1.1
	Site 6 4m	16.7	42.9	35.5	3.7	0.9
	Site 6 6m	46.3	29.3	20.2	3	1
	Site 6 8m	59.2	29.2	10	1.5	
	Site 6 10m	55.2	20.8	20.8	3.1	
28/7/92	Site 7 2m	82	9.3	6	2	0.6
	Site 7 4m	83	16	1		
	Site 7 8m	50.5	25.8	22.4	1.1	
8/9/92	Site 7 2m	75.7	22.7	1.5		

Date	Site	I	II	III	IV	V
	Site 7 4m	86.5	13.4			
	Site 7 8m	68.9	20	11.1		
1/10/92	Site 7 2m	33.1	34.2	29.3	2.7	0.5
	Site 7 4m	62.1	24.8	10	2.1	
	Site 7 8m	70.6	20	6.6	1.3	1.3
21/10/92	Site 7 2m	30.6	37.6	20.8	4.9	
	Site 7 4m	43.3	40	10	6.6	
	Site 7 8m	29.6	40.7	29.6		
4/11/92	Site 7 2m	46.1	21.5	15.4	15.4	1.5
	Site 7 4m	53.6	15.8	18.3	10.9	1.2
	Site 7 8m	41.8	14.5	30.9	10.9	1.8
10/2/93	Site 7 2m	65.2	8.7	21.7	4.3	
	Site 7 4m	65.4		34.6		
	Site 7 6m	39.9	13.3	33.3	13.3	
	Site 7 8m	58.3	8.3	25	8.3	
	Site 7 10m	100				
17/2/93	Site 7 2m	65.2	8.7	21.7	4.3	
	Site 7 4m	52	12	32	4	
	Site 7 6m	57.5	12	27.2		3
	Site 7 8m	65.5	13.8	13.8	6.9	
	Site 7 10m	74.9	12.5	27.2		3
3/3/93	Site 7 2m	60.7	17.8	14.3	7.1	
	Site 7 4m	71.4	19.1	9.5		
	Site 7 6m	62.5	45	25	7.5	5
	Site 7 8m	71.4	21.4	3.6	3.6	
	Site 7 10m	36.3	27.3	36.3		
10/3/93	Site 7 2m	66.6	16.6		16.6	
	Site 7 4m	41.1	41.1	14.3	3.6	
	Site 7 6m	27.5	15	5		
	Site 7 8m	71.4	14.3	14.3		
	Site 7 10m	77.1	22.6			
1/4/93	Site 7 2m	67.5	21.6	10.8		
	Site 7 4m	53.3	15.5	26.6	4.4	
	Site 7 6m	49.9	28.6	16.6	4.7	
	Site 7 8m	44.5	29.6	25.9		
	Site 7 10m	38.9	25.9	35.2		
14/4/93	Site 7 2m	87.9	10	2		
	Site 7 4m	88	7	4	1	
	Site 7 6m	73.2	18.3	8.4		
	Site 7 8m	68.7	23.2	7.1	0.9	
	Site 7 10m	69	21.8	9.2		
6/5/93	Site 7 2m	72.2	14.3	10.9	2.5	
	Site 7 4m	84	8	7.2	0.8	
	Site 7 6m	78.4	8.3	6.2		
	Site 7 8m	68.6	20.6	8.8	1.9	
	Site 7 10m	53.6	14	10.5	1.7	
27/5/93	Site 7 2m	47.8	20.1	18.5	12.6	0.8
	Site 7 4m	55.6	13.9	26.6	3.8	
	Site 7 6m	64.5	18.7	14.9	1.8	
	Site 7 8m	79.9	10.5	7.3	2.1	
	Site 7 10m	78.5	10.7	7.1	3.6	
10/6/93	Site 7 2m	90.6	6.2	2.7	0.4	

Date	Site	I	II	III	IV	V
	Site 7 4m	87.5	8.8	3.5		
	Site 7 6m	82.2	9.8	7.8		
	Site 7 8m	69.7	21.2	9.1		
	Site 7 10m	60.3	22.6	15.1	1.9	
29/6/93	Site 7 2m	53.8	31.2	13.9	1.1	
	Site 7 4m	56.6	28.3	15.1		
	Site 7 6m	37.8	38.6	22.8	0.8	
	Site 7 8m	42.8	34.7	20.4		
	Site 7 10m	53.4	29.5	15.9		
14/7/93	Site 7 2m	40.6	42.1	17.9		
	Site 7 4m	44.3	35.8	18.8	0.9	
	Site 7 6m	54.4	35.3	10.3		
	Site 7 8m	56.5	25	19.4		
	Site 7 10m	50.7	39.1	10.1		
29/7/93	Site 7 2m	65.2	34.8			
	Site 7 4m	21	63.1	15.8		
	Site 7 6m	81	14.3	4.7		
	Site 7 8m	55	30	25		
	Site 7 10m	46.1	38.4	15.4		
11/8/93	Site 7 2m	78.5	21.4			
	Site 7 4m	76.8	13.8	6.9	1.7	
	Site 7 6m	53.1	34.4	9.4	3.1	
	Site 7 8m	63.3	19	16.6		
	Site 7 10m	66.6	29.6	3.7		
25/8/93	Site 7 2m	62.5	25	11.1	1.4	
	Site 7 4m	40.5	16.2	41.9		1.3
	Site 7 6m	32.7	28.8	34.6	3.8	
	Site 7 8m	60	18	16	4	2
	Site 7 10m	48.3	26.3	25	1.3	
23/9/93	Site 7 2m	50.5	21.4	22.4	4.1	1
	Site 7 4m	44.4	6.6	31.1	16.6	1.1
	Site 7 6m	40	12.8	32.8	12.8	1.4
	Site 7 8m	47.5	22.9	24.6	4.9	
	Site 7 10m	40.5	32.4	21.6	5.	

1985

Date	I	II	II	III	IV	V
15/3/85	60	19	18	3		
22/3/85	60	18.1	18.7	3.1		
29/3/85	54.4	15.5	19.4	10.7		
16/4/85	47	20.3	22.4	9.5	0.7	
19/4/85	72.9	20.7	4.7	1.3		
26/4/85	81.1	9.6	5.5	3.8		
3/5/85	68.7	16.3	9.2	5.1	0.4	
10/5/85	57.1	24.3	10.4	7.7	0.5	
17/5/85	44.2	27.5	16.6	6.5	1.4	
23/5/85	54.8	24.4	17.2	3.5		
31/5/85	54.6	25.6	13.8	4.6	1.3	
7/6/85	59.7	11.2	15.3	10.4	3.3	
17/6/85	87	6.7	1.7	4.2	0.4	
21/6/85	77.2	15.5	5	2.2		
28/6/85	85.1	8.5	5.9	0.4		
5/7/85	85.5	34.8	31.5	1.1		
22/7/85	59.3	18.8	11.9	8.8	0.9	
26/7/85	61.7	18.8	5.4	14.1		
9/8/85	77.9	13.9	3.3	2.8	1.9	
23/8/85	62.2	14.3	16.7	4.8	1.9	
6/9/85	53.1	19.5	14.7	11	1.6	
13/9/85	78.9	15.7	3.4	1.7	0.3	
7/10/85	52.8	27.4	14.1	5.3	0.3	
18/10/85	35.5	33.3	12.7		0.5	
8/10/85	48.4	23.6	21.4	5.7	0.9	

1990-1991

Date	I	I	III	IV	V
15/10/90	84	14	2		
22/10/90	80	20			
29/10/90	82	18			
5/11/90	86	12	2		
12/11/90	42	44	14		
19/11/90	74	16	10		
26/11/90	74	22	4		
3/12/90	88	10	2		
17/12/90	42	26	12		
7/1/91	76	18	6		
14/1/91	90	8	2		
21/1/91	100				
28/1/91	96	14	4		
4/2/91	92	6	2		
20/2/91	66	14	20		
25/2/91	58	14	16	2	
4/3/91	36	34	24	4	
11/3/91	48	34	18		
18/3/91	40	44	14	2	
26/3/91	38	24	36	2	
3/4/91	74	16	8	2	
8/4/91	54	18	26	2	
16/4/91	76	12	6	6	
22/4/91	62	12	18	8	
7/5/91	68	22	8	2	
13/5/91	88	8	2	2	
20/5/91	26	26	38	10	
28/5/91	90	4	4	2	
3/6/91	82	8	6	4	
10/6/91	82	10	6	2	
17/6/91	30	46	18	4	2
24/6/91	50	36	10	4	4
1/7/91	70	20	8	2	

II (o) Length of egg-bearing female *Daphnia longispina* 1992-1993

	Site						
Month	1	2	3	4	5	6	7
July	1.39	1.54	1.42	1.45	1.33	1.42	1.41
Aug		1.38				1.36	
Aug		1.27				1.18	
Sept	1.37	1.22	1.23	1.31	1.28	1.14	1.08
Sept		1.33		1.22		1.26	
Oct	1.33	1.47	1.23	1.38	1.45	1.38	1.63
Oct	1.4		1.45	1.68	1.37	1.52	1.55
Nov	1.65	1.59	1.51	1.64		1.44	1.64
Feb	1.56	1.51		1.49		1.48	1.41
Feb	1.3	1.57	1.56	1.55		1.52	1.55
Mar	1.44	1.46	1.47	1.58		1.57	1.53
Mar	1.42	1.5	1.39	1.54		1.43	1.61
Apr	1.47	1.32	1.38	1.51	1.34	1.38	1.36
Apr	1.37	1.35	1.38	1.43	1.4	1.31	1.33
May			1.42	1.38	1.36	1.37	1.38
May	1.53	1.44		1.38	1.53	1.49	1.5
Jun	1.39	1.47	1.44	1.45	1.51	1.36	1.39
Jun	1.34	1.29	1.39	1.41	1.45	1.29	1.43
July	1.42	1.27	1.38	1.32	1.48	1.29	1.39
July	1.25	1.33	1.31	1.3	1.31	1.36	1.19
Aug	1.39	1.38	1.29		1.45	1.27	1.29
Aug	1.36	1.36	1.43		1.41	1.35	1.43
Sept							
Sept	1.47	1.45	1.51		1.51	1.49	1.5

1985		1990-1991	
Date	LT	Date	LT
15/3/85	1.49	15/10/90	1.24
22/3/85	1.47	29/10/90	1.24
29/3/85	1.48	5/11/90	1.44
16/4/85	1.62	12/11/90	1.34
19/4/85	1.62	19/11/90	1.37
10/5/85	1.69	26/11/90	1.3
17/5/85	1.74	3/12/90	1.28
23/5/85	1.78	17/12/90	1.35
31/5/85	1.86	7/1/91	1.34
7/6/85	1.75	4/2/91	1.32
17/6/85	1.72	20/2/91	1.53
21/6/85	1.89	25/2/91	1.53
28/6/85	1.53	4/3/91	1.51
5/7/85	1.45	11/3/91	1.39
22/7/85	1.75	18/3/91	1.48
26/7/85	1.7	26/3/91	1.36
9/8/85	1.75	3/4/91	1.2
23/8/85	1.67	8/4/91	1.5
6/9/85	1.78	16/4/91	1.67
7/10/85	1.65	22/4/91	1.47
18/10/85	1.43	7/5/91	1.47
8/11/85	1.52	20/5/91	1.77
		28/5/91	1.69
		3/6/91	1.71
		17/6/91	1.77
		24/6/91	1.89
		1/7/91	1.57

II (p) Calculated filtering area in Daphnids from sites S12 and N1 in Rutland Water 1992

S12 27/05/1992

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.53	0.138	0.036
0.53	0.138	0.036
0.54	0.139	0.036
0.54	0.139	0.036
0.61	0.148	0.041
0.61	0.148	0.041
0.64	0.144	0.039
0.64	0.144	0.039
0.66	0.144	0.039
0.66	0.141	0.037
0.66	0.144	0.039
0.66	0.141	0.037
0.66	0.142	0.038
0.69	0.142	0.038
0.69	0.142	0.038
0.71	0.169	0.054
0.71	0.162	0.049
0.71	0.152	0.043
0.71	0.169	0.054
0.71	0.162	0.049
0.71	0.152	0.043
0.71	0.152	0.043
0.72	0.155	0.045
0.72	0.15	0.042
0.72	0.155	0.045
0.72	0.15	0.042
0.73	0.141	0.037
0.73	0.141	0.037
0.74	0.152	0.043
0.74	0.152	0.043
0.8	0.162	0.049
0.8	0.162	0.049
0.81	0.165	0.051
0.81	0.161	0.049
0.81	0.165	0.051
0.81	0.161	0.049
0.81	0.171	0.055
0.81	0.17	0.054
0.83	0.174	0.057
0.83	0.174	0.057
0.84	0.168	0.053
0.84	0.164	0.051
0.84	0.168	0.053
0.84	0.164	0.051
0.85	0.17	0.054
0.85	0.17	0.054
0.86	0.17	0.054
0.86	0.17	0.054
0.88	0.166	0.052
0.88	0.166	0.052
0.89	0.161	0.049
0.89	0.161	0.049

N1 27/5/92

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.6	0.13	0.032
0.6	0.13	0.032
0.6	0.121	0.028
0.6	0.131	0.032
0.6	0.13	0.032
0.6	0.132	0.033
0.61	0.13	0.032
0.61	0.135	0.034
0.61	0.123	0.028
0.63	0.13	0.032
0.64	0.12	0.027
0.7	0.137	0.035
0.7	0.13	0.032
0.7	0.122	0.028
0.7	0.131	0.032
0.7	0.14	0.037
0.71	0.141	0.037
0.71	0.14	0.037
0.72	0.131	0.032
0.72	0.134	0.034
0.72	0.133	0.033
0.72	0.132	0.033
0.73	0.159	0.048
0.73	0.131	0.032
0.74	0.136	0.035
0.76	0.142	0.038
0.79	0.144	0.039
0.8	0.13	0.032
0.8	0.141	0.037
0.8	0.151	0.043
0.8	0.14	0.037
0.81	0.142	0.038
0.81	0.141	0.037
0.81	0.15	0.042
0.81	0.141	0.037
0.81	0.14	0.037
0.81	0.151	0.043
0.81	0.132	0.033
0.82	0.149	0.042
0.83	0.135	0.034
0.83	0.141	0.037
0.84	0.141	0.037
0.85	0.131	0.032
0.89	0.1	0.019
0.9	0.15	0.042
0.9	0.15	0.042
0.9	0.163	0.050
0.9	0.154	0.045
0.9	0.16	0.048
0.9	0.16	0.048
0.91	0.161	0.049
0.91	0.154	0.045

S12 27/05/1992

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.9	0.18	0.061
0.9	0.171	0.055
0.9	0.18	0.061
0.9	0.171	0.055
0.9	0.18	0.061
0.91	0.172	0.056
0.91	0.176	0.058
0.91	0.172	0.056
0.91	0.176	0.058
0.91	0.186	0.065
0.91	0.171	0.055
0.91	0.172	0.056
0.91	0.176	0.058
0.91	0.172	0.056
0.91	0.176	0.058
0.91	0.186	0.065
0.91	0.171	0.055
0.93	0.189	0.067
0.93	0.189	0.067
0.94	0.17	0.054
0.94	0.173	0.056
0.94	0.17	0.054
0.94	0.173	0.056
0.96	0.183	0.063
0.96	0.183	0.063
0.97	0.184	0.064
0.97	0.184	0.064
1	0.185	0.064
1	0.19	0.068
1	0.17	0.054
1	0.18	0.061
1	0.194	0.071
1	0.185	0.064
1	0.19	0.068
1	0.17	0.054
1	0.18	0.061
1	0.194	0.071
1	0.192	0.069
1.01	0.19	0.068
1.03	0.21	0.083
1.03	0.21	0.083
1.04	0.2	0.075
1.04	0.2	0.075
1.06	0.194	0.071
1.06	0.194	0.071
1.1	0.191	0.069
1.1	0.2	0.075
1.1	0.21	0.083
1.1	0.21	0.083
1.1	0.216	0.088
1.1	0.191	0.069
1.1	0.2	0.075

N1 27/5/92

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.92	0.15	0.042
0.92	0.15	0.042
0.92	0.14	0.037
0.92	0.151	0.043
0.92	0.15	0.042
0.94	0.14	0.037
0.94	0.15	0.042
0.96	0.154	0.045
0.99	0.151	0.043
1	0.16	0.048
1	0.151	0.043
1	0.15	0.042
1	0.16	0.048
1.01	0.161	0.049
1.01	0.164	0.051
1.01	0.172	0.056
1.01	0.163	0.050
1.01	0.151	0.043
1.01	0.166	0.052
1.02	0.16	0.048
1.02	0.16	0.048
1.02	0.173	0.056
1.02	0.153	0.044
1.02	0.171	0.055
1.04	0.162	0.049
1.04	0.16	0.048
1.04	0.165	0.051
1.04	0.157	0.046
1.05	0.168	0.053
1.06	0.171	0.055
1.08	0.167	0.052
1.1	0.17	0.054
1.1	0.172	0.056
1.1	0.171	0.055
1.1	0.18	0.061
1.11	0.174	0.057
1.11	0.172	0.056
1.11	0.171	0.055
1.11	0.17	0.054
1.11	0.163	0.050
1.11	0.171	0.055
1.11	0.18	0.061
1.11	0.161	0.049
1.12	0.17	0.054
1.12	0.18	0.061
1.12	0.162	0.049
1.13	0.163	0.050
1.13	0.183	0.063
1.13	0.17	0.054
1.14	0.182	0.062
1.14	0.171	0.055
1.17	0.171	0.055

S12 27/05/1992

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
1.1	0.21	0.083
1.1	0.21	0.083
1.1	0.216	0.088
1.1	0.2	0.075
1.11	0.22	0.091
1.11	0.22	0.091
1.12	0.2	0.075
1.12	0.186	0.065
1.12	0.2	0.075
1.12	0.186	0.065
1.12	0.22	0.091
1.12	0.23	0.099
1.17	0.22	0.091
1.17	0.25	0.117
1.2	0.221	0.092
1.2	0.235	0.104
1.2	0.242	0.110
1.2	0.218	0.089
1.21	0.262	0.129
1.21	0.271	0.138
1.21	0.265	0.132
1.21	0.221	0.092
1.21	0.226	0.096
1.21	0.21	0.083
1.21	0.225	0.095
1.21	0.235	0.104
1.22	0.263	0.130
1.22	0.225	0.095
1.23	0.224	0.094
1.23	0.238	0.106
1.24	0.267	0.134
1.24	0.295	0.164
1.24	0.28	0.147
1.24	0.285	0.153
1.24	0.271	0.138
1.24	0.28	0.147
1.26	0.263	0.130
1.26	0.263	0.130
1.31	0.294	0.162
1.31	0.291	0.159
1.31	0.294	0.162
1.31	0.297	0.166
1.31	0.29	0.158
1.31	0.3	0.169
1.32	0.291	0.159
1.32	0.289	0.157
1.33	0.301	0.170
1.33	0.304	0.174
1.34	0.295	0.164
1.34	0.294	0.162
1.34	0.292	0.160
1.34	0.295	0.164

N1 27/5/92

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
1.17	0.178	0.060
1.19	0.161	0.049
1.19	0.144	0.039
1.2	0.196	0.072
1.2	0.184	0.064
1.2	0.173	0.056
1.2	0.172	0.056
1.21	0.171	0.055
1.21	0.177	0.059
1.21	0.185	0.064
1.21	0.18	0.061
1.21	0.184	0.064
1.21	0.183	0.063
1.22	0.18	0.061
1.22	0.19	0.068
1.22	0.194	0.071
1.22	0.191	0.069
1.22	0.181	0.062
1.23	0.183	0.063
1.23	0.19	0.068
1.23	0.188	0.066
1.24	0.189	0.067
1.24	0.184	0.064
1.26	0.186	0.065
1.3	0.19	0.068
1.3	0.193	0.070
1.3	0.19	0.068
1.31	0.191	0.069
1.31	0.199	0.074
1.31	0.203	0.077
1.31	0.181	0.062
1.32	0.18	0.061
1.32	0.191	0.069
1.32	0.193	0.070
1.32	0.201	0.076
1.32	0.192	0.069
1.33	0.184	0.064
1.33	0.201	0.076
1.34	0.19	0.068
1.35	0.187	0.066
1.36	0.23	0.099
1.36	0.19	0.068
1.4	0.192	0.069
1.4	0.202	0.077
1.4	0.21	0.083
1.41	0.2	0.075
1.41	0.203	0.077
1.41	0.193	0.070
1.41	0.2	0.075
1.41	0.2	0.075
1.41	0.191	0.069
1.42	0.21	0.083

S12 27/05/1992

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
1.34	0.294	0.162
1.34	0.292	0.160
1.38	0.304	0.174
1.38	0.291	0.159
1.38	0.304	0.174
1.38	0.291	0.159
1.4	0.303	0.173
1.41	0.314	0.185
1.42	0.303	0.173
1.42	0.317	0.189
1.42	0.303	0.173
1.42	0.317	0.189
1.43	0.305	0.175
1.43	0.305	0.175
1.44	0.31	0.181
1.44	0.31	0.181
1.49	0.318	0.190
1.49	0.318	0.190
1.51	0.312	0.183
1.51	0.312	0.183
1.51	0.291	0.159
1.52	0.322	0.195
1.52	0.312	0.183
1.52	0.322	0.195
1.52	0.312	0.183
1.53	0.322	0.195
1.6	0.336	0.212
1.6	0.336	0.212
1.6	0.322	0.195
1.61	0.321	0.194
1.61	0.321	0.194
1.63	0.322	0.195
1.63	0.322	0.195
1.66	0.326	0.200
1.66	0.326	0.200
1.7	0.342	0.220
1.71	0.34	0.217
1.71	0.34	0.217
1.73	0.343	0.221
1.73	0.343	0.221
1.77	0.346	0.225
1.77	0.346	0.225
1.8	0.351	0.231
1.8	0.351	0.231

N1 27/5/92

Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
1.42	0.212	0.084
1.44	0.213	0.085
1.45	0.2	0.075
1.46	0.194	0.071
1.46	0.191	0.069
1.5	0.23	0.099
1.5	0.243	0.111
1.5	0.231	0.100
1.5	0.232	0.101
1.5	0.22	0.091
1.51	0.243	0.111
1.52	0.21	0.083
1.52	0.213	0.085
1.52	0.221	0.092
1.52	0.241	0.109
1.52	0.222	0.093
1.54	0.242	0.110
1.54	0.222	0.093
1.58	0.2	0.075
1.59	0.22	0.091
1.6	0.222	0.093
1.6	0.22	0.091
1.6	0.23	0.099
1.61	0.232	0.101
1.62	0.232	0.101
1.63	0.23	0.099
1.63	0.222	0.093
1.64	0.223	0.093
1.66	0.21	0.083
1.7	0.23	0.099
1.7	0.236	0.105
1.7	0.241	0.109
1.7	0.23	0.099
1.71	0.221	0.092
1.71	0.24	0.108
1.71	0.24	0.108
1.72	0.231	0.100
1.73	0.232	0.101
1.73	0.241	0.109
1.76	0.241	0.109
1.76	0.223	0.093
1.76	0.22	0.091
1.78	0.244	0.112
1.79	0.232	0.101

II (q) Calculated filtering area in daphnids from sites 1 - 7 in Rutland Water 1992

28/07/92

Site 1			Site 2			Site*n			Site*s			Site 3		
Standard length (mm)	Mean setae length (mm)	Calculate d filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculate d filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculate d filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculate d filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculate d filtering area (mm2)
0.640	0.159	0.048	0.690	0.169	0.054	0.650	0.149	0.042	0.680	0.152	0.043	0.690	0.155	0.045
0.690	0.164	0.051	0.720	0.160	0.048	0.700	0.154	0.045	0.720	0.152	0.043	0.700	0.150	0.042
0.790	0.153	0.044	0.730	0.168	0.053	0.870	0.187	0.066	0.720	0.158	0.047	0.760	0.161	0.049
0.840	0.192	0.069	0.760	0.181	0.062	0.890	0.190	0.068	0.760	0.161	0.049	0.760	0.166	0.052
0.840	0.192	0.069	0.890	0.194	0.071	0.900	0.190	0.068	0.760	0.169	0.054	0.780	0.169	0.054
0.860	0.177	0.059	0.890	0.174	0.057	0.910	0.196	0.072	0.870	0.194	0.071	0.790	0.157	0.046
0.890	0.199	0.074	0.900	0.190	0.068	0.910	0.194	0.071	0.890	0.200	0.075	0.850	0.183	0.063
0.890	0.176	0.058	0.920	0.197	0.073	1.030	0.200	0.075	0.910	0.201	0.076	0.890	0.190	0.068
0.930	0.201	0.076	1.000	0.191	0.069	1.100	0.220	0.091	0.910	0.200	0.075	0.920	0.193	0.070
1.020	0.182	0.062	1.010	0.187	0.066	1.110	0.220	0.091	0.920	0.194	0.071	1.000	0.200	0.075
1.110	0.231	0.100	1.100	0.230	0.099	1.140	0.201	0.076	1.000	0.209	0.082	1.010	0.189	0.067
1.140	0.202	0.077	1.210	0.251	0.118	1.210	0.224	0.094	1.010	0.199	0.074	1.020	0.206	0.080
1.140	0.203	0.077	1.240	0.240	0.108	1.210	0.238	0.106	1.100	0.228	0.098	1.210	0.234	0.103
1.140	0.238	0.106	1.270	0.198	0.074	1.210	0.222	0.093	1.100	0.220	0.091	1.210	0.241	0.109
1.210	0.241	0.109	1.280	0.251	0.118	1.280	0.241	0.109	1.120	0.200	0.075	1.210	0.221	0.092
1.210	0.241	0.109	1.370	0.251	0.118	1.340	0.259	0.126	1.160	0.231	0.100	1.340	0.222	0.093
1.260	0.220	0.091	1.380	0.254	0.121	1.380	0.264	0.131	1.210	0.239	0.107	1.350	0.250	0.117
1.270	0.243	0.111	1.380	0.225	0.095	1.410	0.264	0.131	1.260	0.220	0.091	1.380	0.263	0.130
1.370	0.234	0.103	1.410	0.286	0.154	1.420	0.270	0.137	1.290	0.254	0.121	1.390	0.262	0.129
1.390	0.262	0.129	1.410	0.271	0.138	1.420	0.236	0.105	1.380	0.261	0.128	1.420	0.272	0.139
1.420	0.266	0.133	1.410	0.243	0.111	1.430	0.271	0.138	1.400	0.276	0.143	1.420	0.260	0.127
1.540	0.284	0.152	1.420	0.269	0.136	1.490	0.269	0.136	1.420	0.241	0.109	1.520	0.271	0.138
1.580	0.299	0.168	1.420	0.268	0.135	1.520	0.284	0.152	1.420	0.280	0.147	1.540	0.276	0.143
1.610	0.270	0.137	1.490	0.269	0.136	1.520	0.291	0.159	1.600	0.289	0.157	1.610	0.263	0.130
1.620	0.322	0.195	1.520	0.298	0.167	1.580	0.291	0.159	1.610	0.257	0.124	1.620	0.291	0.159
1.620	0.300	0.169	1.580	0.297	0.166	1.610	0.254	0.121	1.640	0.289	0.157	1.630	0.271	0.138
1.690	0.316	0.188	1.620	0.311	0.182	1.610	0.298	0.167	1.690	0.319	0.191	1.630	0.298	0.167
1.710	0.334	0.210	1.620	0.271	0.138	1.630	0.291	0.159	1.710	0.267	0.134	1.710	0.310	0.181
1.720	0.330	0.205	1.710	0.326	0.200	1.630	0.301	0.170	1.720	0.321	0.194	1.800	0.325	0.198
1.720	0.270	0.137	1.710	0.331	0.206	1.810	0.324	0.197	1.720	0.318	0.190	1.810	0.320	0.192

Site 4			Site 5			Site 6			Site 7		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.580	0.141	0.037	0.680	0.151	0.043	0.620	0.153	0.044	0.640	0.153	0.044
0.690	0.148	0.041	0.700	0.156	0.046	0.690	0.151	0.043	0.770	0.160	0.048
0.720	0.154	0.045	0.710	0.152	0.043	0.800	0.169	0.054	0.820	0.172	0.056
0.780	0.161	0.049	0.720	0.160	0.048	0.850	0.166	0.052	0.860	0.175	0.058
0.870	0.199	0.074	0.820	0.170	0.054	0.860	0.167	0.052	0.910	0.190	0.068
0.870	0.181	0.062	0.850	0.173	0.056	0.920	0.179	0.060	0.910	0.187	0.066
0.900	0.186	0.065	0.900	0.178	0.060	0.920	0.200	0.075	0.920	0.189	0.067
0.910	0.182	0.062	0.910	0.181	0.062	0.980	0.180	0.061	0.930	0.180	0.061
0.920	0.186	0.065	0.940	0.186	0.065	1.020	0.191	0.069	0.970	0.210	0.083
1.000	0.189	0.067	0.990	0.201	0.076	1.040	0.181	0.062	1.000	0.189	0.067
1.000	0.191	0.069	1.000	0.192	0.069	1.050	0.189	0.067	1.090	0.228	0.098
1.110	0.196	0.072	1.010	0.187	0.066	1.070	0.184	0.064	1.110	0.191	0.069
1.210	0.221	0.092	1.170	0.210	0.083	1.130	0.222	0.093	1.110	0.200	0.075
1.210	0.241	0.109	1.210	0.240	0.108	1.190	0.209	0.082	1.140	0.201	0.076
1.260	0.224	0.094	1.290	0.223	0.093	1.210	0.219	0.090	1.140	0.238	0.106
1.270	0.198	0.074	1.290	0.220	0.091	1.260	0.220	0.091	1.210	0.221	0.092
1.310	0.235	0.104	1.370	0.221	0.092	1.280	0.210	0.083	1.240	0.241	0.109
1.310	0.232	0.101	1.370	0.235	0.104	1.320	0.224	0.094	1.260	0.220	0.091
1.340	0.237	0.106	1.390	0.265	0.132	1.340	0.221	0.092	1.270	0.198	0.074
1.370	0.261	0.128	1.410	0.266	0.133	1.370	0.231	0.100	1.290	0.224	0.094
1.380	0.234	0.103	1.420	0.239	0.107	1.380	0.227	0.097	1.310	0.235	0.104
1.410	0.245	0.113	1.430	0.246	0.114	1.380	0.226	0.096	1.320	0.256	0.123
1.410	0.239	0.107	1.480	0.241	0.109	1.410	0.271	0.138	1.320	0.221	0.092
1.420	0.245	0.113	1.480	0.243	0.111	1.410	0.236	0.105	1.360	0.230	0.099
1.430	0.246	0.114	1.490	0.248	0.116	1.460	0.245	0.113	1.380	0.225	0.095
1.610	0.263	0.130	1.620	0.263	0.130	1.460	0.268	0.135	1.420	0.243	0.111
1.620	0.261	0.128	1.620	0.301	0.170	1.490	0.291	0.159	1.450	0.240	0.108
1.620	0.234	0.103	1.630	0.251	0.118	1.520	0.295	0.164	1.690	0.321	0.194
1.620	0.301	0.170	1.640	0.270	0.137	1.620	0.257	0.124	1.720	0.275	0.142
1.810	0.280	0.147	1.810	0.284	0.152	1.720	0.268	0.135	1.810	0.281	0.148

08/09/92

Site 1			Site 2			Site*n			Site*s			Site 3		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.640	0.153	0.044	0.680	0.166	0.052	0.640	0.155	0.045	0.690	0.146	0.040	0.690	0.172	0.056
0.730	0.171	0.055	0.710	0.152	0.043	0.690	0.199	0.074	0.710	0.139	0.036	0.740	0.172	0.056
0.810	0.199	0.074	0.760	0.161	0.049	0.730	0.189	0.067	0.760	0.171	0.055	0.780	0.172	0.056
0.910	0.200	0.075	0.890	0.193	0.070	0.740	0.156	0.046	0.840	0.192	0.069	0.870	0.134	0.034
0.990	0.196	0.072	1.000	0.196	0.072	0.890	0.192	0.069	0.920	0.200	0.075	0.910	0.196	0.072
1.000	0.210	0.083	1.110	0.221	0.092	0.910	0.201	0.076	0.930	0.201	0.076	0.920	0.196	0.072
1.080	0.220	0.091	1.110	0.224	0.094	0.990	0.199	0.074	0.970	0.200	0.075	0.990	0.198	0.074
1.110	0.223	0.093	1.140	0.233	0.102	1.000	0.200	0.075	1.000	0.189	0.067	1.000	0.216	0.088
1.110	0.226	0.096	1.210	0.256	0.123	1.000	0.203	0.077	1.000	0.200	0.075	1.030	0.201	0.076
1.110	0.227	0.097	1.210	0.241	0.109	1.110	0.226	0.096	1.110	0.231	0.100	1.110	0.224	0.094
1.160	0.234	0.103	1.260	0.250	0.117	1.210	0.251	0.118	1.160	0.233	0.102	1.160	0.238	0.106
1.210	0.255	0.122	1.260	0.257	0.124	1.210	0.247	0.115	1.210	0.246	0.114	1.210	0.253	0.120
1.210	0.261	0.128	1.290	0.263	0.130	1.270	0.243	0.111	1.210	0.257	0.124	1.270	0.246	0.114
1.210	0.255	0.122	1.310	0.259	0.126	1.280	0.246	0.114	1.210	0.241	0.109	1.280	0.251	0.118
1.370	0.281	0.148	1.310	0.261	0.128	1.360	0.253	0.120	1.350	0.266	0.133	1.320	0.272	0.139
1.380	0.264	0.131	1.370	0.261	0.128	1.360	0.271	0.138	1.380	0.274	0.141	1.370	0.257	0.124
1.410	0.280	0.147	1.380	0.259	0.126	1.390	0.277	0.144	1.390	0.270	0.137	1.380	0.277	0.144
1.420	0.281	0.148	1.380	0.269	0.136	1.390	0.277	0.144	1.410	0.287	0.155	1.390	0.257	0.124
1.420	0.286	0.154	1.410	0.270	0.137	1.420	0.241	0.109	1.430	0.276	0.143	1.390	0.261	0.128
1.470	0.284	0.152	1.420	0.271	0.138	1.420	0.281	0.148	1.430	0.288	0.156	1.390	0.264	0.131
1.490	0.271	0.138	1.420	0.271	0.138	1.430	0.247	0.115	1.470	0.279	0.146	1.410	0.271	0.138
1.490	0.286	0.154	1.430	0.276	0.143	1.460	0.287	0.155	1.480	0.277	0.144	1.410	0.291	0.159
1.520	0.293	0.161	1.460	0.278	0.145	1.540	0.288	0.156	1.540	0.292	0.160	1.410	0.277	0.144
1.580	0.299	0.168	1.470	0.271	0.138	1.620	0.309	0.179	1.540	0.299	0.168	1.420	0.238	0.106
1.610	0.310	0.181	1.540	0.291	0.159	1.690	0.314	0.185	1.560	0.288	0.156	1.460	0.284	0.152
1.650	0.301	0.170	1.560	0.291	0.159	1.710	0.326	0.200	1.610	0.300	0.169	1.520	0.284	0.152
1.660	0.314	0.185	1.680	0.300	0.169	1.720	0.250	0.117	1.620	0.266	0.133	1.610	0.314	0.185
1.710	0.332	0.207	1.690	0.321	0.194	1.760	0.329	0.203	1.620	0.294	0.162	1.620	0.314	0.185
1.720	0.330	0.205	1.710	0.331	0.206	1.770	0.331	0.206	1.650	0.314	0.185	1.690	0.314	0.185
1.800	0.330	0.205	1.710	0.326	0.200	1.840	0.325	0.198	1.710	0.314	0.185	1.710	0.319	0.191

Site 4			Site 5			Site 6			Site 7		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.690	0.145	0.040	0.680	0.145	0.040	0.690	0.154	0.045	0.640	0.149	0.042
0.760	0.152	0.043	0.690	0.151	0.043	0.720	0.158	0.047	0.760	0.161	0.049
0.840	0.176	0.058	0.720	0.164	0.051	0.810	0.173	0.056	0.790	0.161	0.049
0.910	0.200	0.075	0.730	0.160	0.048	0.910	0.191	0.069	0.790	0.170	0.054
1.010	0.200	0.075	0.840	0.176	0.058	0.970	0.194	0.071	0.810	0.173	0.056
1.020	0.191	0.069	0.920	0.183	0.063	1.040	0.196	0.072	0.920	0.176	0.058
1.030	0.187	0.066	0.960	0.184	0.064	1.090	0.204	0.078	1.010	0.192	0.069
1.110	0.206	0.080	1.020	0.180	0.061	1.110	0.200	0.075	1.060	0.190	0.068
1.110	0.209	0.082	1.110	0.207	0.081	1.210	0.223	0.093	1.080	0.191	0.069
1.110	0.200	0.075	1.130	0.204	0.078	1.280	0.236	0.105	1.100	0.204	0.078
1.210	0.226	0.096	1.140	0.209	0.082	1.290	0.220	0.091	1.210	0.223	0.093
1.210	0.225	0.095	1.140	0.211	0.084	1.330	0.224	0.094	1.230	0.220	0.091
1.210	0.214	0.086	1.140	0.211	0.084	1.360	0.224	0.094	1.290	0.197	0.073
1.270	0.226	0.096	1.190	0.222	0.093	1.380	0.242	0.110	1.320	0.221	0.092
1.280	0.210	0.083	1.210	0.224	0.094	1.380	0.224	0.094	1.380	0.229	0.099
1.370	0.231	0.100	1.210	0.226	0.096	1.390	0.225	0.095	1.390	0.228	0.098
1.380	0.221	0.092	1.210	0.221	0.092	1.410	0.246	0.114	1.410	0.241	0.109
1.380	0.224	0.094	1.260	0.220	0.091	1.410	0.240	0.108	1.410	0.238	0.106
1.380	0.224	0.094	1.360	0.226	0.096	1.410	0.240	0.108	1.420	0.240	0.108
1.390	0.223	0.093	1.360	0.225	0.095	1.410	0.242	0.110	1.490	0.248	0.116
1.410	0.251	0.118	1.380	0.221	0.092	1.460	0.240	0.108	1.500	0.246	0.114
1.410	0.243	0.111	1.400	0.244	0.112	1.480	0.251	0.118	1.580	0.271	0.138
1.490	0.246	0.114	1.420	0.244	0.112	1.520	0.251	0.118	1.610	0.270	0.137
1.490	0.241	0.109	1.480	0.247	0.115	1.580	0.250	0.117	1.610	0.266	0.133
1.560	0.251	0.118	1.480	0.243	0.111	1.610	0.271	0.138	1.620	0.279	0.146
1.590	0.253	0.120	1.520	0.257	0.124	1.620	0.286	0.154	1.620	0.284	0.152
1.610	0.287	0.155	1.530	0.261	0.128	1.620	0.276	0.143	1.680	0.254	0.121
1.620	0.270	0.137	1.540	0.251	0.118	1.620	0.246	0.114	1.710	0.289	0.157
1.620	0.251	0.118	1.710	0.281	0.148	1.710	0.274	0.141	1.710	0.277	0.144
1.670	0.248	0.116	1.710	0.279	0.146	1.810	0.290	0.158	1.710	0.279	0.146

II (r) Calculated filtering area in daphnids from 30 sites in Rutland Water 1993

july site1			site2			site3			site4			site5		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.64	0.135	0.034	0.62	0.130	0.032	0.64	0.138	0.036	0.69	0.138	0.036	0.62	0.137	0.035
0.76	0.139	0.036	0.71	0.141	0.037	0.64	0.130	0.032	0.71	0.143	0.038	0.79	0.139	0.036
0.76	0.138	0.036	0.79	0.136	0.035	0.81	0.152	0.043	0.76	0.132	0.033	0.84	0.149	0.042
0.81	0.152	0.043	0.81	0.141	0.037	0.85	0.144	0.039	0.84	0.153	0.044	0.89	0.158	0.047
0.84	0.152	0.043	0.85	0.143	0.038	0.87	0.153	0.044	0.89	0.155	0.045	0.91	0.164	0.051
0.90	0.163	0.050	1.00	0.162	0.049	0.91	0.161	0.049	0.92	0.162	0.049	0.96	0.168	0.053
0.91	0.166	0.052	1.09	0.180	0.061	0.94	0.170	0.054	1.00	0.146	0.040	1.01	0.147	0.041
0.92	0.166	0.052	1.11	0.172	0.056	1.00	0.162	0.049	1.01	0.141	0.037	1.06	0.152	0.043
0.92	0.205	0.079	1.17	0.178	0.060	1.01	0.164	0.051	1.11	0.171	0.055	1.07	0.153	0.044
1.04	0.201	0.076	1.21	0.182	0.062	1.09	0.171	0.055	1.13	0.171	0.055	1.09	0.149	0.042
1.09	0.167	0.052	1.22	0.187	0.066	1.13	0.171	0.055	1.13	0.172	0.056	1.10	0.169	0.054
1.09	0.185	0.064	1.23	0.182	0.062	1.18	0.169	0.054	1.18	0.177	0.059	1.14	0.166	0.052
1.11	0.208	0.081	1.28	0.200	0.075	1.23	0.169	0.054	1.20	0.170	0.054	1.17	0.164	0.051
1.12	0.173	0.056	1.29	0.179	0.060	1.26	0.173	0.056	1.24	0.179	0.060	1.18	0.165	0.051
1.14	0.162	0.049	1.31	0.230	0.099	1.32	0.200	0.075	1.29	0.175	0.058	1.21	0.183	0.063
1.18	0.170	0.054	1.34	0.204	0.078	1.34	0.209	0.082	1.32	0.194	0.071	1.25	0.187	0.066
1.23	0.170	0.054	1.36	0.200	0.075	1.37	0.208	0.081	1.38	0.207	0.081	1.26	0.184	0.064
1.26	0.176	0.058	1.39	0.182	0.062	1.42	0.199	0.074	1.41	0.200	0.075	1.31	0.191	0.069
1.31	0.199	0.074	1.39	0.208	0.081	1.46	0.209	0.082	1.45	0.211	0.084	1.34	0.202	0.077
1.32	0.191	0.069	1.40	0.189	0.067	1.47	0.211	0.084	1.48	0.209	0.082	1.37	0.207	0.081
1.39	0.201	0.076	1.42	0.209	0.082	1.49	0.200	0.075	1.52	0.221	0.092	1.42	0.209	0.082
1.43	0.182	0.062	1.46	0.210	0.083	1.52	0.220	0.091	1.53	0.220	0.091	1.47	0.213	0.085
1.43	0.200	0.075	1.47	0.211	0.084	1.53	0.219	0.090	1.58	0.222	0.093	1.47	0.216	0.088
1.46	0.224	0.094	1.53	0.221	0.092	1.57	0.224	0.094	1.61	0.224	0.094	1.49	0.218	0.089
1.49	0.231	0.100	1.58	0.227	0.097	1.66	0.231	0.100	1.65	0.229	0.099	1.51	0.226	0.096
1.54	0.236	0.105	1.62	0.231	0.100	1.67	0.233	0.102	1.72	0.231	0.100	1.53	0.223	0.093
1.62	0.220	0.091	1.67	0.236	0.105	1.69	0.231	0.100	1.73	0.234	0.103	1.53	0.229	0.099
1.63	0.230	0.099	1.71	0.239	0.107	1.72	0.234	0.103	1.78	0.238	0.106	1.54	0.231	0.100
1.71	0.233	0.102	1.73	0.236	0.105	1.73	0.238	0.106	1.80	0.241	0.109	1.62	0.236	0.105
1.79	0.239	0.107	1.81	0.241	0.109	1.77	0.241	0.109	1.82	0.245	0.113	1.78	0.242	0.110

site6			site7			site8			site9			site10		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.61	0.134	0.034	0.65	0.135	0.034	0.61	0.131	0.032	0.69	0.134	0.034	0.61	0.134	0.034
0.72	0.135	0.034	0.72	0.139	0.036	0.72	0.135	0.034	0.73	0.136	0.035	0.68	0.139	0.036
0.81	0.152	0.043	0.78	0.139	0.036	0.79	0.137	0.035	0.78	0.139	0.036	0.71	0.143	0.038
0.84	0.153	0.044	0.81	0.143	0.038	0.81	0.141	0.037	0.79	0.143	0.038	0.76	0.150	0.042
0.92	0.164	0.051	0.89	0.141	0.037	0.84	0.153	0.044	0.82	0.156	0.046	0.84	0.144	0.039
0.92	0.161	0.049	0.92	0.148	0.041	0.86	0.153	0.044	0.86	0.159	0.048	0.87	0.147	0.041
0.96	0.164	0.051	0.92	0.134	0.034	0.99	0.157	0.046	0.89	0.158	0.047	0.89	0.148	0.041
0.96	0.168	0.053	0.94	0.151	0.043	1.02	0.149	0.042	0.91	0.162	0.049	0.89	0.146	0.040
0.97	0.171	0.055	1.00	0.163	0.050	1.04	0.153	0.044	0.93	0.159	0.048	0.89	0.153	0.044
1.00	0.163	0.050	1.00	0.166	0.052	1.12	0.161	0.049	0.97	0.166	0.052	0.93	0.152	0.043
1.00	0.162	0.049	1.11	0.174	0.057	1.16	0.163	0.050	1.00	0.160	0.048	0.96	0.153	0.044
1.06	0.168	0.053	1.11	0.173	0.056	1.19	0.163	0.050	1.04	0.163	0.050	0.99	0.156	0.046
1.08	0.165	0.051	1.12	0.173	0.056	1.26	0.164	0.051	1.05	0.166	0.052	1.00	0.166	0.052
1.11	0.172	0.056	1.14	0.172	0.056	1.29	0.169	0.054	1.13	0.168	0.053	1.00	0.141	0.037
1.16	0.162	0.049	1.21	0.181	0.062	1.34	0.172	0.056	1.16	0.168	0.053	1.00	0.143	0.038
1.17	0.168	0.053	1.29	0.174	0.057	1.36	0.174	0.057	1.26	0.171	0.055	1.11	0.148	0.041
1.24	0.172	0.056	1.32	0.177	0.059	1.38	0.174	0.057	1.28	0.179	0.060	1.21	0.183	0.063
1.26	0.174	0.057	1.35	0.203	0.077	1.42	0.183	0.063	1.32	0.184	0.064	1.26	0.181	0.062
1.31	0.179	0.060	1.35	0.209	0.082	1.43	0.189	0.067	1.38	0.188	0.066	1.31	0.200	0.075
1.34	0.181	0.062	1.41	0.189	0.067	1.49	0.191	0.069	1.43	0.191	0.069	1.39	0.203	0.077
1.42	0.204	0.078	1.41	0.212	0.084	1.54	0.204	0.078	1.49	0.212	0.084	1.40	0.200	0.075
1.42	0.200	0.075	1.43	0.213	0.085	1.57	0.206	0.080	1.56	0.221	0.092	1.41	0.204	0.078
1.45	0.204	0.078	1.52	0.216	0.088	1.62	0.217	0.088	1.59	0.231	0.100	1.43	0.204	0.078
1.48	0.209	0.082	1.55	0.219	0.090	1.65	0.213	0.085	1.62	0.231	0.100	1.52	0.229	0.099
1.48	0.201	0.076	1.59	0.221	0.092	1.68	0.218	0.089	1.64	0.237	0.106	1.54	0.226	0.096
1.54	0.237	0.106	1.62	0.229	0.099	1.71	0.229	0.099	1.69	0.234	0.103	1.62	0.233	0.102
1.62	0.237	0.106	1.68	0.236	0.105	1.73	0.223	0.093	1.71	0.241	0.109	1.65	0.236	0.105
1.69	0.239	0.107	1.71	0.237	0.106	1.76	0.228	0.098	1.72	0.239	0.107	1.66	0.233	0.102
1.72	0.241	0.109	1.73	0.231	0.100	1.81	0.241	0.109	1.72	0.235	0.104	1.72	0.238	0.106
1.78	0.241	0.109	1.78	0.235	0.104	1.84	0.239	0.107	1.78	0.243	0.111	1.78	0.245	0.113

site11			site12			site13			site14			site15		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.62	0.130	0.032	0.61	0.134	0.034	0.64	0.135	0.034	0.67	0.138	0.036	0.61	0.135	0.034
0.69	0.138	0.036	0.73	0.139	0.036	0.67	0.139	0.036	0.71	0.141	0.037	0.79	0.141	0.037
0.71	0.141	0.037	0.73	0.138	0.036	0.71	0.138	0.036	0.72	0.143	0.038	0.81	0.143	0.038
0.74	0.144	0.039	0.81	0.141	0.037	0.78	0.141	0.037	0.74	0.148	0.041	0.82	0.137	0.035
0.89	0.148	0.041	0.84	0.153	0.044	0.79	0.139	0.036	0.79	0.152	0.043	0.86	0.139	0.036
0.92	0.159	0.048	0.87	0.159	0.048	0.84	0.143	0.038	0.84	0.161	0.049	0.87	0.141	0.037
0.96	0.153	0.044	0.89	0.153	0.044	0.91	0.152	0.043	0.89	0.149	0.042	0.92	0.151	0.043
0.97	0.149	0.042	0.92	0.153	0.044	0.95	0.153	0.044	0.89	0.163	0.050	0.99	0.148	0.041
1.03	0.132	0.033	0.98	0.159	0.048	0.98	0.153	0.044	0.91	0.167	0.052	1.00	0.153	0.044
1.03	0.136	0.035	1.00	0.161	0.049	1.01	0.162	0.049	0.99	0.168	0.053	1.04	0.153	0.044
1.09	0.139	0.036	1.02	0.164	0.051	1.04	0.163	0.050	1.00	0.164	0.051	1.09	0.158	0.047
1.11	0.144	0.039	1.07	0.147	0.041	1.13	0.164	0.051	1.04	0.179	0.060	1.11	0.159	0.048
1.14	0.147	0.041	1.10	0.153	0.044	1.15	0.166	0.052	1.06	0.168	0.053	1.14	0.163	0.050
1.17	0.149	0.042	1.14	0.154	0.045	1.24	0.163	0.050	1.12	0.161	0.049	1.19	0.168	0.053
1.26	0.172	0.056	1.16	0.170	0.054	1.26	0.162	0.049	1.14	0.169	0.054	1.21	0.155	0.045
1.29	0.168	0.053	1.21	0.174	0.057	1.31	0.171	0.055	1.14	0.161	0.049	1.28	0.172	0.056
1.36	0.208	0.081	1.23	0.172	0.056	1.35	0.172	0.056	1.19	0.161	0.049	1.29	0.161	0.049
1.38	0.201	0.076	1.31	0.191	0.069	1.39	0.179	0.060	1.23	0.163	0.050	1.32	0.174	0.057
1.41	0.183	0.063	1.34	0.198	0.074	1.41	0.183	0.063	1.24	0.168	0.053	1.35	0.177	0.059
1.43	0.183	0.063	1.37	0.204	0.078	1.43	0.189	0.067	1.31	0.172	0.056	1.37	0.176	0.058
1.45	0.187	0.066	1.42	0.183	0.063	1.46	0.181	0.062	1.37	0.179	0.060	1.39	0.181	0.062
1.52	0.223	0.093	1.49	0.189	0.067	1.51	0.193	0.070	1.38	0.191	0.069	1.47	0.180	0.061
1.53	0.228	0.098	1.52	0.225	0.095	1.53	0.197	0.073	1.41	0.196	0.072	1.48	0.216	0.088
1.56	0.219	0.090	1.54	0.208	0.081	1.56	0.200	0.075	1.42	0.181	0.062	1.52	0.226	0.096
1.61	0.233	0.102	1.57	0.228	0.098	1.62	0.209	0.082	1.49	0.199	0.074	1.53	0.228	0.098
1.63	0.228	0.098	1.59	0.228	0.098	1.67	0.201	0.076	1.52	0.204	0.078	1.54	0.221	0.092
1.64	0.229	0.099	1.61	0.231	0.100	1.71	0.214	0.086	1.53	0.201	0.076	1.63	0.208	0.081
1.70	0.232	0.101	1.62	0.239	0.107	1.73	0.213	0.085	1.56	0.201	0.076	1.68	0.231	0.100
1.71	0.238	0.106	1.68	0.233	0.102	1.80	0.241	0.109	1.64	0.203	0.077	1.68	0.201	0.076
1.72	0.242	0.110	1.71	0.231	0.100	1.81	0.244	0.112	1.68	0.204	0.078	1.72	0.233	0.102

site16			site17			site18			site19			site20		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.62	0.135	0.034	0.69	0.143	0.038	0.66	0.151	0.043	0.62	0.148	0.041	0.61	0.153	0.044
0.68	0.138	0.036	0.71	0.147	0.041	0.66	0.153	0.044	0.68	0.141	0.037	0.68	0.162	0.049
0.71	0.146	0.040	0.78	0.148	0.041	0.69	0.153	0.044	0.71	0.153	0.044	0.72	0.178	0.060
0.73	0.147	0.041	0.81	0.167	0.052	0.71	0.153	0.044	0.74	0.157	0.046	0.78	0.181	0.062
0.78	0.142	0.038	0.84	0.163	0.050	0.76	0.152	0.043	0.78	0.173	0.056	0.79	0.176	0.058
0.81	0.141	0.037	0.89	0.164	0.051	0.81	0.161	0.049	0.79	0.161	0.049	0.81	0.184	0.064
0.84	0.148	0.041	0.89	0.169	0.054	0.84	0.167	0.052	0.81	0.181	0.062	0.89	0.187	0.066
0.91	0.159	0.048	0.93	0.178	0.060	0.86	0.169	0.054	0.88	0.189	0.067	0.94	0.193	0.070
0.96	0.163	0.050	0.98	0.181	0.062	0.89	0.166	0.052	0.89	0.183	0.063	1.02	0.207	0.081
0.99	0.160	0.048	0.98	0.183	0.063	0.92	0.201	0.076	0.92	0.183	0.063	1.06	0.203	0.077
1.00	0.161	0.049	1.02	0.198	0.074	0.96	0.209	0.082	1.06	0.193	0.070	1.10	0.200	0.075
1.00	0.163	0.050	1.05	0.201	0.076	1.02	0.214	0.086	1.09	0.199	0.074	1.17	0.219	0.090
1.04	0.169	0.054	1.06	0.193	0.070	1.09	0.216	0.088	1.10	0.203	0.077	1.19	0.220	0.091
1.06	0.158	0.047	1.08	0.199	0.074	1.11	0.219	0.090	1.14	0.204	0.078	1.21	0.221	0.092
1.11	0.172	0.056	1.11	0.203	0.077	1.14	0.221	0.092	1.23	0.214	0.086	1.24	0.219	0.090
1.11	0.171	0.055	1.19	0.215	0.087	1.25	0.219	0.090	1.27	0.223	0.093	1.29	0.236	0.105
1.14	0.173	0.056	1.23	0.226	0.096	1.27	0.228	0.098	1.34	0.242	0.110	1.31	0.238	0.106
1.23	0.173	0.056	1.26	0.231	0.100	1.29	0.223	0.093	1.36	0.237	0.106	1.33	0.236	0.105
1.29	0.175	0.058	1.31	0.236	0.105	1.37	0.226	0.096	1.37	0.234	0.103	1.38	0.233	0.102
1.32	0.200	0.075	1.38	0.243	0.111	1.38	0.228	0.098	1.42	0.239	0.107	1.42	0.254	0.121
1.36	0.200	0.075	1.42	0.248	0.116	1.39	0.229	0.099	1.46	0.243	0.111	1.46	0.246	0.114
1.41	0.219	0.090	1.47	0.248	0.116	1.41	0.238	0.106	1.49	0.246	0.114	1.49	0.248	0.116
1.49	0.214	0.086	1.54	0.248	0.116	1.46	0.243	0.111	1.52	0.246	0.114	1.52	0.258	0.125
1.54	0.220	0.091	1.59	0.251	0.118	1.52	0.246	0.114	1.53	0.248	0.116	1.54	0.253	0.120
1.56	0.224	0.094	1.62	0.268	0.135	1.54	0.258	0.125	1.58	0.266	0.133	1.55	0.256	0.123
1.62	0.228	0.098	1.62	0.275	0.142	1.56	0.266	0.133	1.61	0.268	0.135	1.56	0.254	0.121
1.66	0.231	0.100	1.66	0.262	0.129	1.62	0.276	0.143	1.66	0.273	0.140	1.61	0.273	0.140
1.71	0.232	0.101	1.68	0.272	0.139	1.66	0.278	0.145	1.69	0.274	0.141	1.62	0.267	0.134
1.73	0.229	0.099	1.69	0.273	0.140	1.71	0.274	0.141	1.70	0.278	0.145	1.68	0.266	0.133
1.78	0.224	0.094	1.71	0.274	0.141	1.72	0.273	0.140	1.71	0.278	0.145	1.71	0.276	0.143

site21			site22			site23			site24			site25		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.61	0.150	0.042	0.76	0.151	0.043	0.65	0.150	0.042	0.66	0.147	0.041	0.69	0.142	0.038
0.66	0.152	0.043	0.81	0.189	0.067	0.72	0.160	0.048	0.69	0.148	0.041	0.70	0.148	0.041
0.67	0.153	0.044	0.84	0.191	0.069	0.81	0.170	0.054	0.71	0.154	0.045	0.71	0.150	0.042
0.72	0.161	0.049	0.89	0.179	0.060	0.89	0.181	0.062	0.76	0.159	0.048	0.81	0.183	0.063
0.78	0.166	0.052	0.91	0.184	0.064	0.92	0.191	0.069	0.80	0.181	0.062	0.85	0.185	0.064
0.84	0.172	0.056	0.93	0.193	0.070	0.92	0.199	0.074	0.91	0.187	0.066	0.89	0.191	0.069
0.92	0.183	0.063	1.01	0.183	0.063	0.95	0.193	0.070	1.00	0.201	0.076	0.90	0.192	0.069
0.99	0.191	0.069	1.02	0.184	0.064	0.97	0.191	0.069	1.03	0.203	0.077	0.90	0.192	0.069
1.03	0.193	0.070	1.06	0.187	0.066	0.99	0.201	0.076	1.04	0.205	0.079	1.00	0.193	0.070
1.09	0.199	0.074	1.10	0.191	0.069	1.00	0.203	0.077	1.11	0.212	0.084	1.00	0.194	0.071
1.10	0.193	0.070	1.11	0.193	0.070	1.00	0.201	0.076	1.16	0.217	0.088	1.10	0.196	0.072
1.10	0.215	0.087	1.14	0.201	0.076	1.03	0.207	0.081	1.19	0.229	0.099	1.14	0.191	0.069
1.14	0.223	0.093	1.14	0.208	0.081	1.07	0.215	0.087	1.21	0.231	0.100	1.19	0.193	0.070
1.16	0.221	0.092	1.21	0.210	0.083	1.19	0.207	0.081	1.22	0.232	0.101	1.22	0.201	0.076
1.18	0.211	0.084	1.22	0.219	0.090	1.21	0.211	0.084	1.29	0.239	0.107	1.23	0.204	0.078
1.23	0.205	0.079	1.26	0.221	0.092	1.22	0.224	0.094	1.32	0.239	0.107	1.26	0.206	0.080
1.29	0.195	0.071	1.29	0.216	0.088	1.23	0.213	0.085	1.36	0.242	0.110	1.31	0.233	0.102
1.34	0.225	0.095	1.32	0.227	0.097	1.31	0.230	0.099	1.37	0.243	0.111	1.33	0.237	0.106
1.38	0.241	0.109	1.33	0.233	0.102	1.33	0.231	0.100	1.38	0.246	0.114	1.34	0.237	0.106
1.39	0.228	0.098	1.38	0.239	0.107	1.34	0.228	0.098	1.41	0.257	0.124	1.41	0.239	0.107
1.42	0.236	0.105	1.41	0.240	0.108	1.34	0.236	0.105	1.44	0.257	0.124	1.47	0.243	0.111
1.42	0.246	0.114	1.43	0.248	0.116	1.42	0.248	0.116	1.47	0.245	0.113	1.47	0.247	0.115
1.49	0.239	0.107	1.44	0.238	0.106	1.46	0.249	0.116	1.48	0.246	0.114	1.48	0.244	0.112
1.49	0.243	0.111	1.46	0.246	0.114	1.47	0.241	0.109	1.51	0.261	0.128	1.53	0.253	0.120
1.54	0.246	0.114	1.51	0.247	0.115	1.49	0.253	0.120	1.54	0.265	0.132	1.56	0.256	0.123
1.56	0.252	0.119	1.55	0.256	0.123	1.49	0.245	0.113	1.59	0.267	0.134	1.57	0.257	0.124
1.59	0.243	0.111	1.61	0.270	0.137	1.51	0.249	0.116	1.60	0.269	0.136	1.61	0.264	0.131
1.63	0.264	0.131	1.62	0.266	0.133	1.56	0.259	0.126	1.62	0.271	0.138	1.62	0.267	0.134
1.72	0.273	0.140	1.72	0.276	0.143	1.62	0.258	0.125	1.68	0.269	0.136	1.66	0.269	0.136
1.74	0.276	0.143	1.76	0.278	0.145	1.66	0.268	0.135	1.71	0.267	0.134	1.66	0.274	0.141

site26			site27			site28			site29			site30		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.89	0.186	0.065	0.72	0.161	0.049	0.69	0.151	0.043	0.71	0.161	0.049	0.62	0.154	0.045
0.92	0.193	0.070	0.76	0.166	0.052	0.69	0.153	0.044	0.78	0.171	0.055	0.66	0.153	0.044
0.94	0.193	0.070	0.81	0.187	0.066	0.72	0.164	0.051	0.80	0.191	0.069	0.71	0.158	0.047
1.01	0.197	0.073	0.84	0.193	0.070	0.76	0.167	0.052	0.80	0.185	0.064	0.71	0.164	0.051
1.06	0.197	0.073	0.93	0.206	0.080	0.78	0.169	0.054	0.84	0.192	0.069	0.86	0.193	0.070
1.08	0.199	0.074	0.96	0.198	0.074	0.81	0.175	0.058	0.90	0.195	0.071	0.87	0.197	0.073
1.10	0.199	0.074	0.99	0.204	0.078	0.84	0.181	0.062	0.96	0.203	0.077	0.88	0.198	0.074
1.14	0.203	0.077	1.01	0.203	0.077	0.86	0.179	0.060	0.97	0.201	0.076	0.91	0.204	0.078
1.14	0.204	0.078	1.01	0.209	0.082	0.99	0.203	0.077	0.99	0.203	0.077	0.99	0.206	0.080
1.21	0.211	0.084	1.06	0.209	0.082	0.99	0.207	0.081	1.01	0.219	0.090	1.06	0.192	0.069
1.23	0.213	0.085	1.07	0.210	0.083	1.02	0.209	0.082	1.01	0.213	0.085	1.07	0.196	0.072
1.25	0.220	0.091	1.11	0.219	0.090	1.11	0.219	0.090	1.07	0.218	0.089	1.09	0.199	0.074
1.26	0.223	0.093	1.23	0.221	0.092	1.16	0.225	0.095	1.09	0.221	0.092	1.15	0.214	0.086
1.26	0.224	0.094	1.26	0.224	0.094	1.18	0.227	0.097	1.10	0.213	0.085	1.15	0.198	0.074
1.29	0.225	0.095	1.27	0.239	0.107	1.19	0.230	0.099	1.10	0.223	0.093	1.16	0.219	0.090
1.30	0.225	0.095	1.33	0.218	0.089	1.19	0.233	0.102	1.20	0.235	0.104	1.21	0.226	0.096
1.30	0.231	0.100	1.36	0.244	0.112	1.21	0.213	0.085	1.20	0.232	0.101	1.21	0.227	0.097
1.32	0.231	0.100	1.41	0.247	0.115	1.24	0.224	0.094	1.29	0.218	0.089	1.26	0.223	0.093
1.33	0.235	0.104	1.47	0.248	0.116	1.26	0.219	0.090	1.30	0.240	0.108	1.31	0.221	0.092
1.39	0.238	0.106	1.47	0.246	0.114	1.31	0.235	0.104	1.32	0.249	0.116	1.33	0.228	0.098
1.42	0.239	0.107	1.49	0.252	0.119	1.32	0.231	0.100	1.37	0.245	0.113	1.34	0.227	0.097
1.44	0.243	0.111	1.52	0.249	0.116	1.38	0.239	0.107	1.38	0.246	0.114	1.36	0.231	0.100
1.46	0.243	0.111	1.52	0.251	0.118	1.41	0.251	0.118	1.40	0.251	0.118	1.42	0.232	0.101
1.47	0.248	0.116	1.53	0.250	0.117	1.48	0.257	0.124	1.41	0.253	0.120	1.44	0.235	0.104
1.51	0.251	0.118	1.54	0.261	0.128	1.49	0.263	0.130	1.44	0.250	0.117	1.47	0.239	0.107
1.52	0.253	0.120	1.56	0.257	0.124	1.52	0.261	0.128	1.56	0.258	0.125	1.51	0.243	0.111
1.54	0.258	0.125	1.57	0.253	0.120	1.54	0.263	0.130	1.58	0.253	0.120	1.52	0.245	0.113
1.59	0.261	0.128	1.61	0.277	0.144	1.61	0.280	0.147	1.61	0.263	0.130	1.56	0.241	0.109
1.60	0.263	0.130	1.62	0.276	0.143	1.61	0.278	0.145	1.61	0.276	0.143	1.61	0.269	0.136
1.62	0.273	0.140	1.62	0.278	0.145	1.62	0.281	0.148	1.62	0.274	0.141	1.68	0.277	0.144

Novembe site1				site2			site3			site4			site5	
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.65	0.141	0.037	0.65	0.147	0.041	0.64	0.147	0.041	0.66	0.154	0.045	0.61	0.152	0.043
0.68	0.143	0.038	0.68	0.151	0.043	0.69	0.145	0.040	0.72	0.168	0.053	0.68	0.162	0.049
0.73	0.148	0.041	0.71	0.163	0.050	0.72	0.149	0.042	0.79	0.163	0.050	0.69	0.158	0.047
0.79	0.147	0.041	0.86	0.162	0.049	0.79	0.153	0.044	0.81	0.177	0.059	0.73	0.161	0.049
0.85	0.153	0.044	0.92	0.172	0.056	0.83	0.159	0.048	0.84	0.178	0.060	0.74	0.168	0.053
0.93	0.162	0.049	0.94	0.176	0.058	0.87	0.161	0.049	0.91	0.162	0.049	0.79	0.163	0.050
0.99	0.168	0.053	1.06	0.190	0.068	0.89	0.158	0.047	0.93	0.173	0.056	0.81	0.158	0.047
1.03	0.169	0.054	1.09	0.190	0.068	0.93	0.168	0.053	0.98	0.168	0.053	0.81	0.160	0.048
1.09	0.173	0.056	1.11	0.181	0.062	0.97	0.172	0.056	1.02	0.178	0.060	0.84	0.162	0.049
1.11	0.176	0.058	1.11	0.192	0.069	1.03	0.182	0.062	1.06	0.168	0.053	0.89	0.168	0.053
1.18	0.175	0.058	1.15	0.187	0.066	1.03	0.186	0.065	1.18	0.187	0.066	0.93	0.174	0.057
1.23	0.183	0.063	1.18	0.186	0.065	1.07	0.183	0.063	1.19	0.193	0.070	0.98	0.173	0.056
1.26	0.185	0.064	1.22	0.192	0.069	1.14	0.191	0.069	1.21	0.201	0.076	1.03	0.189	0.067
1.32	0.189	0.067	1.26	0.197	0.073	1.16	0.193	0.070	1.23	0.191	0.069	1.03	0.181	0.062
1.33	0.193	0.070	1.26	0.199	0.074	1.21	0.199	0.074	1.23	0.203	0.077	1.08	0.184	0.064
1.36	0.192	0.069	1.32	0.214	0.086	1.21	0.203	0.077	1.28	0.192	0.069	1.13	0.197	0.073
1.42	0.218	0.089	1.32	0.206	0.080	1.27	0.214	0.086	1.29	0.203	0.077	1.14	0.193	0.070
1.44	0.219	0.090	1.37	0.209	0.082	1.30	0.209	0.082	1.31	0.198	0.074	1.23	0.211	0.084
1.46	0.224	0.094	1.38	0.210	0.083	1.30	0.211	0.084	1.37	0.210	0.083	1.29	0.209	0.082
1.53	0.229	0.099	1.41	0.221	0.092	1.34	0.218	0.089	1.38	0.210	0.083	1.36	0.209	0.082
1.54	0.231	0.100	1.49	0.228	0.098	1.36	0.219	0.090	1.39	0.200	0.075	1.39	0.214	0.086
1.59	0.238	0.106	1.54	0.241	0.109	1.39	0.223	0.093	1.43	0.231	0.100	1.42	0.221	0.092
1.63	0.244	0.112	1.55	0.235	0.104	1.43	0.229	0.099	1.44	0.228	0.098	1.48	0.219	0.090
1.66	0.247	0.115	1.61	0.246	0.114	1.47	0.232	0.101	1.48	0.221	0.092	1.51	0.227	0.097
1.69	0.249	0.116	1.66	0.241	0.109	1.53	0.238	0.106	1.49	0.229	0.099	1.52	0.238	0.106
1.72	0.256	0.123	1.68	0.243	0.111	1.56	0.241	0.109	1.52	0.249	0.116	1.56	0.238	0.106
1.73	0.249	0.116	1.71	0.249	0.116	1.58	0.244	0.112	1.53	0.248	0.116	1.63	0.243	0.111
1.77	0.241	0.109	1.72	0.253	0.120	1.63	0.253	0.120	1.57	0.238	0.106	1.69	0.251	0.118
1.78	0.255	0.122	1.75	0.251	0.118	1.66	0.256	0.123	1.61	0.236	0.105	1.73	0.241	0.109
1.81	0.259	0.126	1.80	0.252	0.119	1.68	0.253	0.120	1.62	0.241	0.109	1.74	0.248	0.116

site6			site7			site8			site9			site10		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.63	0.148	0.041	0.63	0.138	0.036	0.68	0.145	0.040	0.64	0.139	0.036	0.61	0.141	0.037
0.64	0.142	0.038	0.67	0.143	0.038	0.71	0.151	0.043	0.72	0.149	0.042	0.69	0.153	0.044
0.65	0.141	0.037	0.67	0.149	0.042	0.77	0.143	0.038	0.73	0.144	0.039	0.71	0.152	0.043
0.67	0.153	0.044	0.71	0.153	0.044	0.86	0.156	0.046	0.77	0.153	0.044	0.76	0.163	0.050
0.71	0.158	0.047	0.76	0.158	0.047	0.87	0.153	0.044	0.83	0.158	0.047	0.81	0.166	0.052
0.76	0.162	0.049	0.77	0.162	0.049	0.91	0.158	0.047	0.83	0.162	0.049	0.83	0.161	0.049
0.81	0.171	0.055	0.80	0.153	0.044	0.93	0.163	0.050	0.87	0.163	0.050	0.91	0.177	0.059
0.83	0.176	0.058	0.81	0.162	0.049	1.02	0.168	0.053	0.88	0.153	0.044	0.93	0.176	0.058
0.89	0.178	0.060	0.93	0.166	0.052	1.11	0.173	0.056	0.91	0.164	0.051	0.99	0.176	0.058
0.93	0.183	0.063	0.97	0.171	0.055	1.11	0.174	0.057	0.91	0.176	0.058	1.01	0.181	0.062
0.96	0.184	0.064	1.00	0.172	0.056	1.18	0.177	0.059	0.94	0.181	0.062	1.03	0.189	0.067
1.01	0.197	0.073	1.00	0.165	0.051	1.19	0.176	0.058	0.98	0.172	0.056	1.14	0.181	0.062
1.01	0.193	0.070	1.09	0.178	0.060	1.23	0.186	0.065	1.01	0.162	0.049	1.18	0.186	0.065
1.06	0.199	0.074	1.13	0.179	0.060	1.26	0.185	0.064	1.06	0.179	0.060	1.20	0.191	0.069
1.09	0.201	0.076	1.14	0.183	0.063	1.32	0.189	0.067	1.10	0.179	0.060	1.21	0.199	0.074
1.14	0.207	0.081	1.23	0.181	0.062	1.37	0.193	0.070	1.12	0.184	0.064	1.25	0.190	0.068
1.19	0.202	0.077	1.27	0.179	0.060	1.38	0.190	0.068	1.16	0.182	0.062	1.29	0.201	0.076
1.21	0.208	0.081	1.33	0.199	0.074	1.42	0.191	0.069	1.23	0.189	0.067	1.33	0.209	0.082
1.28	0.212	0.084	1.34	0.204	0.078	1.45	0.190	0.068	1.26	0.193	0.070	1.35	0.200	0.075
1.32	0.214	0.086	1.39	0.209	0.082	1.45	0.223	0.093	1.32	0.198	0.074	1.38	0.221	0.092
1.38	0.218	0.089	1.42	0.221	0.092	1.48	0.221	0.092	1.33	0.204	0.078	1.42	0.214	0.086
1.43	0.221	0.092	1.44	0.219	0.090	1.51	0.226	0.096	1.39	0.216	0.088	1.47	0.211	0.084
1.47	0.229	0.099	1.52	0.227	0.097	1.52	0.221	0.092	1.42	0.219	0.090	1.52	0.231	0.100
1.52	0.228	0.098	1.53	0.228	0.098	1.54	0.230	0.099	1.47	0.223	0.093	1.57	0.239	0.107
1.59	0.232	0.101	1.57	0.231	0.100	1.63	0.238	0.106	1.51	0.228	0.098	1.60	0.230	0.099
1.63	0.238	0.106	1.62	0.238	0.106	1.65	0.231	0.100	1.53	0.239	0.107	1.65	0.241	0.109
1.69	0.241	0.109	1.63	0.244	0.112	1.67	0.229	0.099	1.58	0.241	0.109	1.72	0.241	0.109
1.69	0.233	0.102	1.63	0.248	0.116	1.67	0.237	0.106	1.62	0.226	0.096	1.76	0.253	0.120
1.71	0.243	0.111	1.72	0.253	0.120	1.71	0.244	0.112	1.68	0.233	0.102	1.77	0.256	0.123
1.76	0.249	0.116	1.76	0.248	0.116	1.73	0.243	0.111	1.71	0.241	0.109	1.81	0.252	0.119

site11			site12			site13			site14			site15		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.63	0.139	0.036	0.62	0.138	0.036	0.61	0.141	0.037	0.65	0.146	0.040	0.66	0.139	0.036
0.67	0.143	0.038	0.69	0.142	0.038	0.66	0.148	0.041	0.71	0.149	0.042	0.69	0.143	0.038
0.72	0.148	0.041	0.72	0.148	0.041	0.73	0.153	0.044	0.76	0.144	0.039	0.73	0.148	0.041
0.78	0.149	0.042	0.77	0.144	0.039	0.78	0.157	0.046	0.81	0.149	0.042	0.78	0.158	0.047
0.81	0.145	0.040	0.79	0.131	0.032	0.81	0.163	0.050	0.86	0.153	0.044	0.84	0.163	0.050
0.89	0.156	0.046	0.83	0.152	0.043	0.85	0.169	0.054	0.91	0.171	0.055	0.86	0.173	0.056
0.93	0.153	0.044	0.84	0.153	0.044	0.87	0.161	0.049	0.93	0.168	0.053	0.93	0.169	0.054
0.99	0.159	0.048	0.90	0.158	0.047	0.90	0.166	0.052	1.01	0.187	0.066	0.94	0.174	0.057
1.01	0.168	0.053	0.91	0.158	0.047	0.90	0.173	0.056	1.01	0.183	0.063	0.99	0.188	0.066
1.09	0.166	0.052	0.95	0.162	0.049	0.96	0.181	0.062	1.03	0.197	0.073	1.03	0.177	0.059
1.11	0.168	0.053	0.97	0.161	0.049	0.97	0.169	0.054	1.09	0.201	0.076	1.06	0.176	0.058
1.11	0.169	0.054	1.02	0.176	0.058	1.03	0.173	0.056	1.09	0.194	0.071	1.11	0.191	0.069
1.17	0.178	0.060	1.06	0.182	0.062	1.04	0.181	0.062	1.11	0.201	0.076	1.14	0.199	0.074
1.18	0.173	0.056	1.11	0.193	0.070	1.07	0.179	0.060	1.14	0.193	0.070	1.17	0.194	0.071
1.23	0.184	0.064	1.11	0.192	0.069	1.11	0.183	0.063	1.19	0.191	0.069	1.26	0.206	0.080
1.26	0.186	0.065	1.14	0.194	0.071	1.14	0.183	0.063	1.21	0.203	0.077	1.29	0.210	0.083
1.29	0.185	0.064	1.21	0.206	0.080	1.18	0.176	0.058	1.25	0.210	0.083	1.36	0.221	0.092
1.35	0.193	0.070	1.26	0.208	0.081	1.26	0.193	0.070	1.26	0.207	0.081	1.39	0.214	0.086
1.38	0.196	0.072	1.32	0.213	0.085	1.27	0.201	0.076	1.32	0.209	0.082	1.47	0.226	0.096
1.42	0.199	0.074	1.36	0.223	0.093	1.33	0.214	0.086	1.37	0.218	0.089	1.49	0.228	0.098
1.48	0.208	0.081	1.41	0.238	0.106	1.35	0.206	0.080	1.41	0.219	0.090	1.51	0.231	0.100
1.51	0.206	0.080	1.43	0.238	0.106	1.43	0.214	0.086	1.48	0.221	0.092	1.54	0.222	0.093
1.57	0.211	0.084	1.51	0.231	0.100	1.47	0.214	0.086	1.49	0.221	0.092	1.55	0.223	0.093
1.62	0.224	0.094	1.54	0.236	0.105	1.49	0.223	0.093	1.52	0.233	0.102	1.59	0.228	0.098
1.63	0.226	0.096	1.62	0.223	0.093	1.53	0.233	0.102	1.55	0.239	0.107	1.62	0.248	0.116
1.66	0.241	0.109	1.66	0.229	0.099	1.58	0.241	0.109	1.62	0.231	0.100	1.63	0.234	0.103
1.67	0.244	0.112	1.69	0.237	0.106	1.63	0.239	0.107	1.65	0.241	0.109	1.67	0.245	0.113
1.69	0.231	0.100	1.72	0.246	0.114	1.68	0.238	0.106	1.71	0.249	0.116	1.71	0.241	0.109
1.74	0.241	0.109	1.76	0.243	0.111	1.71	0.248	0.116	1.73	0.261	0.128	1.73	0.253	0.120
1.81	0.253	0.120	1.80	0.244	0.112	1.78	0.251	0.118	1.78	0.257	0.124	1.74	0.250	0.117

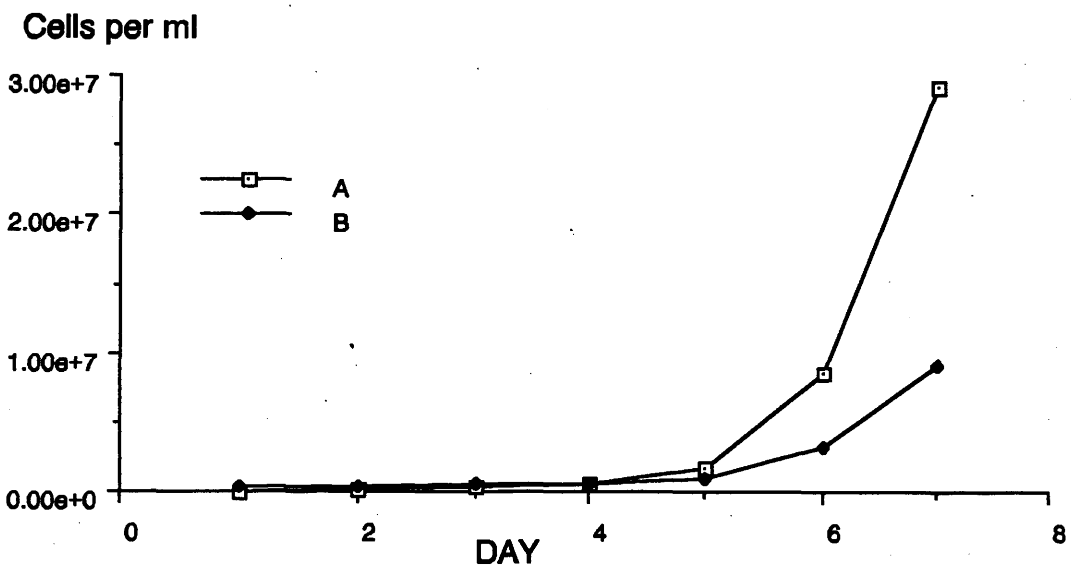
site16			site17			site18			site19			site20		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.68	0.151	0.043	0.73	0.151	0.043	0.60	0.136	0.035	0.67	0.138	0.036	0.71	0.166	0.052
0.72	0.149	0.042	0.78	0.153	0.044	0.66	0.141	0.037	0.69	0.142	0.038	0.73	0.169	0.054
0.79	0.153	0.044	0.81	0.149	0.042	0.71	0.161	0.049	0.70	0.148	0.041	0.76	0.166	0.052
0.81	0.163	0.050	0.81	0.158	0.047	0.76	0.166	0.052	0.73	0.147	0.041	0.81	0.173	0.056
0.86	0.166	0.052	0.85	0.163	0.050	0.77	0.158	0.047	0.77	0.149	0.042	0.87	0.177	0.059
0.99	0.173	0.056	0.87	0.166	0.052	0.81	0.173	0.056	0.83	0.153	0.044	0.87	0.176	0.058
0.99	0.163	0.050	0.90	0.173	0.056	0.83	0.161	0.049	0.84	0.152	0.043	0.93	0.193	0.070
1.01	0.184	0.064	0.93	0.184	0.064	0.87	0.181	0.062	0.91	0.161	0.049	0.97	0.197	0.073
1.06	0.184	0.064	0.94	0.161	0.049	0.90	0.163	0.050	0.99	0.166	0.052	1.00	0.201	0.076
1.09	0.189	0.067	0.97	0.184	0.064	0.93	0.186	0.065	0.99	0.167	0.052	1.03	0.208	0.081
1.11	0.196	0.072	0.98	0.193	0.070	0.98	0.189	0.067	1.00	0.172	0.056	1.06	0.202	0.077
1.14	0.193	0.070	1.03	0.203	0.077	1.00	0.206	0.080	1.00	0.165	0.051	1.12	0.213	0.085
1.16	0.198	0.074	1.07	0.199	0.074	1.01	0.201	0.076	1.08	0.178	0.060	1.16	0.224	0.094
1.18	0.201	0.076	1.08	0.196	0.072	1.06	0.209	0.082	1.09	0.173	0.056	1.17	0.216	0.088
1.22	0.206	0.080	1.09	0.191	0.069	1.11	0.210	0.083	1.14	0.178	0.060	1.21	0.213	0.085
1.27	0.204	0.078	1.11	0.193	0.070	1.14	0.210	0.083	1.17	0.173	0.056	1.26	0.227	0.097
1.32	0.211	0.084	1.13	0.201	0.076	1.17	0.211	0.084	1.23	0.187	0.066	1.27	0.228	0.098
1.35	0.209	0.082	1.14	0.214	0.086	1.23	0.221	0.092	1.26	0.189	0.067	1.32	0.249	0.116
1.39	0.211	0.084	1.21	0.203	0.077	1.24	0.210	0.083	1.31	0.206	0.080	1.36	0.241	0.109
1.42	0.221	0.092	1.23	0.211	0.084	1.29	0.209	0.082	1.36	0.214	0.086	1.37	0.243	0.111
1.42	0.216	0.088	1.27	0.209	0.082	1.36	0.221	0.092	1.42	0.221	0.092	1.42	0.259	0.126
1.45	0.210	0.083	1.36	0.218	0.089	1.39	0.221	0.092	1.47	0.223	0.093	1.45	0.253	0.120
1.51	0.232	0.101	1.39	0.211	0.084	1.41	0.249	0.116	1.53	0.228	0.098	1.47	0.256	0.123
1.55	0.233	0.102	1.43	0.201	0.076	1.44	0.241	0.109	1.56	0.231	0.100	1.50	0.261	0.128
1.60	0.246	0.114	1.48	0.229	0.099	1.47	0.226	0.096	1.58	0.241	0.109	1.52	0.263	0.130
1.62	0.238	0.106	1.55	0.235	0.104	1.52	0.231	0.100	1.61	0.241	0.109	1.53	0.260	0.127
1.68	0.234	0.103	1.58	0.236	0.105	1.53	0.244	0.112	1.63	0.242	0.110	1.59	0.266	0.133
1.70	0.253	0.120	1.63	0.241	0.109	1.60	0.238	0.106	1.70	0.248	0.116	1.63	0.272	0.139
1.71	0.239	0.107	1.63	0.241	0.109	1.61	0.241	0.109	1.70	0.256	0.123	1.66	0.277	0.144
1.76	0.248	0.116	1.72	0.253	0.120	1.68	0.249	0.116	1.73	0.243	0.111	1.70	0.286	0.154

site21			site22			site23			site24			site25		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.71	0.162	0.049	0.69	0.151	0.043	0.67	0.152	0.043	0.73	0.152	0.043	0.69	0.153	0.044
0.75	0.167	0.052	0.71	0.176	0.058	0.73	0.158	0.047	0.80	0.168	0.053	0.73	0.158	0.047
0.83	0.174	0.057	0.77	0.162	0.049	0.78	0.168	0.053	0.81	0.173	0.056	0.78	0.163	0.050
0.86	0.178	0.060	0.82	0.191	0.069	0.83	0.176	0.058	0.85	0.171	0.055	0.84	0.176	0.058
0.93	0.189	0.067	0.84	0.187	0.066	0.87	0.181	0.062	0.91	0.186	0.065	0.89	0.177	0.059
0.99	0.193	0.070	0.94	0.193	0.070	0.91	0.189	0.067	0.92	0.199	0.074	0.90	0.176	0.058
0.99	0.196	0.072	1.01	0.211	0.084	0.93	0.196	0.072	0.97	0.193	0.070	0.95	0.181	0.062
1.02	0.198	0.074	1.06	0.208	0.081	0.94	0.192	0.069	1.02	0.203	0.077	0.97	0.196	0.072
1.07	0.199	0.074	1.09	0.203	0.077	0.99	0.199	0.074	1.03	0.200	0.075	1.01	0.203	0.077
1.09	0.201	0.076	1.11	0.206	0.080	1.00	0.203	0.077	1.07	0.219	0.090	1.03	0.209	0.082
1.13	0.216	0.088	1.19	0.203	0.077	1.06	0.206	0.080	1.11	0.223	0.093	1.06	0.208	0.081
1.14	0.221	0.092	1.21	0.211	0.084	1.09	0.210	0.083	1.14	0.226	0.096	1.11	0.218	0.089
1.17	0.219	0.090	1.21	0.231	0.100	1.11	0.221	0.092	1.18	0.238	0.106	1.16	0.226	0.096
1.26	0.224	0.094	1.26	0.229	0.099	1.18	0.226	0.096	1.20	0.231	0.100	1.17	0.229	0.099
1.29	0.238	0.106	1.31	0.241	0.109	1.19	0.228	0.098	1.21	0.243	0.111	1.20	0.233	0.102
1.32	0.247	0.115	1.32	0.248	0.116	1.26	0.233	0.102	1.23	0.236	0.105	1.25	0.239	0.107
1.32	0.231	0.100	1.35	0.246	0.114	1.29	0.241	0.109	1.29	0.244	0.112	1.26	0.238	0.106
1.38	0.234	0.103	1.36	0.241	0.109	1.33	0.246	0.114	1.31	0.244	0.112	1.30	0.246	0.114
1.42	0.250	0.117	1.39	0.231	0.100	1.36	0.248	0.116	1.34	0.248	0.116	1.34	0.246	0.114
1.47	0.244	0.112	1.41	0.245	0.113	1.43	0.253	0.120	1.38	0.250	0.117	1.35	0.244	0.112
1.49	0.248	0.116	1.45	0.239	0.107	1.47	0.258	0.125	1.40	0.261	0.128	1.41	0.251	0.118
1.51	0.256	0.123	1.46	0.241	0.109	1.53	0.256	0.123	1.42	0.254	0.121	1.43	0.249	0.116
1.53	0.252	0.119	1.46	0.251	0.118	1.54	0.256	0.123	1.47	0.251	0.118	1.47	0.257	0.124
1.59	0.258	0.125	1.52	0.263	0.130	1.58	0.261	0.128	1.48	0.261	0.128	1.53	0.258	0.125
1.61	0.261	0.128	1.55	0.261	0.128	1.61	0.283	0.150	1.52	0.266	0.133	1.57	0.259	0.126
1.66	0.263	0.130	1.58	0.273	0.140	1.63	0.269	0.136	1.53	0.259	0.126	1.58	0.263	0.130
1.71	0.271	0.138	1.62	0.276	0.143	1.66	0.276	0.143	1.54	0.267	0.134	1.63	0.273	0.140
1.71	0.288	0.156	1.65	0.281	0.148	1.71	0.281	0.148	1.60	0.273	0.140	1.66	0.276	0.143
1.73	0.278	0.145	1.66	0.279	0.146	1.77	0.283	0.150	1.61	0.286	0.154	1.67	0.279	0.146
1.78	0.294	0.162	1.70	0.286	0.154	1.78	0.287	0.155	1.63	0.281	0.148	1.72	0.286	0.154

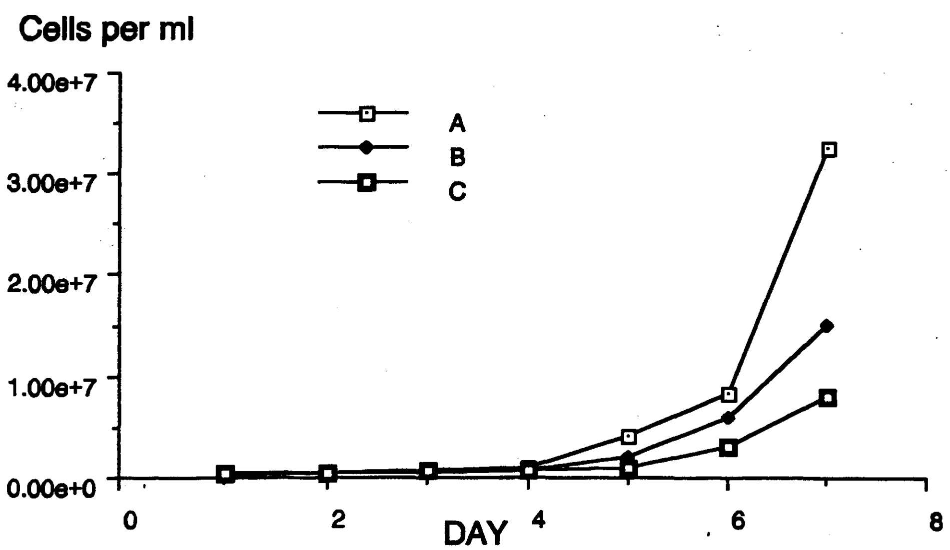
site26			site27			site28			site29			site30		
Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)	Standard length (mm)	Mean setae length (mm)	Calculated filtering area (mm2)
0.69	0.153	0.044	0.66	0.143	0.038	0.71	0.153	0.044	0.73	0.152	0.043	0.64	0.148	0.041
0.76	0.161	0.049	0.76	0.153	0.044	0.87	0.178	0.060	0.84	0.166	0.052	0.7	0.153	0.044
0.80	0.176	0.058	0.78	0.163	0.050	0.96	0.183	0.063	0.92	0.168	0.053	0.72	0.156	0.046
0.82	0.183	0.063	0.84	0.183	0.063	1.01	0.194	0.071	0.99	0.173	0.056	0.82	0.176	0.058
0.87	0.181	0.062	0.89	0.176	0.058	1.01	0.191	0.069	1.03	0.186	0.065	0.84	0.187	0.066
0.91	0.189	0.067	0.93	0.193	0.070	1.05	0.201	0.076	1.07	0.191	0.069	0.9	0.191	0.069
0.93	0.193	0.070	0.97	0.187	0.066	1.07	0.203	0.077	1.09	0.182	0.062	0.96	0.193	0.070
1.03	0.187	0.066	1.03	0.203	0.077	1.11	0.202	0.077	1.11	0.196	0.072	1.02	0.203	0.077
1.06	0.193	0.070	1.07	0.207	0.081	1.14	0.209	0.082	1.11	0.198	0.074	1.1	0.211	0.084
1.08	0.178	0.060	1.14	0.211	0.084	1.17	0.211	0.084	1.16	0.204	0.078	1.11	0.214	0.086
1.11	0.199	0.074	1.16	0.219	0.090	1.19	0.219	0.090	1.17	0.201	0.076	1.14	0.219	0.090
1.14	0.191	0.069	1.21	0.224	0.094	1.19	0.209	0.082	1.23	0.218	0.089	1.21	0.223	0.093
1.18	0.193	0.070	1.26	0.224	0.094	1.24	0.228	0.098	1.28	0.216	0.088	1.26	0.224	0.094
1.19	0.201	0.076	1.29	0.226	0.096	1.25	0.219	0.090	1.31	0.228	0.098	1.29	0.214	0.086
1.22	0.211	0.084	1.33	0.229	0.099	1.28	0.224	0.094	1.35	0.233	0.102	1.31	0.231	0.100
1.26	0.216	0.088	1.33	0.233	0.102	1.32	0.236	0.105	1.36	0.228	0.098	1.32	0.221	0.092
1.27	0.207	0.081	1.36	0.230	0.099	1.35	0.234	0.103	1.38	0.221	0.092	1.35	0.229	0.099
1.31	0.229	0.099	1.39	0.231	0.100	1.35	0.236	0.105	1.43	0.234	0.103	1.39	0.226	0.096
1.32	0.231	0.100	1.44	0.248	0.116	1.37	0.228	0.098	1.47	0.236	0.105	1.39	0.221	0.092
1.38	0.239	0.107	1.45	0.243	0.111	1.41	0.236	0.105	1.52	0.246	0.114	1.41	0.236	0.105
1.39	0.243	0.111	1.47	0.247	0.115	1.42	0.238	0.106	1.53	0.238	0.106	1.43	0.243	0.111
1.43	0.243	0.111	1.52	0.261	0.128	1.46	0.241	0.109	1.57	0.249	0.116	1.49	0.244	0.112
1.47	0.248	0.116	1.53	0.256	0.123	1.50	0.250	0.117	1.59	0.251	0.118	1.49	0.246	0.114
1.51	0.258	0.125	1.56	0.251	0.118	1.51	0.251	0.118	1.60	0.258	0.125	1.51	0.253	0.120
1.52	0.253	0.120	1.57	0.249	0.116	1.53	0.258	0.125	1.60	0.263	0.130	1.56	0.249	0.116
1.59	0.263	0.130	1.61	0.259	0.126	1.58	0.258	0.125	1.63	0.263	0.130	1.58	0.259	0.126
1.60	0.276	0.143	1.63	0.263	0.130	1.60	0.261	0.128	1.67	0.266	0.133	1.61	0.273	0.140
1.62	0.278	0.145	1.66	0.269	0.136	1.63	0.271	0.138	1.68	0.266	0.133	1.62	0.269	0.136
1.67	0.281	0.148	1.71	0.274	0.141	1.65	0.266	0.133	1.69	0.269	0.136	1.66	0.277	0.144
1.73	0.287	0.155	1.71	0.279	0.146	1.71	0.276	0.143	1.72	0.277	0.144	1.73	0.281	0.148

II (s) **Growth rates of *Chlorella* cultures for use in growth inhibition experiments**

Dissolved iron investigations



Particulate iron investigations



II (t) Growth rates of *Chlorella vulgaris* in iron sulphate

Cell counts from dissolved iron experiments

Test a Vessel	24	48	72	96	129	144	168hr
A	1.7×10^{5}	3.1×10^{5}	7.4×10^{5}	9.4×10^{5}	1.1×10^{6}	1.8×10^{6}	2.2×10^{6}
B	1.7×10^{5}	3.2×10^{5}	7.7×10^{5}	9.5×10^{5}	1.1×10^{6}	1.8×10^{6}	2.2×10^{6}
C	1.6×10^{5}	3.4×10^{5}	8.1×10^{5}	9.8×10^{5}	1.1×10^{6}	1.6×10^{6}	2.2×10^{6}
D	1.5×10^{5}	3.1×10^{5}	8.1×10^{5}	9.9×10^{5}	1.1×10^{6}	1.9×10^{6}	2.3×10^{6}
E	1.6×10^{5}	3.2×10^{5}	7.4×10^{5}	1.0×10^{6}	1.1×10^{6}	1.9×10^{6}	2.3×10^{6}
F	1.8×10^{5}	3.0×10^{5}	8.1×10^{5}	9.5×10^{5}	1.1×10^{6}	1.7×10^{6}	2.2×10^{6}
G	1.7×10^{5}	3.1×10^{5}	8.2×10^{5}	9.4×10^{5}	1.1×10^{6}	2.0×10^{6}	2.3×10^{6}
H	1.7×10^{5}	3.5×10^{5}	7.9×10^{5}	9.5×10^{5}	1.1×10^{6}	1.9×10^{6}	2.2×10^{6}
I	1.7×10^{5}	3.2×10^{5}	8.0×10^{5}	9.1×10^{5}	1.1×10^{6}	1.9×10^{6}	2.2×10^{6}
J	1.4×10^{5}	3.2×10^{5}	7.9×10^{5}	9.2×10^{5}	1.1×10^{6}	1.8×10^{6}	2.3×10^{6}
K	1.5×10^{5}	3.0×10^{5}	7.8×10^{5}	9.4×10^{5}	1.1×10^{6}	1.9×10^{6}	2.2×10^{6}
L	1.7×10^{5}	3.1×10^{5}	7.7×10^{5}	8.9×10^{5}	1.1×10^{6}	1.8×10^{6}	2.3×10^{6}
M	1.4×10^{5}	2.9×10^{5}	8.2×10^{5}	8.9×10^{5}	1.1×10^{6}	1.9×10^{6}	2.1×10^{6}
N	1.3×10^{5}	3.4×10^{5}	8.1×10^{5}	9.3×10^{5}	1.1×10^{6}	1.9×10^{6}	2.2×10^{6}

Test a Vessel	24	48	72	96	129	144	168hr
A	1.7×10^{5}	3.5×10^{5}	6.8×10^{5}	1.0×10^{6}	1.3×10^{6}	1.8×10^{6}	2.1×10^{6}
B	1.8×10^{5}	3.3×10^{5}	6.9×10^{5}	1.0×10^{6}	1.3×10^{6}	1.8×10^{6}	2.2×10^{6}
C	2.2×10^{5}	3.5×10^{5}	6.6×10^{5}	1.1×10^{6}	1.3×10^{6}	1.8×10^{6}	2.1×10^{6}
D	1.9×10^{5}	3.4×10^{5}	6.9×10^{5}	1.1×10^{6}	1.4×10^{6}	1.8×10^{6}	2.1×10^{6}
E	1.7×10^{5}	3.4×10^{5}	7.3×10^{5}	1.1×10^{6}	1.4×10^{6}	1.9×10^{6}	2.0×10^{6}
F	2.4×10^{5}	3.4×10^{5}	6.8×10^{5}	1.1×10^{6}	1.4×10^{6}	1.9×10^{6}	2.1×10^{6}
G	2.1×10^{5}	3.6×10^{5}	7.0×10^{5}	1.1×10^{6}	1.3×10^{6}	1.9×10^{6}	2.3×10^{6}
H	1.8×10^{5}	3.9×10^{5}	7.0×10^{5}	1.1×10^{6}	1.4×10^{6}	1.9×10^{6}	2.2×10^{6}
I	1.8×10^{5}	3.4×10^{5}	7.1×10^{5}	1.1×10^{6}	1.4×10^{6}	1.8×10^{6}	2.2×10^{6}
J	1.8×10^{5}	3.6×10^{5}	6.9×10^{5}	1.1×10^{6}	1.4×10^{6}	1.8×10^{6}	2.2×10^{6}
K	2.0×10^{5}	3.4×10^{5}	6.8×10^{5}	1.1×10^{6}	1.4×10^{6}	1.8×10^{6}	2.2×10^{6}
L	1.8×10^{5}	3.6×10^{5}	6.6×10^{5}	1.1×10^{6}	1.4×10^{6}	1.8×10^{6}	2.2×10^{6}
M	1.6×10^{5}	3.5×10^{5}	7.0×10^{5}	1.1×10^{6}	1.4×10^{6}	1.9×10^{6}	2.3×10^{6}
N	2.1×10^{5}	3.5×10^{5}	6.8×10^{5}	1.1×10^{6}	1.4×10^{6}	1.9×10^{6}	2.3×10^{6}

Cell counts of *Chlorella* in particulate iron

Test A

Vessel	24	48	72	96	120	144	168
A	1.65×10^{5}	2.37×10^{5}	3.63×10^{5}	5.32×10^{5}	6.75×10^{5}	2.46×10^{6}	2.64×10^{6}
B	1.54×10^{5}	2.57×10^{5}	3.92×10^{5}	4.66×10^{5}	6.96×10^{5}	2.62×10^{6}	2.64×10^{6}
C	2.39×10^{5}	2.7×10^{5}	4.89×10^{5}	5.32×10^{5}	7.83×10^{5}	2.98×10^{6}	3.07×10^{6}
D	2.49×10^{5}	2.9×10^{5}	5.01×10^{5}	5.47×10^{5}	8.08×10^{5}	3.14×10^{6}	3.27×10^{6}
E	1.12×10^{5}	1.46×10^{5}	3.24×10^{5}	4.49×10^{5}	6.8×10^{5}	1.53×10^{6}	1.61×10^{6}
F	8.89×10^{4}	1.61×10^{5}	3.43×10^{5}	4.3×10^{5}	7.01×10^{5}	1.55×10^{6}	1.63×10^{6}
G	8.44×10^{4}	1.49×10^{5}	3.35×10^{5}	4.82×10^{5}	6.57×10^{5}	9.86×10^{5}	1.13×10^{6}
H	7.2×10^{4}	1.4×10^{5}	3.34×10^{5}	4.31×10^{5}	6.58×10^{5}	9.7×10^{5}	1.1×10^{6}
I	6.7×10^{4}	1.14×10^{5}	3.34×10^{5}	4.2×10^{5}	6.25×10^{5}	8.35×10^{5}	8.89×10^{5}
J	7.2×10^{4}	1.19×10^{5}	3.28×10^{5}	4.42×10^{5}	5.7×10^{5}	8.22×10^{5}	8.7×10^{5}
K	6.9×10^{4}	9.12×10^{4}	2.96×10^{5}	4.53×10^{5}	5.5×10^{5}	7.41×10^{5}	8.06×10^{5}
L	5.7×10^{4}	1.02×10^{5}	3.1×10^{5}	4.05×10^{5}	5.4×10^{5}	7.05×10^{5}	7.46×10^{5}
M	5.8×10^{4}	9.12×10^{4}	3.25×10^{5}	4.08×10^{5}	5.2×10^{5}	6.64×10^{5}	7.19×10^{5}
N	5.6×10^{4}	9.01×10^{4}	3.23×10^{5}	4.3×10^{5}	5.2×10^{5}	6.28×10^{5}	6.8×10^{5}

B

Vessel	24	48	72	96	120	144
A	1.52×10^{5}	4.6×10^{5}	8.8×10^{5}	1.07×10^{6}	1.18×10^{6}	1.29×10^{6}
B	1.25×10^{5}	4.5×10^{5}	9.0×10^{5}	9.8×10^{5}	1.14×10^{6}	1.39×10^{6}
C	1.4×10^{5}	4.4×10^{5}	1.0×10^{6}	1.1×10^{6}	1.17×10^{6}	1.41×10^{6}
D	1.8×10^{5}	5.2×10^{5}	1.0×10^{6}	1.1×10^{6}	1.49×10^{6}	1.56×10^{6}
E	7.43×10^{4}	2.6×10^{5}	7.3×10^{5}	7.95×10^{5}	9.5×10^{5}	1.05×10^{6}
F	7.3×10^{4}	2.4×10^{5}	7.5×10^{5}	8.4×10^{5}	9.6×10^{5}	1.05×10^{6}
G	5.7×10^{4}	2.2×10^{5}	6.2×10^{5}	7.4×10^{5}	8.3×10^{5}	8.6×10^{5}
H	5.7×10^{4}	2.4×10^{5}	5.3×10^{5}	6.8×10^{5}	8.13×10^{5}	8.5×10^{5}
I	4.5×10^{4}	2.3×10^{5}	5.4×10^{5}	7.3×10^{5}	7.7×10^{5}	8.2×10^{5}
J	4.3×10^{4}	1.9×10^{5}	5.6×10^{5}	6.4×10^{5}	6.93×10^{5}	7.2×10^{5}
K	3.8×10^{4}	1.9×10^{5}	4.5×10^{5}	5.4×10^{5}	6.1×10^{5}	6.7×10^{5}
L	3.7×10^{4}	1.9×10^{5}	3.6×10^{5}	4.7×10^{5}	5.4×10^{5}	6.01×10^{5}
M	3.0×10^{4}	1.4×10^{5}	3.5×10^{5}	4.4×10^{5}	4.9×10^{5}	5.3×10^{5}
N	2.9×10^{4}	1.4×10^{5}	3.4×10^{5}	4.04×10^{5}	4.59×10^{5}	4.8×10^{5}

C

Vessel	24	48	72	96	120	144	168
A			2.5×10^{6}	3.7×10^{6}	4.3×10^{6}	6.6×10^{6}	7.0×10^{6}
B			2.4×10^{6}	3.7×10^{6}	4.1×10^{6}	5.8×10^{6}	7.0×10^{6}
C			1.4×10^{6}	2.0×10^{6}	2.3×10^{6}	2.6×10^{6}	3.2×10^{6}
D			1.3×10^{6}	2.1×10^{6}	2.5×10^{6}	3.2×10^{6}	3.4×10^{6}
E			7.1×10^{5}	9.0×10^{5}	1.1×10^{6}	1.3×10^{6}	1.5×10^{6}
F			6.7×10^{5}	8.5×10^{5}	9.6×10^{5}	1.2×10^{6}	1.5×10^{6}
G			3.0×10^{5}	4.0×10^{5}	5.6×10^{5}	7.4×10^{5}	9.9×10^{5}
H			3.2×10^{5}	4.3×10^{5}	6.2×10^{5}	7.4×10^{5}	9.9×10^{5}
I			2.6×10^{5}	3.4×10^{5}	5.1×10^{5}	6.0×10^{5}	8.5×10^{5}
J			2.3×10^{5}	3.4×10^{5}	5.2×10^{5}	6.2×10^{5}	8.7×10^{5}
K			1.9×10^{5}	2.8×10^{5}	4.3×10^{5}	5.3×10^{5}	7.5×10^{5}
L			1.8×10^{5}	2.7×10^{5}	4.1×10^{5}	5.4×10^{5}	7.7×10^{5}
M			1.1×10^{5}	1.8×10^{5}	2.9×10^{5}	3.9×10^{5}	5.4×10^{5}
N			1.1×10^{5}	1.7×10^{5}	2.8×10^{5}	3.8×10^{5}	5.4x1

Area 'A' resulting from growth curves in particulate iron experiments

Experiment Vessel	A Area	B Area	C Area
A	$1.35x10^8$	$1.02x10^8$	$5.48x10^8$
B	$1.39x10^8$	$1.0x10^8$	$5.2x10^8$
C	$1.47x10^8$	$1.06x10^8$	$2.66x10^8$
D	$1.69x10^8$	$1.19x10^8$	$2.85x10^8$
E	$9.49x10^7$	$7.71x10^7$	$1.26x10^8$
F	$9.67x10^7$	$6.67x10^7$	$1.17x10^8$
G	$7.6x10^7$	$5.46x10^7$	$6.21x10^8$
H	$6.22x10^7$	$5.5x10^7$	$6.52x10^7$
I	$6.59x10^7$	$5.08x10^7$	$5.26x10^7$
J	$6.46x10^7$	$5.68x10^7$	$5.21x10^7$
K	$6.02x10^7$	$4.9x10^7$	$4.3x10^7$
L	$5.77x10^7$	$4.27x10^7$	$4.22x10^7$
M	$5.33x10^7$	$3.82x10^7$	$2.76x10^7$
N	$5.47x10^7$	$3.58x10^7$	$2.68x10^7$

II (u) Summary of results from 48hour toxicity tests on *Daphnia* in ferric iron

Summary of daphnid acute toxicity tests in dissolved iron

Nominal Fe (mg/l)	Measured Fe (mg/l) To	Measured Fe (mg/l) Ti	No. tested	24hr dead	48hr dead	Percentage mortality
0.00	0.00	0.00	48	0	3	6.25
0.10	0.01	0.06	24	0	3	12.50
0.30	0.32	0.08	48	2	3	10.42
0.45	0.46	0.09	48	1	5	12.50
0.55	0.53	0.09	24	1	1	8.34
0.85	0.86	0.42	48	1	4	10.42
0.60	0.86	0.06	48	1	5	16.70

Summary of daphnid acute toxicity tests in particulate iron

Nominal Fe (mg/l)	Measured Fe (mg/l)	No. tested	24hr dead	48hr dead	Percentage mortality
0.00	0.00	72	0	7	9.73
1.00	1.04	24	0	2	8.34
2.00	1.98	48	8	8	16.67
8.00	8.29	48	1	4	8.84
10.00	10.84	24	10	14	58.34
15.00	15.93	72	27	45	62.50
25.00	25.48	72	53	70	97.23
30.00	31.14	48	42	48	100.00
50.00	50.56	24	23	24	100.00

II (v) Iron content of test concentrations in laboratory investigations

Dissolved iron in Jaworski's medium

Ferric sulphate (mg/l)	Dissolved iron concentratrion					Mean Fe	S.E.
0	0.06	0.06	0.05	0.08	0.07	0.064	0.0015
0.348	0.08	0.09	0.08	0.08	0.07	0.08	0.0005
0.657	0.09	0.08	0.08	0.09	0.08	0.084	0.0003
1.02	0.09	0.09	0.1	0.08	0.09	0.09	0.0005
1.264	1.2	1.36	1.25	1.14	1.19	1.23	0.004
1.547	1.6	1.43	1.45	1.57	1.71	1.56	0.012
1.71	2	2.15	2.23	1.97	1.99	2.07	0.013

Particulate iron in Jaworski's medium

Ferric sulphate (mg/l)	Particulate iron concentratrion					Mean Fe	S.E.
0	0.07	0.05	0.05	0.04	0.06	0.05	0.005
0.348	57.2	64.8	51.3	67.1	60.8	60.25	3.65
0.657	112.8	132.4	108.3	109.4	117.9	116.16	24.8
1.02	154.4	187.3	191.2	191.1	176.8	180.18	7.03
1.264	223.9	191.8	247.1	241.8	211.1	223.14	10.12
1.547	278.6	241.1	263.7	294.3	289.6	273.46	9.65
1.71	379.4	297.6	334.4	263.8	259.8	306.96	22.57

Dissolved iron acute tests on *Daphnia longispina*

Ferric sulphate (mg/l)	Dissolved iron concentratrion					Mean Fe	S.E.
0	0.07	0.06	0.06	0.05	0.08	0.07	0.005
14	0.13	0.05	0.14	0.05	0.12	0.098	0.002
21	0.21	0.37	0.31	0.36	0.28	0.306	0.004
64	0.43	0.51	0.35	0.44	0.42	0.43	0.003
107	0.46	0.44	0.57	0.59	0.61	0.534	0.006
178	0.76	0.79	0.93	0.84	0.82	0.828	0.004
357	1.21	1.34	0.94	0.96	0.99	1.088	0.031

Particulate iron acute tests on *Daphnia longispina*

Ferric sulphate (mg/l)	Particulate iron concentratrion					Mean Fe	S.E.
0	0.06	0.05	0.07	0.04	0.05	0.07	0.005
4	0.54	0.43	0.74	0.62	0.47	0.57	0.015
14	2.41	2.12	1.71	1.54	1.83	1.92	0.119
21	2.89	3.43	3.21	2.94	2.78	3.05	0.07
57	8.24	8.21	7.69	7.84	7.91	7.98	0.057
64	9.52	8.36	8.49	9.76	9.21	9.07	0.468
71	10.63	10.21	9.62	9.64	10.36	10.02	0.201
107	14.31	14.69	15.91	15.36	15.34	15.12	0.393
178	25.41	24.36	25.13	25.48	23.94	24.86	0.213
214	28.91	28.99	32.46	31.69	32.29	30.87	3.148
357	50.52	52.44	48.17	49.63	49.77	50.11	2.596

Particulate iron chronic tests on *Daphnia longispina*

Nominal iron conc (Fe mg/l)	Test	Particulate iron		Mean	S.E.
0	a	0.07	0.07	0.07	
0	b	0.068	0.072	0.07	
0.5	a	0.664	0.692	0.678	0.0004
0.5	b	0.685	0.653	0.669	0.0005
2	a	1.971	1.927	1.949	0.0009
2	b	1.984	1.968	1.976	0.0001
3	a	2.704	2.952	2.828	0.031
3	b	2.721	2.975	2.848	0.032
9	a	8.863	8.585	8.724	0.038
9	b	8.702	8.93	8.816	0.026
15	a	15.999	15.885	15.942	0.006
15	b	15.684	16.17	15.927	0.118

II (w) Results of chronic toxicity tests on *Daphnia longispina*

Ferric sulphate test a

Vessel	Dead	Neonates	Vessel	Dead	Neonates
Day 4			38		6
22	*		39		2
28	*		Day 15		
52	*		2		8
58	*		4		8
Day 6			5		7
1	*		13	*	
3		4	21		3
5		4	31		2
8		6	33		2
11	*		37		4
29	*		42	*	
30	*		45	*	
32	*		Day 16		
34	*		3		9
35	*		7		7
41	*		8		8
43	*		9		6
46	*		17	*	
49	*		19		3
50	*		20		2
54	*		24	*	
55	*		26	*	
59	*		60	*	
Day 7			Day 12		3
2		8			
4		6			
Day 8					
7		9			
9		7			
12		3			
Day 9					
23		3			
Day 10					
6	*				
14		4			
25		2			
Day 12					
10	*				
15		3			
Day 13					
36		3			
40		2			
Day 14					
16		6			
19		3			
27		2			

Ferric sulphate test b

Vessel	Dead	Neonates
Day 3		
2		6
4		6
13		1
14		4
15	*	
Day 4		
23	*	
25	*	
30	*	
35	*	
50	*	
57	*	
Day 5		
12	*	
52	*	
59	*	
Day 6		
2		4
3		2
5	*	
26	*	
29	*	
46	*	
Day 7		
4		6
6		4
9	*	
10		3
32	*	
38	*	
45	*	
53	*	
Day 8		
1		4
7		4
8		4
16		2
22		3
28	*	
56	*	
Day 9		
2		4
3		5
13		3
15		2
17		3
19		5
27	*	
44	*	
Day 10		
14		3
Day 11		
11		3
16		3
19		3
20		2
21		3
22		1
Day 13		
31	*	
39	*	
54	*	
55	*	
Day 14		
1		6
3		5
6		5
7		4
8		4
10		7
11		2
19		4
20		4
22		3
Day 15		
17		4
18		4
21		2
37	*	
Day 16		
2		6
10	*	
14		3
24		2
Day 18		
1		6
3		7
4		9
6		7
7		5
8		3
18		4
20		5
21		3
42		2
47		2
58	*	

China clay test a

Vessel	Dead	Neonates	Vessel	Dead	Neonates
Day 3			7		6
45	*		28		2
Day 4			Day 14		
33	*		1	*	
50	*		29	*	
Day 5			Day 15		
25	*		3		6
39	*		9		7
Day 6			10		7
2		7	12		4
3		6	15		4
4	*		16		3
5	6	37		2	
6	5	Day 17			
7		6	17		4
14	*		19		4
32	*		Day 18		
38	*		11		5
46	*		20		5
Day 7			22		4
1		6	23		3
10		6	36		2
13	*		Day 20		
24	*		35		2
Day 8			40		3
8		6	Day 21		
9		7	8		6
12		4			
15		4			
16		5			
19		2			
30	*				
41	*				
Day 9					
11		4			
17		3			
22		2			
23		2			
Day 12					
18	*				
21		3			
26		3			
27		3			
34		3			
44	*				
Day 13					
2		8			
5		5			
6		6			

China clay test b

Vessel	Dead	Neonates	Vessel	Dead	Neonates
Day 4			Day 13		
33	*		10		4
47	*		32		1
Day 5			Day 14		
42	*		1		6
44	*		2		6
Day 6			28		3
3		2	30		2
26	*		38		3
34	*		Day 15		
Day 7			4		7
1		5	5		6
6		6	6		6
4		6	7		6
11	*		8		6
14	*		15	*	
19	*		Day 16		
23	*		13		4
36	*		Day 17		
48	*		16		4
Day 8			17		5
5		5	18		6
6		6	20		4
7		5	38		2
8		5	Day 18		
13		3	7	*	
16		3	21		2
25		3	24		3
Day 9			25		3
7		6	39		2
12		3	Day 19		
15		3	40		2
17		3	Day 20		
18		4	27		3
20		3	Day 21		
21		2	1		7
24		3	2		7
27		2	9		7
Day 10			10		5
15	*				
22	*				
Day 11					
29	*				
35		2			
Day 12					
31	*				

II (x) Effect of ferric sulphate and china clay on feeding of *Daphnia*

Thoracic appendage beat rates of *Daphnia* in ferric sulphate and china clay

Test medium	Concentration (mg/l)	Thoracic beats per minute					No. ceased beating
0	0 (no food)	364.5	239.5	360.5	438.0	341.0	0
0	0 (with food)	380.0	336.0	347.0	360.5	381.0	0
Ferric	0.5	359.0	324.5	368.5	341.0	372.0	0
Ferric	1.0	316.5	290.5	150.5	270.5	256.5	3
Ferric	2.0	269.5	276.5	240.0	279.5	278.5	4
Ferric	8.5	280.0	287.0	196.0	336.5	220.5	5
Ferric	17.0	155.0	119.0	188.5	213.0	201.5	5
Ferric	30.0	164.5	155.5	135.5	148.0	170.5	6
China clay	1.5	350.5	333.5	387.5	299.0	304.5	0
China clay	25.0	302.0	310.5	354.0	307.0	394.5	0

Post-abdominal rejection rates of *Daphnia* in ferric sulphate and china clay

Test medium	Concentration (mg/l)	Rejections per minute				
0	0 (no food)	6.0	7.5	3.5	8.0	13.5
0	0 (with food)	8.0	7.5	6.0	7.0	6.5
Ferric	0.5	6.0	8.0	5.0	9.0	3.5
Ferric	1.0	22.0	19.5	22.0	7.0	10.5
Ferric	2.0	8.0	10.5	10.5	9.5	7.0
Ferric	8.5	9.0	7.5	11.0	7.0	21.0
Ferric	17.0	7.5	7.5	5.5	7.0	7.0
Ferric	30.0	5.5	9.0	8.5	7.0	5.5
China clay	1.5	9.0	9.5	8.0	12.5	10.5
China clay	25.0	9.5	10.5	12.0	13.0	11.5

II (y) Filtering area of *Daphnia* in ferric iron and china clay

Standard length (mm)	Calculated filtering area (mm2) in particulate iron					
	0mg/l Fe	0.5mg/l Fe	2mg/l Fe	3mg/l Fe	9mg/l Fe	15mg/l Fe
0.44				0.031		
0.46				0.027	0.031	0.034
0.47			0.029			0.031
0.48					0.033	0.035
0.49			0.03	0.031		
0.51					0.034	0.039
0.52		0.029			0.033	
0.53			0.031		0.036	
0.56					0.037	
0.57			0.034			0.044
0.58				0.033		
0.59			0.037	0.036		0.045
0.61				0.042		
0.63			0.038			0.044
0.64	0.033	0.034				0.052
0.66			0.036			
0.67			0.044			
0.68	0.036					
0.71			0.041			
0.74				0.044		
0.75	0.039					
0.78			0.05		0.052	0.06
0.83			0.049	0.044		
0.84			0.049			
0.89	0.046					
0.92	0.047					
0.97		0.05				
1.02		0.054				0.094
1.06		0.056				
1.11				0.06		
1.12						0.114
1.17						0.109
1.19						0.113
1.22				0.077		
1.23				0.08		
1.24			0.075			0.124
1.26					0.102	
1.27					0.105	0.128
1.28				0.083		
1.29					0.104	
1.31		0.076			0.106	
1.32				0.086		0.138
1.33			0.083			0.144
1.34		0.078			0.109	
1.35				0.085		
1.36						0.145
1.37		0.08				
1.38	0.071			0.092	0.104	

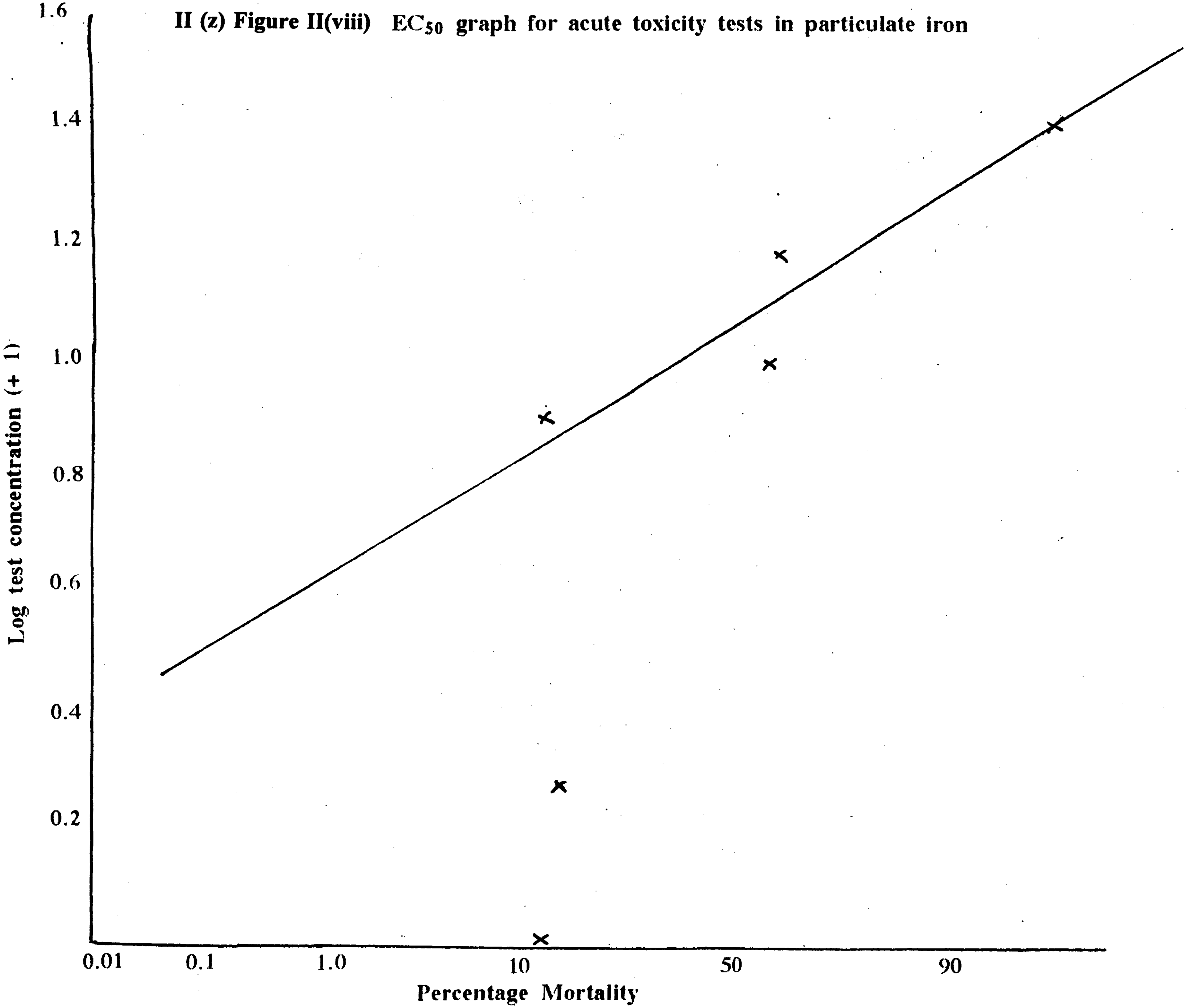
Calculated filtering area (mm2) in particulate iron

Standard length (mm)	0mg/l Fe	0.5mg/l Fe	2mg/l Fe	3mg/l Fe	9mg/l Fe	15mg/l Fe
1.42	0.073		0.094		0.11	
1.43					0.113	
1.44				0.096	0.116	
1.45			0.091			
1.46				0.097		
1.47	0.081		0.093	0.098		
1.48	0.083	0.082	0.09			
1.49				0.1		
1.51	0.084					
1.53		0.083	0.096			
1.54	0.08	0.083				
1.55	0.086					
1.57		0.09				
1.58	0.087					
1.59		0.092				
1.61	0.09	0.095				
1.62	0.093					
1.64	0.09					
1.67	0.09	0.099				
1.68	0.086					
1.69		0.102				
1.72		0.105				
1.74		0.107				

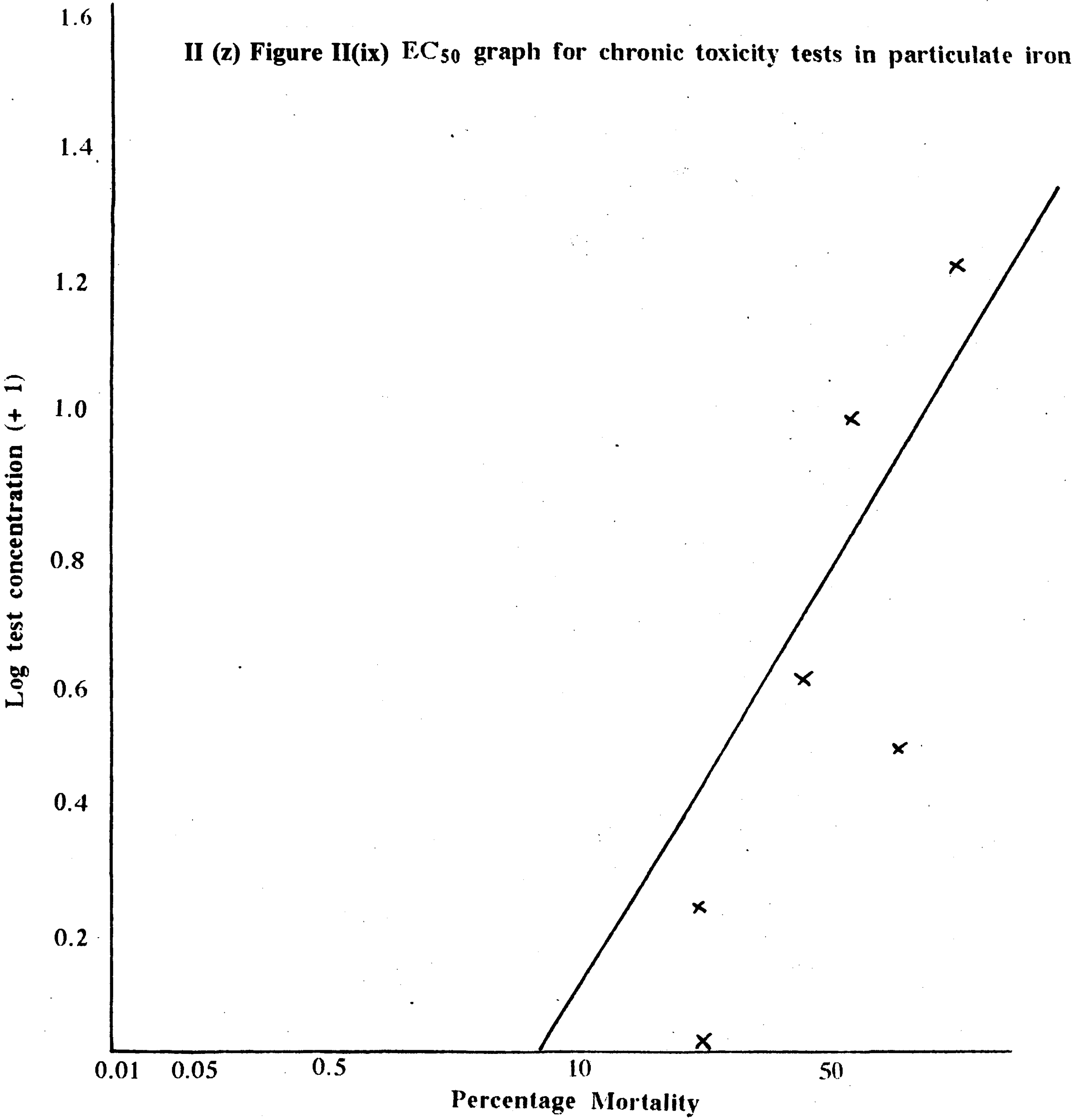
Standard length (mm)	Calculated filtering area (mm2) in china clay 0mg/l DW China clay	0.1mg/l DW China	1.2mg/l DW China	2.0mg/l DW China	7.0mg/l DW China
0.48					0.033
0.49					0.034
0.52					0.036
0.54				0.033	
0.57				0.033	0.037
0.59					0.039
0.6			0.037		
0.61				0.039	
0.63			0.038	0.041	
0.64	0.033	0.034	0.038	0.04	0.039
0.66		0.035			0.046
0.67		0.037			
0.68	0.036				
0.71			0.042		0.05
0.75	0.039				
0.78		0.041			
0.84		0.046			
0.86					0.055
0.88			0.051		
0.89	0.046			0.045	
0.92			0.052		
1.02		0.054			
1.11					0.07
1.16				0.061	
1.18					0.074
1.2	0.047				0.079
1.21			0.074	0.077	
1.24			0.076	0.081	
1.29		0.075	0.082	0.083	0.105
1.31			0.084	0.086	
1.32			0.082		0.112
1.33				0.087	
1.34				0.088	
1.35			0.087		
1.36			0.088	0.092	
1.37		0.081			
1.38	0.071		0.087	0.095	0.111
1.39		0.082	0.093		
1.4		0.087			
1.41					0.121
1.42	0.073				0.122
1.44					
1.47	0.081				
1.48	0.083				
1.51	0.084	0.088			
1.53		0.085			
1.54	0.08				
1.55	0.086				

Standard length (mm)	Calculated filtering area (mm2) in china clay 0mg/l DW China clay	0.1mg/l DW China	1.2mg/l DW China	2.0mg/l DW China	7.0mg/l DW China
1.56		0.085			
1.58	0.087	0.09			
1.61	0.09	0.096			
1.62	0.093				
1.63					
1.64	0.09	0.093			
1.66					
1.67	0.09				
1.68	0.086	0.094			

II (z) Figure II(viii) EC_{50} graph for acute toxicity tests in particulate iron



II (z) Figure II(ix) EC_{50} graph for chronic toxicity tests in particulate iron



Bibliography

ABRAHAM, F.S.H., & COLLINS, L. (1981). The Foxcote Reservoir - Toxicity of ferric and aluminium sulphates to trout. Anglian Water Authority.

ADEMA, D. M. M. (1978). *Daphnia magna* as a test animal in acute and chronic toxicity tests. Hydrobiologia, 59 (2), 125-134.

ALLNUTT, F. C. T., & BONNER, W. D. (1987a). Characterisation of iron uptake from ferrioxamine B by *Chlorella vulgaris.* Plant Physiology (Bethesda), 85 (3), 746-750.

ALLNUTT, F. C. T., & BONNER, W. D. (1987b). Evaluation of reductive release as a mechanism for iron uptake from ferrioxamine B by *Chlorella vulgaris.* Plant Physiology (Bethesda), 85 (3), 751-756.

ANON (1990). Methods manual for Quickchem automated ion analyser. Lachat Instruments.

ARNOLD, D. E. (1971). Ingestion, assimilation, survival and reproduction by *Daphnia pulex* fed seven species of blue-green algae. Limnology and Oceanography, 16 (6), 906-920.

ARTHUR, J. W., & LEONARD, E. N. (1970). Effects of copper on *Gammarus pseudolimnaeus, Physa integra* and *Campeloma decism* in soft water. Journal of Fisheries Research Board of Canada, 27, 1277-1238.

BAIRD, D. J., BARBER, I., & CALOW, P. (1990). Clonal variation in general responses of *Daphnia magna* Straus to toxic stress I. Chronic life-history effects. Functional Ecology, 4, 399-407.

BALISTRIERI, L. S., MURRAY, J. W., & PAUL, B. (1992). The cycling of iron and manganese in the water column of Lake Sammanish, Washington. Limnology & Oceanography, 37 (3), 510-528.

BANSE, K. (1991). Rates of phytoplankton cell division in iron enrichment experiments. Limnology and Oceanogarphy, 36 (8), 1886-1898.

BARANATHANITT, J., COCKRELL, D. J., & JOHN, P. H. (1982). The effects of Langmuir circulation on the distribution and settling of algae and suspended particles. Hydrobiologia, 88, 88.

BARBER, I., BAIRD, D. J., & CALOW, P. (1990). Clonal variation in general responses of *Daphnia magna* Straus to toxic stress. II. Physiological effects. Functional Ecology, 4, 409-414.

BECKER, A. J., & KELLER, E. C. (1973). The effects of iron and sulphate compounds on the growth of *Chlorella vulgaris.* Proceedings of West Virginia Academy of Science, 45 (2), 127-135.

BENNDORF, J. (1987). Food web manipulation without nutrient control: A useful strategy in lake restoration? Schweizerische Zeitung Hydrologie, 49, 237-248.

BENNDORF, J., & HENNING, M. (1989). *Daphnia* and toxic blooms of *Microcystis aeruginosa* in Bautzen Reservoir GDR. Internationale Revue der gesamten Hydrobiologia, 74 (3), 233-248.

BENNDORF, J., & HORN, W. (1985). Theoretical considerations on the relative importance of food limitation and predation in structuring zooplankton communities. Archives für Hydrobiologia, 21, 383-396.

BENNDORF, J., SCHULTZ, H., BENNDORF, A., UNGER, R., PENZ, U., KNESCHKE, H., KOSSATZ, K., DUMKE, R., HORNIG, U., KRUSPE, R., & REICHEL, S. (1988). Food web manipulation by enhancement of piscivorous fish stocks: Long-term effects in the hypertrophic Bautzen Reservoir. Limnologica (Berlin), 19 (1), 97-110.

BERN, L. (1990). Size-related discrimination of nutritive and inert particles by freshwater zooplankton. Journal of Plankton Research, 12 (5), 1059-1067.

BIESINGER, K. E., & CHRISTENSEN, G. M. (1972). Effects of various metals on survival, growth, reproduction and metabolism of *Daphnia magna*. Journal of Fisheries Research Board of Canada, 29, 1691-1700.

BJORK, S. (1985). Scandinavian lake restoration activities. In: EWPC ASSOCIATION (Eds.). Lake pollution and recovery. Pp293-301. EWPC Association, Rome.

BJORK, S. (1994). Lake Trummen, Sweden. In: M EISELOTOVÁ (Ed.). Restoration of lake ecosystems - A holistic approach. pp130-140. International Waterfowl Research Bureau Publication no. 32. Slimbridge, Gloucestershire.

BODAR, C. W. M., SLUIS, I. V. D., MONTFORT, J. C. P. V., VOOGT, P. A., & ZANDEE, D. I. (1990). Cadmium resistance in *Daphnia magna*.. Aquatic Toxicology, 16, 33-40.

BÖSTROM, B., ANDERSEN, J.M., FLEISCHER, S., & JANSSON, M. (1988). Exchange of phosphorus across the sediment-water interface. Hydrobiologia, 170, 229-244.

BOTTRELL, H. H., DUNCAN, A., GLIWICZ, Z., GRYGIEREK, E., HERZIG, A., HILLBRICHT-ILLKOWSKA, A., KURASAWA, H., LARSSON, P., & WEGLENSKA, T. (1976). A review of some problems in zooplankton production studies. Norwegian Journal of Zoology, 24, 419-456.

BOYT, F.L. (1977). Removal of nutrients from treated municipal wastewater by wetland vegetation. Journal of the Water Pollution Control Federation, 48, 789.

BRAND, L. E. (1991). Minimum iron requirements of marine phytoplankton and the implications for the biogeochemical control of new production. Limnology and Oceanography, 36 (8), 1756-1771.

BREEN, P.F. (1990). A mass balance method for assessing the potential of artificial wetlands for waste water treatment. Water Research, 24 (6), 689-697.

BRENDELBERGER, H. (1985). Filter mesh-size relations and retention efficiency for small particles: comparative studies with Cladocera. Archive für Hydrobiologia, 21, 135-146.

BRETT, M. T. (1993). Resource quality effects on *Daphnia longispina* offspring fitness. Journal of Plankton Research, 15 (4), 403-412.

BROOKSEN, R. W., DAVIS, G. E., & WARDEN, C. E. (1970). Analysis of trophic processes on the basis of density-dependent functions. In J. H. STEELE (Ed.), Marine Food Chains Edinburgh: Oliver and Boyd.

BRUNGS, W. A. (1969). Chronic toxicity of zinc to the fathead minnow *Pimephales promelas* Rafinesque. Transactions of American Fisheries Society, 98, 272-279.

BUMA, A. G. J., de BARR, H. J. W., NOLTING, R. F., & Van BENNEKOM, A. J. (1991). Metal enrichment experiments in the Weddell-Scotia seas: Effects of iron and manganese on various plankton communities. Limnology and Oceanography, 36 (8), 1865-1878.

BURNS, C. W. (1968). Direct obsrevations of mechanism regulating feeding behaviour of *Daphnia* in lakewater. Internationale Revue der gesamten Hydrobiologie, 53 (1), 83-100.

BURNS, F.L. (1981). Comment. In: F.L.BURNS & I.J. POWLING (Eds.). Destratification of lakes and reservoirs to improve water quality. pp274. Department of National Development & Energy, Australian Water Resources Council, Australian Government Publishing Service, Melbourne, Australia.

BURNS, C. W., & RIGLER, F. H. (1967). Comparison of filtering rates of *Daphnia rosea* in lake water and in suspensions of yeast. Limnology and Oceanography, 12, 492-502.

CAMPBELL, R. C. (1990). Staitistics for Biologists (3rd edition). Cambridge University Press. 446pp.

CARPENTER, S. R., KITCHELL, J. F., & HODGSON, J. R. (1985). Cascading trophic interactions and lake productivity. Bioscience, 35, 634-639.

CARRILLO, P., L., C.-P., & SANCHEZ-CASTILLO, P. (1990). Analysis of phytoplankton-zooplankton relationships in an oligotrophic lake under natural and manipulated conditions. Hydrobiologia, 200/201, 49-58.

CARVALHO, G. R., & CRISP, D. T. (1987). The clonal ecology of *Daphnia magna* (Crustacea: Cladocera). I Temporal changes in the clonal structure of a natural population. Journal of Animal Ecology, 56, 453-468.

CARVALHO, G. R., & HUGHES, R. N. (1983). The effect of food availability, female culture density and photoperiod on ephippia production in *Daphnia magna* Straus (Crustacea: Cladocera). Freshwater Biology, 13, 37-46.

CASSIE, R.M. (1971). Sampling and Statistics. In: W.T. EDMONDSON & G.G. WINBERG (Eds.). A Manual on methods for the assessment of secondary productivity in freshwaters. IBP Handbook 16. Blackwell, Oxford.

CHANDINI, T. (1991). Reproductive value and the cost of reproduction in *Daphnia cainata* and *Ecvhinisca triserialis* (Crustacea: Cladocera) exposed to food and cadmium stress. Bulletin of Environmental Contamination and Toxicology, 47, 76-83.

CHECKLEY, D. M. (1985). Nitrogen limitation of zooplankton production and its effect on the marine nitrogen cycle. Archive für Hydrobiologia, 21, 103-113.

CHRISTIE, P. (1983). A taxanomic reappraisal of the *Daphnia hyalina* complex (Crustacea: Cladocera): An experimental and ecological approach. Journal of Zoology (London), 199, 75-100.

CLARKE, K.B. & WALSBY, A.E. (1988). Improvements in the treatment of water to remove gas vacuole cyanobacteria. UK Patent Application 2 196 330A.

COALE, K. H. (1991). Effects of iron, manganese, copper and zinc enrichments on productivity and biomass in the subarctic Pacific. Limnology and Oceanography, 36 (8), 1851-1864.

CODD, G. A., & BEATTIE, K. A. (1991). Cyanobacteria (blue-green algae) and their toxins: awareness and action in the United Kingdom. Public Health Laboratory Service Microbiology Digest, 8 (3), 82-86.

COKER, R. E., & HAYES, J. W. (1940). Biological observations in Mountain Lake Virginia. Ecologia, 21, 192-198.

COLEBROOK, J. M. (1960a). Plankton and water movements in Windermere. Journal of Animal Ecology, 29, 217-240.

COLEBROOK, J. M. (1960b). Some observations of zooplankton swarms in Windermere. Journal of Animal Ecology, 29, 241-242.

COLLINGWOOD, R.W. (1977). A survey of eutrophication in Britain and its effects on water supplies. Technical Report TR40, Water Research Centre, Medmenham.

COOKE, G.D., WELCH, E.B., PETERSEN, S.A., & NEWROTH, P.R. (1993). Restoration and management of lakes and reservoirs. (2nd Edition), Lewis, Boca Raton, FA.

COWGILL, U. M. (1987). Critical analysis of factors affecting the sensitivity of zooplankton and the reproducibility of toxicity test results. Water Research, 21 (12), 1453-1462.

CRITTENDEN, R. N. (1981). Morphological characteristics and dimensions of the filter structures from 3 species of *Daphnia* (Cladocera). Crustaceana, 41, 233-248.

DALDORPH, P. & PRICE, R. (1994). Long term phosphorus control at three reservoirs in south-eastern

England. Archive für Hydrobiologia, 40, 231-243.

DALZELL, D. (1996). Regional Operational Investigation 567: Toxicity of iron sulphate to Brown Trout *Salmo trutta* L. PhD. Thesis, Nottingham Trent University.

DAVIES, I. J. (1984). Sampling aquatic insect emergence. In J. A. DOWNING, & F. H. RIGLER (Ed.), A Manual on Methods for the Assessment of Secondary Productivity in Freshwaters. IBP Handbook 17. Blackwell Scientific Publications. 161-222.

DAVISON, W., & TIPPING, E. (1984). Treading in Mortimers footsteps: the geochemical cycling of iron and manganese in Esthwaite Water. 52nd Annual Report Freshwater Biological Association, 91-101.

DAWIDOWICZ, P. (1990). The effect of *Daphnia* on filament length of blue-green algae. Hydrobiologia, 191, 265-268.

DAWIDOWICZ, P., & LOOSE, C. J. (1992). Metabolic costs during predator-induced diel vertical migration of *Daphnia*. Limnology and Oceanography, 37 (8), 1589-1595.

de ANGELIS, D.L. (1980). Energy flow, nutrient cycling, and ecosystem resilience. Ecology, 61, 764-771.

de BERNARDI, R. (1974). The dynamics of a population of *Daphnia hyalina* Leydig in Lago Maggiroe, Northern Italy. Memorie Dell'istituto Italiano di Idrobiologia, 31, 221-243.

de BERNARDI, R., & GIUSSANI, G. (1990). Are blue-green algae a suitable food for zooplankton? An overview. Hydrobiologia , 200/201, 29-41.

DECKER, C., & MENENDEZ, R. (1974). Acute toxicity of iron and aluminium to Brook Trout. Proceedings of West Virginia Academy of Science, 46 (2), 159-167.

DeMOTT, W. R. (1982). Feeding selectivities and relative ingestion rates of *Daphnia* and *Bosmina*. Limnology and Oceanography, 27 (3), 518-527.

DeMOTT, W. R. (1985). Relations between filter mesh-size, feeding mode, and capture efficiency for cladocerans feeding on ultrafine particles. Archive für Hydrobiologia, 21, 125-134.

DINI, M. L., & CARPENTER, S. R. (1992). Fish predators, food availability and diel vertical migration in *Daphnia*. Journal of Plankton Research, 14 (3), 359-377.

DONAGHAY, P. L. (1985). An experimental test of the relative significance of food quality and past feeding history to limitation of egg production of the estuarine copepod *Acartia tonsa*. Archive für Hydrobiologia, 21, 235-245.

DUNCAN, A. (1975a). The importance of zooplankton in the ecology of reservoirs. Proceedings of Symposium on the Effects of Storage on Water Quality, 247-272.

DUNCAN, A. (1975b). Production and biomass of three species of *Daphnia* co-existing in London Reservoirs. Verhandlüngen Internationale Vereinigung für Theoretische und Angewandte Limnologie, 19, 2358-2867.

DUNNETT, C. W. (1955). A multiple comparison procedure for comparing several treatments with a control. Journal of American Statistics Association, 50, 1096-1121.

EKMAN, S. (1947) Ueber die Festigkeit der marinen Sedimente als Factor der Tierverbreitung, ein Beitrag zur. Associations Analyse Zoologische Bidreft, Uppsala, 25.

EDMONDSON, W.T. (1965). Reproductive rate of plantonic rotifers as related to food and temperature in nature. Ecological Monographs, 35, 61-111.

EDMONDSON, W. T. (1968). A graphical model for evaluating the use of the egg ratio for measuring birth and death rates. Oecologia, 1, 1-37.

EGLOFF, D. A., & PALMER, D. S. (1971). Size relations of the filtering areas of two *Daphnia* species. Limnology and Oceanography, 16, 900-905.

ENSERINK, L., LUTTMER, W., & MAAS-DIEPVEEN, H. (1990). Reproductive strategy of *Daphnia magna* affects the sensitivity of its progeny in acute toxicity tests. Aquatic Toxicology, 17, 15-26.

FAAFENG, G., & BRABAND, A. (1990). Biomanipulation of a small, urban lake - removal of fish to exclude blue-green blooms. Verhandlüngen Internationale Vereinigung für Theoretische und Angewandte Limnologie, 24, 597-620.

FERGUSON, A.J.D. & HARPER, D.M. (1982). Rutland Water phytoplankton: The development of an asset or a nuisance? Hydrobiologia, 88, pp117-133.

FERGUSON, A. J. D., THOMPSON, J. M., & REYNOLDS, C. S. (1982). Structure and dynamics of zooplankton communities maintained in closed systems, with special reference to the algal food supply. Journal of Plankton Research, 4 (3), 523-543.

FLOSSNER, D. & KRAUS, K. (1986). On taxonomy of the *Daphnia hyalina galeata* complex. Hydrobiologia, 137, 97-115.

FOTT, J., KORINEK, V., PRAZAKOV'A, M., VODRUS, B., & FOREJT, K. (1974). Seasonal development of phytoplankton in fish ponds. Internationale Revue gesamten Hydrobiologie, 59, 629-664.

FOY, R. H. (1985). Phosphorus inactivation in a eutrophic lake by the direct addition of ferric aluminium sulphate: impact on iron and phosphorus. Freshwater Biology, 15 , 613-629.

FRALEIGH, P.C. & BURNHAM, J.C. (1988). Myxoccal predation on cyanobacterial populations: nutrient effects. Limnology & Oceanography, 33, 476-483.

FROELICH, P.V. (1988). Kinetic control of dissolved phosphates in natural rivers and estuaries: A primer on the phosphate buffer mechanism. Limnology & Oceanography, 33 (4), 649-669.

GALBRAITH, M. G. (1967). Size-selective predation on *Daphnia* by rainbow trout and yellow perch. Transactions of American Fisheries Society, 96, 1-10.

GEERTZ-HANSEN, P., & MORTENSEN, E. (1983). Okkers virkning pa reproduktionen hos orred (*Salmo trutta*). Vatten, 39, 55-62.

GELLER, W. (1985). Production, food utilization and losses of two coexisting, ecologically different *Daphnia* species. Archive für Hydrobiologia, 21, 67-79.

GELLER, W., & MULLER, H. (1981). The filtration apparatus of Cladocera. Filter mesh-sizes and their implications on food selectivity. Oecologia (Berlin), 49, 316-321.

GEORGE, D. G. (1972). Zooplankton studies on a eutrophic reservoir. Ph.D., University of Wales Institute of Science and Technology,

GEORGE, D. G., & EDWARDS, R. W. (1974). Population dynamics and production of *Daphnia hyalina* in a eutrophic reservoir. Freshwater Biology, 4, 445-465.

GEORGE, D. G., & EDWARDS, R. W. (1976). The effect of wind on the distribution of phytoplankton in a small productive lake. Journal of Applied Ecology, 13, 667-690.

GEORGE, D. G., & HEANEY, S. I. (1978). Factors influencing the spatial distribution of phytoplankton in a small productive lake. Journal of Ecology, 66, 133-155.

GERHARDT, A. (1992). Effects of subacute doses of iron (Fe) on *Leptophlebia marginata* (Insecta: Ephemeroptera). Freshwater Biology, 27, 79-84.

GLIWICZ, J. M., & RYKOWSKA, A. (1992). 'Shore avoidance' in zooplankton: a predator- induced behaviour or predator- induced mortality. Journal of Plankton Research, 14 (9), 1331-1342.

GLIWICZ, Z. B., & PREJS, A. (1977). Can planktivorous fish keep in check planktonic crustacean populations? A test of size-efficiency hypothesis in typical Polish lakes. Ecologia Polska, 25 (4), 567-591.

GLIWICZ, Z. M. (1977). Food size selection and seasonal succession of filter-feeding zooplankton in an eutrophic lake. Ekologia Polska, 25 (2), 179-225.

GLIWICZ, Z. M. (1990). *Daphnia* growth at different concentrations of blue-green filaments. Archive für Hydrobiologia, 120 (1), 51-55.

GLIWICZ, Z. M., & LAMPERT, W. (1990). Food thresholds in *Daphnia* species in the absence and presence of blue-green filaments. Eology, 71(2), 691-702.

GOHLKE, A.F. (1972). Algal control with copper sulphate: A literature review. Paper presented to the Committee on Coagulation of the American Water Works Association December 18, 1972.

GOPHEN, M., & POLLONGHER, U. (1985). Relationship between food availability, fish predation and the abundance of the herbivorous zooplankton community in Lake Kinnert. Archive für Hydrobiologia, 21, 397-405.

GULATI, R. D. (1990). Zooplankton structure in the Loosdrecht lakes in relation to trophic status and recent restoration measures. Hydrobiologia, 191, 173-188.

GULATI, R.D. & DeMOTT, W.R. (1997) The role of food quality for zooplankton: remarks on the state of the art, perspectives and priorities. Freshwater Biology, 38 (3) 753-768.

GUTELMAKHER, B. L., & MAKARTSEVA, E. S. (1990). The significance of zooplankton in the cycling of phosphorus in lakes of different trophic categories. Internationale Revue der gesamten Hydrobiologia, 75 (2), 143-151.

HMSO (1979) Atomic absorption spectrophotometry

HMSO (1980). Phosphorus in waters, effluents and sewage. Methods for the examinaltion of waters and associated materials. HMSO.

HMSO (1981a). Flow injection analysis.

HMSO (1981b). The determination of alkalinity and acidity in water.

HMSO (1981c). Oxidised nitrogen in water.

HMSO (1983). Iron and manganese in potable waters by atomic absorption spectophotometry.

HMSO (1985). Methods for the examination of waters and associated materials. HMSO 45pp.

HAIRSTON, N. G., SMITH, F. E., & SLOBODKIN, L. B. (1960). Community structure; population control and competition. American Naturalist, 94, 421-425.

HALL, D. J. (1964). An experimental approach to the dynamics of a natural population of *Daphnia galeata* Mendotae. Ecology, 45 (1), 94-112.

HANEY, J. F. (1987). Field studies on zooplankton - cyanobacteria interactions. New Zealand Journal of Marine and Freshwater Research, 21, 467-475.

HANEY, J. F., & HALL, D. J. (1973). Sugar-coated *Daphnia* : a preservation technique for Cladocera. Limnology and Oceanography, 18, 331-333.

HANEY, J. F., & TROUT, M. A. (1985). Size selective grazing by zooplankton in Lake Titicaca. Archive für Hydrobiologia, 21, 147-160.

HANSON, J. M., & PETERS, R. H. (1984). Empirical prediction of crustacean zooplankton biomass and profundal macrobenthos biomass in lakes. Canadian Journal of Fisheries and Aquatic Sciences, 41, 439-445.

HARPER, D. M. (1978). Limnology of Rutland Water. Verhandlüngen Internationale Verinigung für Theoretiche und Angewandte Limnologie, 20, 1604-1611.

HARPER, D. M. (1992). Eutrophication of freshwaters, principles, problems and restoration.. London: Chapman and Hall.

HARPER, D. M., & FERGUSON, A. J. D. (1982). Zooplankton and their relationships with water quality and fisheries. Hydrobiologia, 88, 135-145.

HARPER, D.M, PACINI, N., & SANDERSON, R. (1995). Regional Operational Investigation 580: The feasibility of biomanipulation in reservoirs and deeper lakes. National Rivers Authority.

HART, R. C. (1992). Experimental studies of food and suspended sediment effects on growth and reproduction of six planktonic crustaceans. Journal of Plankton Research, 14 (9), 1425-1448.

HAURY, L. R. (1976). Method for restraining living planktonic crustaceans. Fishery Bulletin, 74, 220-221.

HEATHWAITE, A.L., BURT, T.P., & TRUDGILL, S.T. (1993). Overview - The nitrate issue. In: T.P. BURT, A.L HEATHWAITE, & S.T. TRUDGILL (Eds.). Nitrate - processes, patterns and management. John Wiley & Sons, Chichester. pp 3-21.

HECKY, R.E. & KILHAM, P. (1988). Nutrient limitation of phytoplankton in freshwater and marine environments: A review of recent evidence on the effects of enrichment. Limnology & Oceanography, 33, 796-822.

HERRINGTON, P. R. (1982). Escaping from prison: an economic reassessment of Rutland Water. Hydrobiologia, 88, 27-40.

HOLTAN, H., KAMP-NIELSEN, L., & STAUNES, A.O. (1988). Phosphorus in soil, water and sediment: An overview. Hydrobiologia 170, 19-34.

HOOPER, F.F. (1973). Origin and fate of organic phosphorus compounds in aquatic systems. In: E.J. GRIFFITH, A.BEETON, J.M. SPENCER (Eds.).pp179-199. Environmental Phosphorus Handbook. John Wiley & Sons.

HORNE, A.J. (1979). Management of lakes containing N_2 - fixing blue-green algae. Archive für Hydrobiologie, 13, 133-144.

HOSPER, S.H. MEIJER, M.L., & WOLKER, P.A. (1992). Handleiding actief biologisch beheer. Ministerie van Verkeer en Waterstaat (RIZA) & Organisatie der Verbetering van de Binnenvisserij, Lelystad, The Netherlands, 102pp.

HOSHI, T., & KOBAYASHI, K. (1972). Studies on physiology and ecology of plankton. xxvi Promotion of haemoglobin synthesis by iron in *Daphnia magna* cultered under low oxygen conditions. Scientific Report of Niigata University. Series D. (Biology), 9, 55-62.

HRBÁCEK, J. (1987). Syatematics and biogeography of *Daphnia* species. Memorie Dell'istituto Italiano Di Idrobiologia, 45, 31-35.

HRBÁCEK, J. (1994). Food web relations. In: M. EISELOTOVÁ (Ed.). Restoration of lake ecosystems: A holistic approach. International Waterfowl Research Bureau Publication 32, Slimbridge, pp 44-58.

HRBACEK, J., DESORTOV'A, B., & POPOVSKY, J. (1979). Influence of the fish state on the phosphorus - chlorophyll ratio. Verheft Internationale Verein Limnologie., 20, 1624-1636.

HRBACEK, J., & HRBACKOVA-ESSLOVA, M. (1960). Fish stock as a protective agent in the occurrence of slow developing dwarf species and strains of the genus *Daphnia*.. International Revue der gesamten Hydrobiologie, 45(3), 355-358.

HUNTER, P. R. (1991). Human illness associated with freshwater cyanobacteria (blue-green algae). Public Health Laboratory Service, 8 (3), 96-100.

HUTCHINSON, G. E. (1957). A Treatise on Limnology Volume 1: Geography, Physics and Chemistry. New York: Wiley.

IMBODEN, D.M. (1974). Phosphorus model in lake eutrophication. Limnology & Oceanography, 19, 297-304.

INFANTE, A. (1973). Untersuchungen über die Ausnutzbarkeit verschiedener Algaen durch das zooplankton. Archive für Hydrobiologia, Supplement 48, 340-405.

IRVINE, K., MOSS, B., & STANSFIELD, J. (1990). The potential of artificial refugia for maintaining a community of large-bodied cladocera against fish predation in a shallow eutrophication lake. Hydrobiologia, 200/201, 379-390.

JACKSON, G. A., & LOCHMANN, S. E. (1992). Effect of coagulation on nutrient and light limitation of an algal bloom. Limnology & Oceanography, 37 (1), 77-89.

JEPPESEN, E., SONDERGAARD, M., SORTKJAER, O., MORTENSEN, E., & KRISTENSEN, P. (1990). Interactions between phytoplankton, zooplankton and fish in a shallow hypertrophic lake: a study of phytoplankton collapses in Lake Sobygard, Denmark. Hydrobiologia, 191, 149-164.

JONES, M., FOLT, C., & GUARDA, S. (1991). Characterizing individual, population, and community effects of sublethal aquatic toxicants: An experimental case study using *Daphnia*. Freshwater Biology, 26, 35-41.

JORDAN, T.E., CORRELL, D.L., & WELLER, D.E. (1993). Nutrient interception by a riparian forest reciving inputs from adjacent cropland. Journal of Environmental Quality, 22 (3), 467-473.

JORGENSEN, S.E., NIELSEN, S.N. & JORGENSEN, L.A. (1981). Handbook of ecological parameters and ecotoxicology. Elsevier, Amsterdam.

JUNGMANN, D., HENNING, M., & JÜTTNER, F. (1991). Are the same compounds in *Microcystis* responsible for toxicity to *Daphnia* and inhibition of its filtering rate. Internationale Revue der gesamten Hydrobiologia, 76 (1), 47-56.

KAISER, K. L. E. (1980). Correlation and prediction of metal toxicity to aquatic biota. Canadian Journal of Aquatic Sciences, 37, 211-218.

KEEVIL, C. W. (1991). Toxicology and detection of cyanobacterial (blue-green algal) blooms. Public Health Laboratory Service, 8 (3), 91-95.

KELLER, E.C., HINTON, D.E., WERNER, D.K., GERBER, R.B., BECKER, A.J., WARGACKI, R., & HOBBS, G.R. (1984). The effect of iron in streams on gill morphology, oxygen consumption & phytoplankton and benthic invertebrate distribution. Water Research Institute. Morgan Town, New York.

van KESSEL, J.F. (1977). Removal of nitrate from effluent following discharge in surface water. Water Research, 11, 533-537.

KHANGOROT, B. S., & RAY, P. K. (1989). Investigation of correlation between physicochemical properties of metals and their toxicity to the water flea *Daphnia magna* Straus. Ecotoxicology and Environmental Safety, 18, 109-120.

KIORBOE, T., & HANSEN, J. L. S. (1993). Plankton aggregate formation: observations of patterns and mechanisms of cell sticking and the significance of exopolymeric material. Journal of Plankton Research., 15 (9), 993-1018.

KIRCHNER, W.B., & DILLON, P.J. (1975). An empirical model of estimating the retention of phosphorus in lakes. Water Resources Research, 11, 182-183.

KIRK, K. L. (1991). Suspended clay particles reduces *Daphnia* feeding rate: behavioural mechanisms. Freshwater Biology, 25 (2), 357-365.

KLAPPER, H. (1991). Control of Eutrophication in Inland Waters. Ellis Horwood Ltd. Chichester, UK. 337pp.

KLOTZ, R.L. (1985). Factors controlling phosphorus limitation in stream sediments. Limnology & Oceanography, 30, 543-553.

KNUDSEN. (1975). Chemistry of Iron. Acta Chamistry, Scandinavia, 29, 883.

KORINEK, V., KREPELOVA-MACHACKOVA, B., & MACHACEK, J. (1985). Filtering structures of cladocera and their ecological significance. II Relation between the concentration of the seston and their size of filtering combs in some species of *Daphnia* and *Ceriodaphnia*. Vestnik Ceskoslovenske Spolecnosti Zoologicke, 50, 244-258.

KORINEK, V., & MACHACEK, J. (1979). Filtering structures of cladocera and their ecological significance I *Daphnia pulicaria*. Vestnik Ceskoslovenske Spolecnosti Zoologicke., 44, 213-218.

KOZA, V., & KORINEK, V. (1985). Adaptability of the filtration screen in *Daphnia* : another answer to the selective pressure of the environment. Archive für Hydrobiologia, 21, 193-198.

LAMMENS, H. R. R., De NIE, H. W., & VIJVERBERG, J. (1985). Resource partitioning and niche shifts of bream (*Abramis brama*) and eel (*Anguilla anguilla*) mediated by predation of smelt (*Osmerus eperlanus*) on *Daphnia hyalina*. Canadian Journal of Fisheries and Aquatic Sciences, 42, 1342-1351.

LAMPERT, W. (1974). A method for determining food selection by zooplankton. Limnology and Oceanogarphy, 31, 478-490.

LAMPERT, W. (1984). The measurement of respiration. In J. A. DOWNING, & F. H. RIGLER (Ed.), A Manual on Methods for the Assessment of Secondary Productivity in Freshwaters. (pp. 413-468). Blackwell Scientific Publications.

LAMPERT, W. (1987). Laboratory studies on zooplankton - cyanobacteria interactions. New Zealand Journal of Marine and Freshwater Research, 21, 283-490.

LAMPERT, W. & BRENDELBERGER, H. (1996). Strategies of phenotypic low-food adaptation in *Daphnia*: Filter screens, mesh sizes, and appendage beat rates. Limnology & Oceanography, 41 (2), 216-223.

LAMPERT, W., & SCHOBER, U. (1980). The importance of 'threshold food concentrations'. In W. C. KERFOOT (Ed.), Evolution and Ecology of Zooplankton Communities (pp. 264-267). University Press, New England.

LANGELAND, A., KOKSVIK, J. I., & OLSEN, Y. (1985). Post-embryonic development and growth rates of *Daphnia galeata* Sars under natural food conditions. Verhandlungen der Internationale Vereinigung für Theoretische und Angewandte Limnologie, 22, 3124-3130.

LANGMUIR, I. (1938). Surface motion of water induced by wind. Science, 87, 119-123.

LETTERMAN, R. D., & MITSCH, W. J. (1978). Impact of mine drainage on a mountain stream in Pennsylvania. Environmental Pollution, 17 (1), 53-73.

LEVENTER, H., & TELTSCH, B. (1990). The contribution of Silver Carp (*Hypophthalmichthys molotrix*) to the biological control of Netofa reservoirs. Hydrobiologia, 191, 47-55.

LITCHFIELD, J. T., & WILCOXEN, F. (1949). A simplified method of evaluating dose-effect experiments. Journal of Pharmacology and Experimental Theory, 96, 99-113.

LUND, J. W. G. (1959). A simple counting chamber for nannoplankton. Limnology & Oceanography, 4 (1), 57-65.

LUND, J. W. G., KIPLING, C., & LE CREN, E. D. (1958). The inverted microscope technique of estimating algal numbers and statistical basis of estimations by counting. Hydrobiologia, 11, 143-170.

LUNDSTEDT, L., & BRETT, M. T. (1991). Differential growth rates of three cladoceran species in response to mono and mixed algal cultures. 36 (1), 159-165.

LYCHE, A. (1989). Plankton community response to reductions of planktivorous fish populations. A review of 11 case studies. Aqua Fennica, 19, 59-66.

LYNCH, D. W. (1981). Water quality management of storage reservoirs. Water, 7 (3), 24-28.

MACKENTHUN, K. M., & KEUP, L. E. (1970). Biological problems encountered in water supplies. Journal of Ammerican Waste Water Association., 62, 520-526.

MAFF (1991). Code of good agricultural practice for the protection of water. Ministry of Agriculture, Fisheries and Food, London.

MALLICK, N., & RAI, L. C. (1992). Impact of spectral quality on toxicity of iron in *Anabaena doliolum* and *Chlorella vulgaris.* Biomedical and environmental Sciences, 5, 65-75.

MALTBY, L., SNART, O. H., & CALOW, P. (1987). Acute toxicity tests on the freshwater isopod *Asellus aquaticus* using ferrous sulphate, with special reference to techniques and the possibility of intraspecific variation. Environmental Pollution, 43, 271-279.

MANCE, G., & CAMPBELL, J. A. (1988). Proposed Environmental Standards for List 2 Substances in Water. (Technical report 258). Water Research Centre, Medmenham, Bucks.

MARTIN, J. H., GORDON, R. M., & FITZWATER, S. E. (1991). The case for iron. Limnology and Oceanography, 36 (8), 1793-1802.

MATVEEV, V. (1985). Delayed density dependence and competitive ability in two cladocerans. Archive für Hydrobiologia, 21, 453-459.

MAYER, L. M. (1982). Retention of riverine iron in estuaries. Geochim Cosmochim Acta, 46, 1003-1009.

McKIM, J. M., & BENOIT, D. A. (1971). Effects of long-term exposures to copper on survival, growth and reproduction of Brook Trout (*Salvelinus fontinalis*). Journal of Fisheries Research Board of Canada, 28, 665-662.

McMAHON, J. W. (1965). Some physical factors influencing the feeding behaviour of *Daphnia magna* Straus. Canadian Journal of Zoology, 43, 603-611.

MCMAHON, J. W., & RIGLER, F. H. (1963). Mechanisms for regulating the feeding rate of *Daphnia magna* (Straus). Canadian Journal of Zoology, 41, 321-332.

MCMAHON, J. W., & RIGLER, F. H. (1965). Feeding rate of *Daphnia magna* Straus in different food labelled with radioactive phosphorus. Limnology and Oceanography, 10, 105-14.

MCQUEEN, D. J. (1990). Manipulating lake community structure: where do we go from here? Freshwater Biology, 23, 613-620.

McQUEEN, D. J., & POST, J. R. (1984). Effects of planktivorous fish on zooplankton, phytoplankton, and water chemistry. Proceedings of 4th Annual Conference of NALMS, 35-42.

McQUEEN, D.J., & POST, J. R. (1986). Trophic relationships in freshwater pelagic ecosystems. Canadian Journal of Fisheries and Aquatic Sciences, 43, 1571-1581.

MEHNER, T., SCHULTZ, H., BENNDORF, J., RITTER, P., & KNESCHKE, H. (1994). Die Talsperre Bautzen (Deutschland). Osterreichische Fischeri, 47, 204-211.

MILBRINK, G., & BENGTSSON, J. (1991). The impact of size-selective predation on competition between two *Daphnia* species: A laboratory study. Journal of Animal Ecology, 60, 1009-1028.

MOEGENBURG, S. M., & VANNI, M. J. (1991). Nutrient regeneration by zooplankton: effects on nutrient limitation of phytoplankton in a eutrophic lake. Journal of Plankton Research, 13 (3), 573-588.

MOORE, D. (1982). Establishing and maintaining the trout fishery at Rutland Water. Hydrobiologia, 88, 179-189.

MOREL, F. M. M., HUDSON, R. J. M., & PRICE, N. M. (1991). Limitation of productivity by trace metals in the sea. Limnology and Oceanography, 36 (8), 1742-1755.

MORTON, S. D., & LEE, T. H. (1974). Algal blooms: possible effects of iron. Environmental Science and Technology, 8 (7), 673-674.

MOSS, B. (1988). Ecology of Freshwaters: Man and Medium (2nd ed.). Oxford: Blackwell Scientific Publications.

MOSS, B. (1990). Engineering and biological approaches to the restoration from eutrophication of shallow lakes in which aquatic and plant communities are important components. Hydrobiologia, 200/201, 367-378.

MOSS, B. (1992). The scope for biomanipulation in improving water quality. In: D.W. SUTCLIFFE & J.G. JOHNES (Eds.). Eutrophication: Research and application to water supply. pp 73-81. Freshwater Biological Association, Ambeside.

MOUNT, D. I. (1968). Chronic toxicity of copper to fathead minnows (*Pimephales promelas* Rafinesqe). Water Research, 2, 215-223.

MOUNT, D. I., & STEPHAN, C. E. (1969). Chronic toxicity of copper to the fathead minnow (*Pimephales promelas*) in soft water. Journal of Fisheries Research Board of Canada, 26, 2449-2457.

MUCK, P. (1980). Feeding of freshwater filter-feeders at very low food concentrations: Poor evidence for 'threshold feeding' and 'optimal foraging' in *Daphnia longispina* and *Eudiaptomus gracilis*. Journal of Plankton Research, 2 (4), 367-379.

MUCK, P., & LAMPERT, W. (1984). Feeding of freshwater filter-feeders at very low concentrations: poor evidence for 'threshold feeding' and 'optimal foraging' in *Daphnia longispina, Eudiaptomus gracilis* and *Daphnia hyalina*. Archive für Hydrobiologia, Supplement 66, 157-179.

MUNZINGER, A., & MONICELLI, F. (1991). A comparison of the sensitivity of 3 *Daphnia magna* populations under chronic heavy metal stress. Ecotoxicology and Environmental Safety, 22, 24-31.

MURPHY, P. M. (1979). A manual for toxicity tests with frehwater macroinvertebrates and a review of the effects of specific toxicants. University of Wales, Institue of Science and Technology.

MUSCATT, A.D., HARRIS, G.L., BARLEY, S.W., & DAVIS, D.B. (1993). Buffer zones to improve water quality: A review of their potential use in agriculture. Agricultural Ecosystems and Environment, 45 (1-2), 59-77.

MYERS, R.J.K. (1992). The effect of sulphide on nitrate reduction in soil. Plants & Soils, 37, 431-433.

NAUMANN, E. (1921). Spezielle untersuchungen über die Emährungsbiologie des tierischen Limnoplanktons (I) Über die Technik für die Biologie der Gewässertypen. Lünds Universitets Arsskrift, 17, 1-27.

NATIONAL RIVERS AUTHORITY (1990). Toxic blue-green algae . NRA.

NATIONAL RIVERS AUTHORITY (1991). Chemistry Laboratory Procedures Manual, Section C. National Rivers Authority.

NEWMAN, J. & BARRETT, P.R.F. (1993). Control of *Microcystis aeruginosa* by decomposing barley straw. Journal of Aquatic Plant Management, 31, 33-49.

NICHOLS, D.S. (1983). Capacity of natural wetlands to remove nutrients from wastewater. Journal of the Water Pollution Control Federation, 55, 495-505.

OECD. (1971). Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. OECD, Paris.

OECD. (1981). OECD Guidelines for Testing Chemicals . OECD, Paris.

OLIVER, R. L., THOMAS, R. H., REYNOLDS, C. S., & WALSBY, A. E. (1985). The sedimentation of bouyant *Microcystis* colonies caused by precipitation with an iron-containing colloid. Proceedings of Royal society of London B. 511-528.

ORCUTT, J. D. (1985). Food level effects on the competitive interactions of two co-occurring cladoceran zooplankton: *Diaphanosoma branchyurum* and *Daphnia ambigua*. Archive für Hydrobiologia, 21, 465-473.

ORCUTT, J. D., & PORTER, K. G. (1983). Diel vertical migration by zooplankton: constant and fluctuating temperature effects on life history parameters of *Daphnia*. Limnology and Oceanography, 28, 720-730.

OSKAM, G. (1994). Begrenzung der Algenentwichlung in Reservoiren durch Lichtlimitierung. In: N.V.W.B. BIESBOSCH (Ed.). International Reservoir Symposium, Werkendam, The Netherlands.

OSKAM, G. & VAN BREEMAN, L. (1992). Management of Biesboch reservoirs for quality control with special reference to eutrophication. In: D.W. SUTCLIFFE & J.G. JONES (Eds.). Eutrophication: Research and application to water supply. Freshwater Biological Association, Ambleside, pp197-213.

PACE, M. L., PORTER, K. G., & FEIG, Y. S. (1983). Species and age specific differences in bacterial resource utilization by two co-occurring cladocerans. Ecology, 64 (5), 1145-1156.

PAFFENHOFFER, G. A., STRICKLER, J. R., & ALCARAZ, M. (1982). Suspension-feeding by herbivorous Calenoid copepods: A cinematographic study. Marine Biology, 67, 193-199.

PALOHEIMO, J. E. (1974). Calculation of instantaneous birth rate. Limnology and Oceanography, 19, 692-694.

PARR, W. & CLARKE, S. (1992). A review of potential methods for controlling phytoplankton, with particular reference to cyanobacteria, and sampling guidelines for the water industry. FR0248. Foundation for Water Research, Marlow, Bucks.

PATALAS, K. (1954). Comparative studies on a new type of self-acting water sampler for plankton and hydrochemical investigations. Ecologia Polska, 2, 231-242.

PERKINS, P. S. (1985). Iron crystals in the attachment organ of the Erythrophagous copepod *Cardiodectes medusaeus* (Pennellidae). Journal of Crustacean Biology, 5 (4), 591-605.

PETERSEN, S. A., SANVILLE, W. D., STAY, F. S., & POWERS, C. F. (1976). Methods of removing phosphorus. Journal of the Water Pollution Control Federation, 48 (5), 815-831.

PHILLIPOVA, T. G., & POSTNOV, A. L. (1988). Effect of food quantitiy on feeding and metabolic expenditure in Cladocera. Internationale Revue der gesamten Hydrobiologia, 73 (6), 601-615.

PHILLIPS, G. & MOSS, B. (1994). Is biomanipulation a useful tool in lake management? R&D Note no. 276. National Rivers Authority.

PICKERING, Q. H., & GAST, M. (1972). Acute and chronic toxicity of cadmium to the fathead minnow (*Pimephales promelas*). Journal of Fisheries Research Board of Canada, 29, 1099-1106.

POP, M. (1991). Mechanisms of the filtering area adaptation of *Daphnia.* Hydrobiologia, 225, 169-176.

PORTER, K. G. (1973). Selective grazing and differential digestion of algae by zooplankton. Nature, 244, 179-180.

PORTER, K. G., & FEIG, Y. S. (1980). The use of DAPI for identifying and counting aquatic microfauna. Limnology and Oceanography, 25 (5), 943-948.

PORTER, K. G., GERRITSEN, J., & ORCUTT, J. D. (1982). The effect of food concentration on swimming patterns, feeding behaviour, ingestion, assimilation and respiration by *Daphnia.* Limnology and Oceanography, 27 (5), 935-949.

PORTER, K. G., & ORCUTT, J. D. (1980). Nutrient adequacy, manageability and toxicity as factors that determine the food quality of green and blue-green algae for *Daphnia.* In W. C. KERFOOT (Ed.), Evolution and Ecology of Zooplankton Communities University Press of New England.

PREPAS, E. (1978). Sugar-frosted *Daphnia* : An improved fixation method for Cladocera. Limnology and Oceanography, 23 (3), 557-559.

PREPAS, E. E. (1984). Some statistical methods for the design of experiments and analysis of samples. In J. A. Downing, & F. H. Rigler (Ed.), A Manual on Methods for the Assessment of Secondary Productivity in Freshwater. IBP Handbook 17.Oxford: Blackwell Scientific Publications. 266-335.

RADFORD, N.P. (1994). Ecotoxicological impact of ferric sulphate on chironomid cultures and profundal reservoir communities. Operational Investigation 534/2/A. National Rivers Authority, Anglian Region.

RASMUSSEN, K., & LINDEGAARD, C. (1988). Effects of iron compounds on macroinvertebrate communities in a Danish lowland river system. Water Research, 22 (9), 1101-1108.

RAVERA, O. (1980). Effects of Eutrophication on zooplankton. Progress in Water Technology, 12, 141-159.

REYNOLDS, C.S. (1984). The ecology of freshwater phytoplankton. Cambridge University Press, Cambridge. 384pp.

REYNOLDS, C. S. (1991). Ecology and Control of Cyanobacteria (blue-green algae). Public Health Laboratory Service Microbiology Digest, 8 (3), 87-90.

REYNOLDS, C.S. (1992). Eutrophication and the management of planktonic algae: What Vollenweider couldn't tell us. In: D.W. SUTCLIFFE & J.G. JONES (Eds.). Eutrophication: Research and application to water supply. Freshwater Biological Association, Ambleside, pp 4-29.

RICKER, W. E. (1938). On adequate quantitative sampling of the pelagic net plankton of a lake. Journal of Fisheries Research Board of Canada, 4, 19-32.

RIDGE, I., PILLINGER, J., & WALTERS, J. (1994). Alleviating the problems of excessive algal growth. In: D.M.HARPER & A.J.D. FERGUSON (Eds.).pp 211-218. The ecological basis for river management. Wiley, Chichester.

RIGLER, F. H., & DOWNING, J. A. (1984a). The calculation of secondary productivity. In J. A. DOWNING, & F. H. RIGLER (Ed.), A Manual on Methods for the Assessment of Secondary Productivity in Freshwaters. IBP Handbook 17 Blackwell Scientific Publications. 19-58.

RIGLER, J. (1961). The relation between concentrations of food and feeding rate of *Daphnia magna* Straus. Canadian Journal of Zoology, 39, 857-868.

RIJSDIJK, R.E. (1994). Mogelijke maatregelen bij de bestrijding van eutrofiering in Nederlandse plassen en meren. Report no 94.103X, RIZA, Leystad, The Netherlands.

ROBINSON, M. (1957). The effects of suspended materials on the reproductive rate of *Daphnia magna*. Publications of the Institute of Marine Science at University of Texas, 4, 265-277.

SALKI, A., TURNER, M., PATALAS, K., RUDD, J., & FINDLAY, D. (1985). The influence of fish-zooplankton-phytoplankton interactions on the results of selenium toxicity experiments within large enclosures. Canadian Journal of Fisheries and Aquatic Sciences, 42, 1132-1143.

SAS, H. (1989). Lake restoration by reduction of nutrient loading: Expectations, experiences, extrapolations. Richarz, Academia Verlag.

SCHULTZ, H., WIELAND, F. & BENNDORF, J. (1992). Raubfischbesatz zür regulation des fischbestandes in einer hypertrophen talsperre. Arbeiten des Deutschen Fisherei Verbandes, Hamburg Heft, 55, 57-92.

SCULLION, J., & EDWARDS, R. W. (1980a). The effect of pollutants from the coal industry on the fish fauna of a small river in the South Wales Coalfield. Environmental Pollution, 21, 141-153.

SCULLION, J., & EDWARDS, R. W. (1980b). The effects of coal industry pollutants on the macro-invertebrate fauna of a small river in the South Wales coalfield. Freshwater Biology, 10, 141-162.

SED'A, J. (1989). Main factors affecting spring development of herbivorous Cladocera in the Rimov Reservoir (Czechoslovakia). Archive für Hydrobiologia, 33, 619-630.

SED'A, J. & DUNCAN, A. (1994). Low fish pressure in London reservoirs: II Consequesnces to zooplankton community structure. Hydrobiologia, 291, 179-191.

SED'A, J. & KUBECKA, J. (1995). Long-term biomanipulation of Rimov reservoir (Czech Republic). Hydrobiologia, 230, 181-199.

SHAPIRO, J. (1990). Current beliefs regarding the dominance by blue-greens: The case for the importance of CO_2 and pH, Verhandlungen der Internationale Vereinigung für Theoretische und Angewandte Limnologie, 24, 38-54.

SHARPLEY, AN, & SMITH, S.J. (1990). Phosphorus transport in agricultural run-off: The role of soil erosion. In: J. BOARDMAN, I.D.L FOSTER & J.A. DEARING (Eds.). pp351-366. Soil erosion on agricultural land. John Wiley & Sons, Chichester.

SHARPLEY, A.N., CHAPRA, S.C., WEDEPOHL, R., SIMS, J.T., DANIEL, T.C. & REDDY, K.R. (1994).

Managing agricultural phosphorus for protection of surface waters: Issues and options. Journal of Environmental Quality, 23, 437-451.

SIMEK, K., MACEK, M., SED'A, J., & VYHNALEK, V. (1990). Possible food chain relationships between bacterioplankton, protozoans and cladocerans in a reservoir. Internationale Revue der gesamten Hydrobiologia, 75(5), 583-596.

SMARIDGE, M. W. (1956). Distribution of iron in *Daphnia* in relation to haemoglobin synthesis and breakdown. Quarterly Journal of Microscopical Science, 97 (2), 205-214.

SMIRNOV, N. N. (1971). Morphofunctional grounds of mode of life of Cladocera v. morphology and adaptive modifications of trunk limbs of Anomopoda. Hydrobiologia, 37 (2), 317-345.

SMITH, C. D. (1988). Aspects of the Ecology of Crustacean Zooplankton in Rutland Water. Ph.D., University of Leicester.

SMITH, I. R. (1975). Turbulence in Lakes and Rivers . Freshwater Biological Association.

SOMMER, U. (1992). Phosphorus-limited *Daphnia* : Intraspecific facilitation. Limnology and Oceanography, 37 (5), 966-973.

SPRAGUE, J. B. (1971). Measurement of pollutant toxicity to fish (II) Sublethal effects and 'safe concentrations'. Water Research, 5, 245-266.

SPRENT, J.I. (1987). The ecology of the nitrogen cycle. Cambridge University Press, Cambridge.

STEEL, J.A. (1975). The management of Thames Vaeely reservoirs. In: Water Research Centre (Eds). The effects of storage on water quality. pp 371-419. Water Research Centre, Medmenham.

STERNER, R., HAGEMEIER, D. D., SMITH, W. L., & SMITH, R. F. (1993). Phytoplankton nutrient limitation and food quality for *Daphnia*.. Limnology and Oceanography, 38 (4), 857-871.

STORCH, O. (1924). Morphologie und physiologie des fangapparates der Daphniden. Ergebnisse Fortschrift Zoologie, 6, 125-234.

STRICKLER, J. R. (1982). Calanoid copepods, feeding currents and the role of buoyancy. Science, 218, 158-160.

STRICKLER, J. R. (1984). Concluding remarks. In D. G. MEYERS, & J. R. STRICKLER (Ed.), Trophic interactions within aquatic ecosystems. AAAS, Selected Symposia. Boulder: Westview Press. 449-460.

STUCHLIK, E. (1991). Feeding behaviour and morphology of filtering combs of *Daphnia galeata*. Hydrobiologia, 225, 115-167.

STUMM, W., & MORGAN, J.J. (1981). Aquatic chemistry. John Wiley & Sons, Chichester.

SYKORA, J. L., SMITH, E. J., SHAPIRO, M. A., & SYNAK, M. (1972). Chronic effect of ferric hydroxide on certain species of aquatic animals. Fourth Symposium on Coal Mine Drainage Research. Mellon Institute Pittsburgh, USA., 347-369.

TALLING, J. F. (1971). The underwater light climate as a controlling factor in the production ecology of freshwater phytoplankton. Mittel International Verienigung für Theoretische und Angewandte Limnologie, 19, 214-243.

TALLING, J. F., & DRIVER, D. (1963). Some problems in the estimation of chlorophyll *a* in phytoplankton. Proceedings of Conference of Primary Productivity and Measurement of Marine and Freshwater, Hawaii. 142-146.

TAYLOR, B. E., & SLATKIN, M. (1981). Estimating birth and death rates of zooplankton. Limnology and Oceanography, 26, 143-158.

TAZIMA, I., HOSHI, T., & INOUE, S. (1975). Histological distribution of ferruginous compounds in *Daphnia*. Zoological Magazine, 84, 67-70.

TEAL, N. (1989). Prediction of temporal and spatial phytoplankton change in Rutland Water. PhD, Leicester Polytechnic.

TEN BERGE, W. F. (1978). Breeding *Daphnia magna*. Hydrobiologia, 59 (2), 121-123.

TESSIER, A. J., YOUNG, A., & LEIBOLD, M. (1992). Population dynamics and body size selection in *Daphnia*. Limnology and Oceanography, 37 (1), 1-13.

TEVLIN, M. P. (1978). An improved experimental medium for freshwater toxicity studies using *Daphnia magna*. Water Research, 12, 1017-1024.

THOMPSON, J. M., FERGUSON, A. J. D., & REYNOLDS, C. S. (1982). Natural filtration rates of zooplankton in a closed system: the derivation of a community grazing index. Journal of Plankton Research, 4, 545-560.

THRELKELD, S. T. (1979). Estimating cladoceran birth rstes: the importance of egg mortality and egg age distribution. Limnology and Oceanography, 24 (4), 601-612.

THRELKELD, S. T. (1988). Planktivory and planktivore biomass effects on zooplankton, phytoplankton and the trophic cascade. Limnology and Oceanography, 33 (6), 1362-1375.

TURNER, J. T., TESTER, P. A., & STRICKLER, J. R. (1993). Zooplankton feeding Ecology: a cinematographic study of animal to animal variability in the feeding behaviour of *Calanus finmarchicus*. Limnology and Oceanography, 38 (2), 255-264.

UNILEVER RESEARCH (1985). Ecotoxicology: Laboratory culture of *Daphnia magna*. Standard Operating Procedures, Unilever Research.

URABE, J. (1991). Effect of food concentration on growth, reproduction and survivorship of *Bosmina longirostris* (Cladocera): an experimental study. Freshwater Biology, 25 (1), 1-8.

URABE, J., & WATANABE, Y. (1991a). Effect of food concentration on the assimilation and production efficiencies of *Daphnia galeata* G.O. sars (Crustacea: Cladocera). Functional Ecology, 5, 635-641.

URABE, J., & WATANABE, Y. (1991b). Effect of food conditions on the bacterial feeding of *Daphnia galeata*. Hydrobiologia, 225, 121-128.

VAQUE, D., & PACE, M. L. (1992). Grazing on bacteria by flagellates and cladocerans in lakes of contrasting food web structures. Journal of Plankton Research, 14 (2), 307-321.

VERNER, B. (1994). Aeration. In: M ESSELOVÁ (Eds.). Restoration of lake ecosystems - A holistic approach. , Publication no. 32, International Wildfowl Research Bureau, Slimbridge, Gloucestershire.

VIJVERBERG, J. (1980). Effect of temperature in laboratory studies on development and growth of cladocera and copepoda from Tjeukemeer, the Netherlands. Freshwater Biology, 10, 317-340.

VIJVERBERG, J. (1989). Culture techniques for studies on the growth, development and reproduction of copepods and cladocerans under laboratory and *in situ* conditions: a review. Freshwater Biology, 21, 317-373.

VIJVERBERG, J., & RICHTER, A. F. (1982). Population dynamics and production of *Acanthocyclops robustus* (Sars) and *Mesocyclops leukarti* (Claus) in Tjeukemeer. Hydrobiologia, 95, 261-274.

VIJVERBERG, J., & VAN DENSEN, W. L. T. (1984). The role of fishin the food web of Tjeukemeer, the Netherlands. Verheft Internationale Verein Limnologie, 22, 891-896.

VISSER, P.M., KETELAARS, H.A.M., & MUR, L.R. (1994). Reduced growth of the cyanobacterium *Microcystis* in artificial, deep mixing lakes. Contribution to the IAWQ-SIL Symposium on the selection mechanisms controlling biomass distribution between cyanobacteria, phytoplankton and microphyte species 11-15 December, Noordwijkeerhout, The Netherlands.

VOLLENWEIDER, R. A., & KERENKES, J. (1982). Eutrophication of water. Monitoring, assessment and control. OECD, Paris.

VOUGHT, L.B.M., DAHL, J., LANGE-PEDERSEN, J., & LACOURSIÈRE, C. (1994). Nutrient retention in riparian ecotones. AMBIO, 23 (6), 342-348.

WALSBY, A.E. (1992). The control of gas-vacuolate cyanobacteria. In: D.W. SUTCLIFFE & J.G. SUTCLIFFE (Eds.). Eutrophication: Research and application to water supply. pp150-162. Freshwater Biological Association, Ambleside.

WALSBY, A.E. & MCALLISTER, G.K. (1987). Buoyancy regulation by *Microcystis* in Lake Okaro. New Zealand Journal of Marine and Freshwater Research, 21, 521-524.

WARNICK, S. L., & BELL, H. L. (1969). The acute toxicity of some heavy metals to different species of aquatic insects. Journal of Water Pollution Control Federation, 41, 280-284.

WELCH, E.B. (1980). Ecological effects of waste water. Cambridge University Press, Cambridge. 337pp.

WILSON, H.M., GIBSON, M.T. & O'SULLIVAN, P.E. (1993). Analysis of current policies and alternative strategies for the reduction of nutrient loads on eutrophicated lakes: The example of Slapton Ley, Devon. Aquatic Conservation: Marine and Freshwater, 3, 239-251.

WINNER, R. W., & FARRELL, M. P. (1976). Acute and chronic toxicity to copper to four species of *Daphnia*. Journal of Fisheries Research Board of Canada, 33, 1685-1691.

WONG, P. J. S., CHAN, Y. K., & PATEL, D. (1982). Physiological and biochemical responses of freshwater algae to a mixture of metals. Chemosphere, 11 (4), 367-376.

WRC. (1973). A method for the determination of chlorophyll a in algae using boiling methanol. Water Research Centre, Medenham.

WURTSBURGH, W. A., & HORNE, A. J. (1983). Iron in eutrophic Clear Lake, California: its importance for algal nitrogen fixation and growth. Canadian Journal of Fisheries and Aquatic Sciences, 40, 1419-1429.

YAN, N. D., MACKIE, G. l., & BOOMER, D. (1989). Chemical and biological correlates of metal levels in crustacean zooplankton from Canadian Shield lakes: A multivariate analysis. The Science of the Total Environment, 87/88, 419-438.

YOUNG, S. N., CLOUGH, W. T., THOMAS, A. J., & SIDDALL, R. (1988). Changes in plant community at Foxcote reservoir following use of ferric sulphate to control nutrient levels. Journal of Institute of Water Engineers and Scientists, 2 (1), 5-12.

ZALEWSKI, M., FRANKIEWICZ, P. & NOWAK, M. (1995). Biomanipulation by ecotone management in a lowland reservoir. Hydrobiologia, 303, 45-60.