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December 2003

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# Summary

In the Forsmark area lakes are continuously formed due to the land-rise since the termination of the last glaciation period some 10 000 years ago. The dominating lake type formed is the oligotrophic hardwater lake. In a previous report, the habitat distribution, water chemistry and biomass of microbiota between the years 2000–2001, as well as preliminary production measurements of microbiota in the oligotrophic hardwater Lake Eckarfjärden, was described /Blomqvist et al, 2002/. In this report, further studies of water chemistry and biomass of microbiota during 2003 are presented together with studies of zooplankton, benthic fauna, macrophytes and production by microbiota.

With respect to water chemistry, Lake Eckarfjärden is unusual compared to other lakes in Sweden. The water is alkaline with high conductivity and pH-value. Concentration of dissolved organic carbon was very high (20 mgC $l^{-1}$), especially when considering the moderate water colour (abs 420 nm; mean=0.127). Nitrogen concentration was high too (tot-N=1009 ±271 µgN $L^{-1}$, mean ±SD), whereas phosphorus concentration was very low (tot-P=7 ±3 µgP $L^{-1}$, mean ±SD). The water chemistry in 2002 was in most respects identical to that in previous years and it can therefore be concluded that the chemical characteristics of the open water now have been reasonably established.

The biomass of microbiota was clearly concentrated to the bottom. Biomass of microphytobenthos was 110 times higher than phytoplankton biomass, and biomass of benthic bacteria was 138 times higher than bacterioplankton biomass. The production of benthic microbiota was as high as or higher than that in the pelagial. Hence, this study further strengthens the view that the benthic community has a key role in the production and metabolism of organic matter in the system.

Zooplankton biomass was dominated by copepods and showed an opposite trend compared to most other Swedish lakes, with a summer minimum and winter maximum. One explanation for this seemingly inverse seasonal development could be that the copepods are mainly benthic but forced to move to higher strata in the winter when oxygen concentrations near the bottom were low. Another possible explanation is a high grazing pressure by fish in the summer. A fish survey in Lake Eckarfjärden /Nyberg, 1999/ showed relatively low fish biomass in Lake Eckarfjärden, but Lake Eckarfjärden is connected to the Baltic Sea via the nearby Lake Bolundsfjärden and its reasonable to believe that fish from the Baltic move up to Lake Eckarfjärden to spawn. The small yearlings would then stay in the lake and feed until they are large enough to move out to the Baltic Sea. The hypothesis of migratory fish as an important factor in the lake food web merits further investigation.

The biomass of benthic fauna was low compared to other lakes. The benthic fauna was dominated by herbivores, both in terms of number of individuals and in terms of biomass.

The macrophyte community was clearly dominated by *Phragmites australis* followed by *Typha sp.* both in terms of biomass and numbers. The third and fourth most common macrophytes, *Schoenoplectus lacustris* and *Equisetum fluviatile,* showed limited areal distribution and biomass.

Overall, this study further strengthens the view that most biomass and production in this lake type is allocated to the illuminated soft bottom habitat.

# Sammanfattning

I Forsmarksområdet bildas nya sjöar kontinuerligt i och med landhöjningen som pågått i området sedan slutet av den senaste istiden för ca 10 000 år sedan. Den dominerande sjötyp som bildas är den kalkoligotrofa sjön. I en tidigare rapport beskrevs habitatutbredning, vattenkemi och biomassor av mikrobiota under åren 2000–2001, tillsammans med preliminära produktionsdata för mikrobiota i den kalkoligotrofa sjön Eckarfjärden /Blomqvist et al, 2002/. I denna rapport beskrivs vattenkemi, biomassor av mikrobiota, zooplankton, bentisk fauna och makrofyter, samt produktion av mikrobiota i Eckarfjärden under 2002.

Med avseende på vattenkemi är de kalkoligotrofa sjöarna mycket ovanliga i Sverige. Alkalinitet, konduktivitet och pH-värden i Eckarfjärden var höga. Koncentrationerna av löst organisk kol var mycket höga (20 mgC $l^{-1}$), särskilt mot bakgrund av den måttliga vattenfärgen (abs 420 nm; medelvärde 0,127). Koncentrationen av kväve var hög (tot-N=1009 ±271 µgN $L^{-1}$, medel ±SD) medan koncentrationen av fosfor var mycket låg (tot-P=7 ±3 µgP $L^{-1}$, medel ±SD). Vattenkemin under 2002 var i stort sett identisk med den som uppmätts under tidigare år och därav drar vi slutsatsen att sjöns vattenkemiska egenskaper nu kan anses vara fastställda.

Biomassan av mikrobiota var liksom tidigare år starkt koncentrerad till bottnarna. Biomassan av mikrofytobentos var 110 ggr högre än fytoplanktonbiomassan och biomassan av bakterier i den mikrobiella mattan var 138 ggr högre än biomassan av bakterioplankton. Produktionen av mikrofytobentos var hög och av samma storleksordning som fytoplanktonproduktionen. Produktionen av bakterier i den mikrobiella mattan var låg jämfört med produktionen av sedimentbakterier i andra sjöar. Den var dock i samma storleksordning som produktionen hos bakterioplankton. Denna studie styrker alltså tidigare studier av att den mikrobiella mattan spelar en viktig roll i produktionen och metabolismen av organiskt material i sjöekosystemet.

Zooplanktonbiomassan uppvisade en säsongsdynamik med ett maximum under vintern och minimum under sommaren, alltså helt olik den som man brukar finna i andra sjöar. Biomassan dominerades av copepoder, förutom under sommaren då rotatorier dominerade. Det kan finnas två skäl till att det var ett vintermaximum av zooplankton. För det första kan det vara så att copepoderna i huvudsak är bentiska, men tvingas upp i vattenmassan under vintern då syrgashalten nära bottnarna är låg. För det andra kan zooplankton vara utsatta för ett högt betningstryck från fisk. Provfiske i Eckarfjärden visade att fiskbiomassan var relativt låg jämfört med andra sjöar i Uppland. Eckarfjärden har dock förbindelse med Östersjön via den närliggande Bolundsfjärden. Det är rimligt att tro att fiskar vandrar upp i Eckafjärden för att lägga rom. Ynglen skulle i sådana fall stanna i Eckarfjärden och äta tills de nått en sådan storlek att de kan återvända till Östersjön. Det behövs fler studier för att kunna fastställa denna teori om migrerande fisk som en viktig reglerande faktor i födoväven.

Bottenfaunabiomassan var låg jämfört med andra sjöar, och den dominerades av herbivorer både till antal och till biomassa.

Makrofytsamhället dominerades av vass (*Phragmites australiensis*) och kaveldun (*Typha sp.*). Säv (*Schoenoplectus lacustris*) och sjöfräken (*Equisetum fluviatile*) förekom, men i mindre omfattning.

Sammanfattningsvis kan sägas att denna studie stärker bilden av att såväl biomassa som produktion är fokuserad till de ljusbelysta bottnarna i de kalkoligotrofa sjöarna och att den mikrobiella mattan där har en stor betydelse för metabolismen av organiskt material i sjöekosystemet.

# Contents

# 1 Introduction

Oligotrophic hardwater lakes dominate the lake population in the Forsmark area in the province of Uppland, central Sweden, one of two selected areas of interest for storage of Swedish nuclear waste. SKB (The Swedish Nuclear Fuel and Waste Management Company) is responsible for the management and disposal of this waste. The company is planning to construct deep repositories, which will keep the radioactive compounds away from the biosphere through hundreds of thousands of years. Site descriptions in the Forsmark area, and at Oskarshamn in southern Sweden, will include the bedrock and overlying geological layers near the tentative location of the repositories. They will also include the terrestrial, wetland, lake, and river ecosystems of all drainage areas that potentially may become affected by the installation. Also coastal and marine ecosystems will be covered. In aquatic ecosystems, special focus will be given to the formation and diagenesis of sediments and to the ontogeny of coastal bays to lakes and wetlands.

Along the coast of Forsmark new lakes are continuously formed due to land-rise since the termination of the last glaciation some 8800 years ago /Ignatius et al, 1981/. The shoreline displacement in the Forsmark area is currently some 60 cm per century /Påsse, 1997/ and numerous new lakes will be formed in the coming five millennia /Brydsten, 1999/. Three main types of lakes are formed due to land rise in Uppland; oligotrophic hardwater lakes, naturally highly eutrophic lakes, and alkaline humic lakes /Brunberg and Blomqvist, 2000/. In the Forsmark area, which was isolated from the Baltic very recently, the dominant lake type formed is the oligotrophic hardwater lake /Brunberg and Blomqvist, 2000/. Paleoecological studies indicate that the oligotrophic hardwater stage is ephemeral, lasting 1000–1500 years /Brunberg and Blomqvist, 2000/ (and references therein). Later, as mires develop in the catchment and often close to the lakes, the lakes evolve into brownwater systems and in the long run their basins are closed by mires /Ingmar, 1963/.

The oligotrophic hardwater lakes in Uppland are unique in several aspects, not only when compared to lakes in the national Swedish lake monitoring programme but most likely also on a global scale /cf. Brunberg et al, 2002/. Compared to the more than 4000 Swedish lakes covered by the national Swedish monitoring programme in 1995, Lake Eckarfjärden showed very unusual water chemistry with high alkalinity, conductivity, and pH-values, very high concentrations of slightly coloured DOC, and high concentrations of nitrogen, but very low concentrations of phosphorus. Phytoplankton and bacterioplankton biomasses were low, and the microbial community in the lake (including autotrophs as well as heterotrophs) was mainly confined to the sediments where a 10–15 cm thick microbial mat, mainly consisting of cyanobacteria, was found. Preliminary primary production measurements in the lake showed that while the production in the pelagial always was low, the production in the microbial mat may potentially be very high /Blomqvist et al, 2002/.

The present study focuses on the characteristics of the ecosystem in one oligotrophic hardwater lake, Lake Eckarfjärden. Special attention was paid to water chemistry, habitat distribution in the lake ecosystem, and biomass and production of different groups of biota. This detailed knowledge about the ecosystem in one lake will be used for modelling of the production processes in other lakes in the area. A first report /Blomqvist et al, 2002/ included the habitat distribution in the lake ecosystem, measurements of water chemistry, measurements of the biomass of microbiota, and preliminary measurements of the production of microbiota, and covered the period from January 2000 to December 2001. In this second report, which covers the conditions during 2002, we describe continued measurements of water chemistry and of the biomass and production of microbiota in the lake. We also report biomasse and community composition of zooplankton, benthic fauna and macrophytes. The evaluation of the data is based on the results from all three years.

# 2 Methods

## 2.1 The study site

Lake Eckarfjärden (Swedish Lake number 669723-163205) is located 2 km east of the village of Forsmark, along the coast of the province of Uppland, Sweden (60°22' N, 18°12' E). The lake has an altitude of 6 m above sea level, which corresponds to an age of about 930 years /Brydsten, 1999/. It is small (area 0.23 km$^2$) and very shallow (maximum depth 2.6 m), and its catchment is dominated by mature coniferous forest /Brunberg and Blomqvist, 1998/. Apart from the deposition of airborne pollutants, anthropogenic impact on the ecosystem is minimal /Franzén, 2002/. For a more detailed description see /Blomqvist et al, 2002/.

## 2.2 Sampling

Sampling for water chemistry, zooplankton and microbiota was performed monthly or biweekly from January 2002 to March 2003. Samples for analysis of plankton and water chemistry were taken with a tube sampler at 15 sites and pooled in a bucket from which sub-samples were drawn. Samples for chemical analysis were brought unpreserved to the laboratory. For zooplankton, 5–10 L water was sieved through a 40 µm sieve. Zooplankton and phytoplankton were preserved in the field with acidified Lugols solution according to /Olrik et al, 1998/. Samples for the analysis of bacterioplankton were preserved with formaldehyde (final concentration 4%).

Samples for dissolved oxygen were taken with a Ruttner sampler from surface and bottom water, and were immediately fixed and later analysed using Winkler methodology according to Swedish Standards /SLU, 2001/. Samples of microphytobenthos and heterotrophic bacteria in the sediments were taken with a tube sampler at a station located in the deepest part of the lake. The upper 0–5 cm layer was transferred into plastic jars and brought to the laboratory where two sub-samples, one for microphytobenthos and one for heterotrophic bacteria, were taken and preserved with formaldehyde (final concentration 2% and 4%, respectively).

Benthic fauna was sampled on 11th of March 2002 at 10 randomly chosen sites (Table 2-1). Samples were taken with an Ekman grabber with an area of 2.5 dm$^2$ and were sieved through a 0.5mm sieve. The benthic animals were identified to species, counted, and weighed.

Areas of macrophyte belts were taken from /Brunberg et al, 2004/ with exception for *Typha sp.* which was discovered to be present within the belts of *Phragmites australis* along the shoreline (Table 2-2). Therefore, *Typha sp.* was sampled in the area of *P. australis* as well as in the area of exclusively *Typha sp.*. Density of macrophytes was measured by randomly placing a frame with the side of 25 cm in belts of *P. australis* (28 times) and *Typha sp.* (28 times), and a frame with the side 50 cm in belts of *Equisetum fluviatile* (10 times) and *Schoenoplectus lacustris* (10 times). The number of straws within the frame was counted. All straws of *P. australis* and *Typha sp.* and subsamples of 10 and 30 straws of *S. lacustris* and *E. fluviatile*, respectively, were taken to lab where dry weight was measured.

**Table 2-1. Sampling points for benthic fauna in Lake Eckarfjärden 2002-03-11. X- and Y-coordinates are given in the Swedish National grid (RT 90 2.5 gon W).**

| Sampling point | X-coordinate | Y-coordinate |
|---|---|---|
| 1 | 1632137 | 6696740 |
| 2 | 1631842 | 6697255 |
| 3 | 1632073 | 6696725 |
| 4 | 1631949 | 6697006 |
| 5 | 1631851 | 6697189 |
| 6 | 1632006 | 6697152 |
| 7 | 1631885 | 6696839 |
| 8 | 1632037 | 6696865 |
| 9 | 1631989 | 6697078 |
| 10 | 1632050 | 6696808 |

**Table 2-2. Area of macrophyte belts in Lake Eckarfjärden.**

| Macrophyte | Area Km$^2$ | Coverage of lake area % |
|---|---|---|
| *Phragmites australis* | 0.0884 | 31 |
| *Typha sp.* | 0.0823 | 29 |
| *Schoenoplectus lacustris* | 0.0073 | 3 |
| *Equisetum fluviatile* | 0.0035 | 1 |

## 2.3 Water chemistry and biota

Water colour, pH-value, alkalinity, conductivity, molybdate-reactive phosphorus, ammonium-nitrogen and dissolved oxygen were all measured within 24 h from sampling. The remaining water was kept frozen until analysis. When no other reference is given, the analyses were carried out according to European and/or Swedish standard methods /SLU, 2001/.

Total phosphorus was analysed according to /Menzel and Corwin, 1965/. Residual phosphorous (organic phosphorus and precipitated phosphorus) was calculated by subtraction of phosphate phosphorus (molybdate-reactive phosphorous) from total phosphorous. $NH_4$-N was analysed according to /Wood et al, 1967/. Organic nitrogen (residual nitrogen) was calculated by subtraction of $NO_2$+$NO_3$-N and $NH_4$-N from total nitrogen.

TOC (unfiltered lake water) and DOC (water filtered through pre-ignited Whatman GF/F filters) were analysed by combustion and IR detection of the resulting carbon dioxide using a Shimadzu TOC 5000 carbon analyser. Water colour was measured spectrophotometrically on filtered water at 420, 436, 525 and 620 nm, using a 5 cm quartz cuvette.

Species composition, length, and width of zooplankton were analysed in an inverted light microscope after sedimentation of the organisms for at least one hour. For rotifers, biovolumes were calculated using /Ruttner-Kolisko, 1977/ with the exception of the genera *Polyarthra*, *Conchilus*, *Synchaeta*, *Collotheca*, *Trichtria* and *Lecane/Lepadella* where linear measurements and geometrical formulae were used according to:

*Polyarthra, Conochilus and Collotheca* = $\pi \times (w/2)^{2 \times a}$

$Synchaeta = 4/3 \times \pi \times (d/2)$

$Trichotria = 0.13 \times a^3$

$Lecane/Lepadella = 0.1 \times a^3$

where $a$ = total length, $w$ = width, and $d$ = diameter

The biovolumes were transformed to biomass assuming a density of 1. Dry weight was assumed to be 10% of the wet weight except for the genus *Asplanchna* where dry weight was assumed to be 3.9% of the wet weight. Carbon content was assumed to be 48% of the dry weight.

For *Cladocera* and *Copepoda*, biomass was calculated from linear measurements directly into dry weight using formulas given in /Botrell et al, 1976/ for *Diaphanosoma* and *Ceriodaphnia*, and /Johansson et al, 1976/ for *Bosmina*, *Daphnia*, *Eudiatomus*, and *Cyclops*. For the genera *Chydorus*, *Acropeus*, and *Leptodora* linear measurements and geometrical formulae were used according to:

*Chydorus and Acropeus:* $\text{Dry weight} = 5.43 \times L^{2.5054} \times 10^{-7}$

*Leptodora:* $\text{Dry weight} = 1.175 \times L^{3.0408} \times 10^{-9}$

As for rotifers, 48% of dry weight was assumed to be carbon biomass.

Species composition and carbon biomass of planktonic microbiota (phytoplankton and heterotrophic nanoflagellates) were determined using an inverted phase-contrast microscope, after overnight sedimentation of the organisms in 10 ml of water /Olrik et al, 1998/. The different taxa of phytoplankton were divided into three groups: autotrophic flagellates, autotrophic non-flagellates and mixotrophic flagellates according to /Jansson et al, 1996/ with modifications according to /Isaksson et al, 1999/.

Species composition and carbon biomass of microphytobenthos were determined in the same way as for phytoplankton, with the exception that sediment samples were diluted with water (1:200) and counted in 1 ml chambers.

Heterotrophic bacterioplankton and sediment bacteria were counted and measured with an epifluorescence microscope. Sediment samples were first sonicated (1 minute, 100 W); the other samples directly stained with acridine orange and filtered through 0.2 µm polycarbonate filters. A total of at least 200 cells were counted for each sample, and the total bacterial biovolume was estimated by sorting the cells into different size classes by measuring at least 100 cells. Bacterial dry weight and carbon content was calculated according to /Loferer-Krössbacher et al, 1998/, using the formula $DW = 435 \cdot V^{0.86}$, and assuming that 50% of the dry weight was carbon.

## 2.4 Production measurements

Primary production was measured in situ with $^{14}C$-incorporations at 9 and 14 occasions in the sediment zone and in the pelagial, respectively. The primary production in the pelagic zone was measured with duplicates at 5, 25, 50, 100 and 150 cm depth in 60 ml bottles. Dark incubations were made at the top and at the bottom. One ml of 5 µCi/ml was added to the bottles, which were incubated between 10 a.m. and 2 p.m. The incubations were stopped with 0.5 ml 37% formaldehyde. A sub-sample of 3 ml were bubbled with HCl over night before treated with scintillation cocktail (Optiphase Hisafe 2) and counted in a scintillation counter.

In the sediment zone, primary production was measured at 150 cm depth and on three occasions also at 50 and 100 cm depth. The sediment was incubated in Jönsson cores, where radioactive tracer is percolated down into the sediment /Jönsson, 1991/. The volume of the cores was 39 ml (Diameter 42mm) and 1 ml of 5 µCi/ml was added to each core. Three light incubations and 2 dark incubations were made at each depth between 11 a.m. and 1 p.m. After the incubation a sub-sample of the top cm was taken from each core. The sub-sample was thoroughly mixed before triplicate samples of 0.2 ml was taken and treated with hydrochloric acid (HCl). The samples were dried in an oven in 40°C for 2 hours and then treated with organic solvent Biolute-S. After approximately 24 hours scintillation cocktail (Optiphase Hisafe 2) was added and the samples were measured in a scintillation counter.

Bacterial production in the water column was measured according to /Bell, 1993/. Incubations were made within an hour after sampling. 5 ml of water was incubated in situ with [methyl-3H]-thymidine (final concentration 20 nM) for 0.5 to 2 hours depending on season and temperature. The incubations were stopped with addition of 0.5 ml of formaldehyde. The samples were transported to lab were they were kept in a fridge until further analysis were performed.

A saturation curve was performed to determine the amount of thymidine needed for measuring bacterial production in the sediments. A total of 0.2 ml of sediment was incubated with 10, 20, 30 or 40 µCi [methyl-3H]-thymidine (48 Ci/mmol, 1,78 TBq/mmol). An addition of 20 µCi [methyl-3H]-thymidine was enough to give result in the scintillation counter but not enough to shut off the *de novo* pathway. Therefore, a dilution curve with non-radioactive thymidine was performed. Non-radioactive thymidine was added 0.5, 1, 2, 3, and 5 times the radioactive [methyl-3H]-thymidine. A dilution with equal amounts of non-radioactive thymidine was enough to shut off the *de novo* pathway. Bacterial production in sediment was measured according to /Bell and Ahlgren, 1987/ within an hour after sampling. In short, triplicates were incubated *in situ* with 0.2 ml sediment and 20 µCi [methyl-3H]-thymidine and equal amount of cold thymidine. A blank was incubated after addition of 5 ml of 80% ethanol. The incubations were made for 0.5 to 2 hours depending on temperature and season. The incubations were stopped with 5 ml of 80% ethanol and the samples were taken to lab where they were kept at 4°C until further analysis. DNA was extracted and the samples were measured in a scintillation counter according to /Bell and Ahlgren, 1987/.

# 3 Results

## 3.1 Water chemistry

All single measurements of water chemistry are presented in Appendix A.

The temperature of the water in Lake Eckarfjärden ranged between 0°C in the winter to 24°C in the summer. Thus, the summer of 2002 was somewhat warmer than the summers of 2000 and 2001 (Figure 3-1). There was no thermal stratification during the ice-free season and surface water temperatures were in most cases identical to those at the bottom. During the winter, on the other hand, there was an inverse thermal stratification with lower temperatures (close to 0°C) immediately under the ice and higher at the bottom.

The conductivity was high and ranged between 20 and 34.5 mS m$^{-1}$, with a mean of 25.7 mS m$^{-1}$, which is of the same magnitude but somewhat lower than during previous years (range 20–35 mS m$^{-1}$, mean 26.5 mS m$^{-1}$). The conductivity followed the same temporal pattern as during 2000 and 2001 with maxima during winter and minima during summer (Figure 3-2).

The alkalinity was high too, and of similar magnitude as during previous years (range 2.0–3.3 meq L$^{-1}$; mean 2.4 meq L$^{-1}$). It also followed the same temporal pattern as before. In accordance with conductivity, the alkalinity was highest during winter and lowest during summer (Figure 3-3).

The pH-values were generally high, with the same mean as for 2000 and 2001 (range 7.5–8.6; mean 8.1), and showed an opposite seasonal variation compared to conductivity and alkalinity. Minimum values were recorded in winter under the ice and maximum values during late summer.

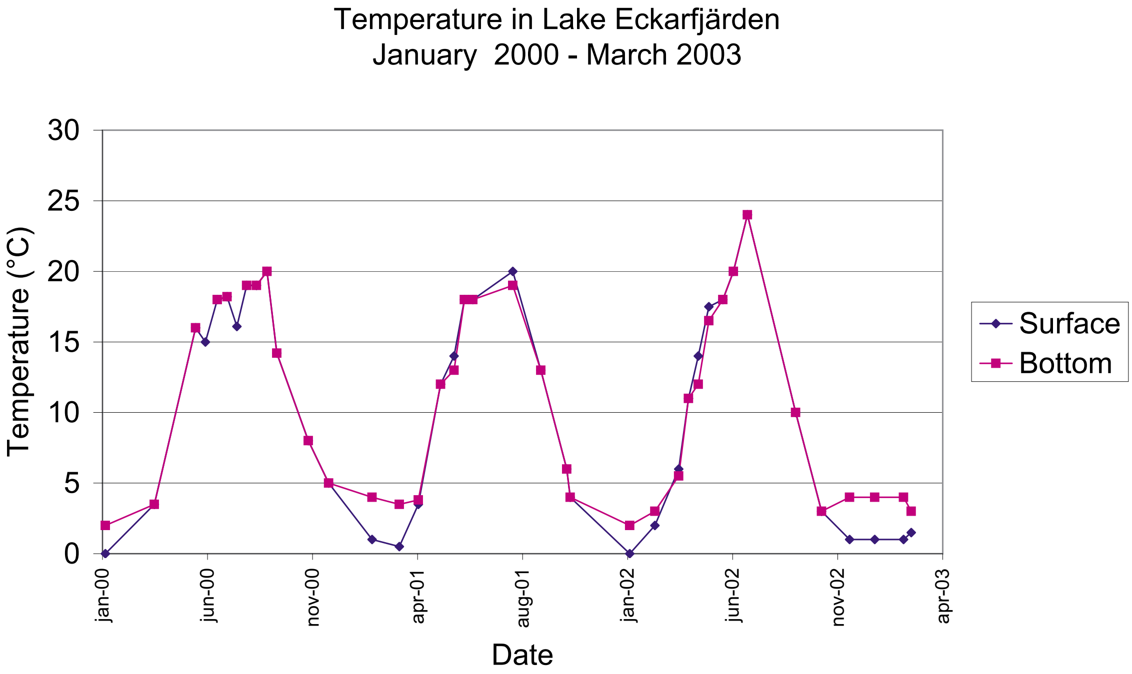


*Figure 3-1. Temperature in surface and bottom waters of Lake Eckarfjärden during the period January 2000 to March 2003.*

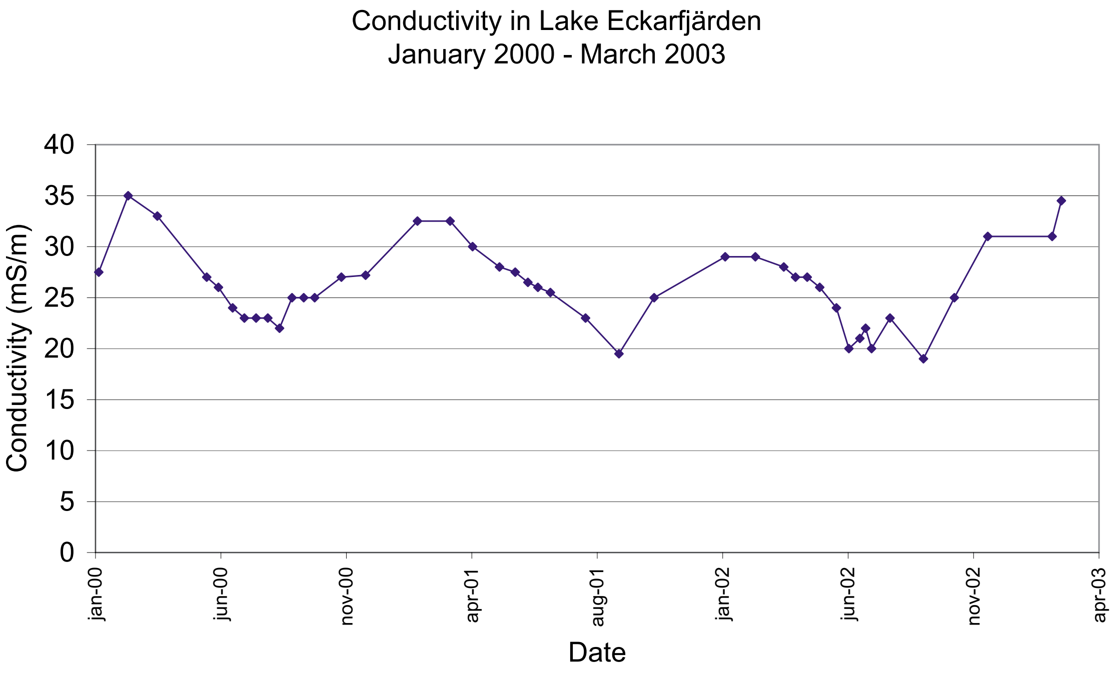


*Figure 3-2.* *Conductivity in Lake Eckarfjärden during the period January 2000 to March 2003.*

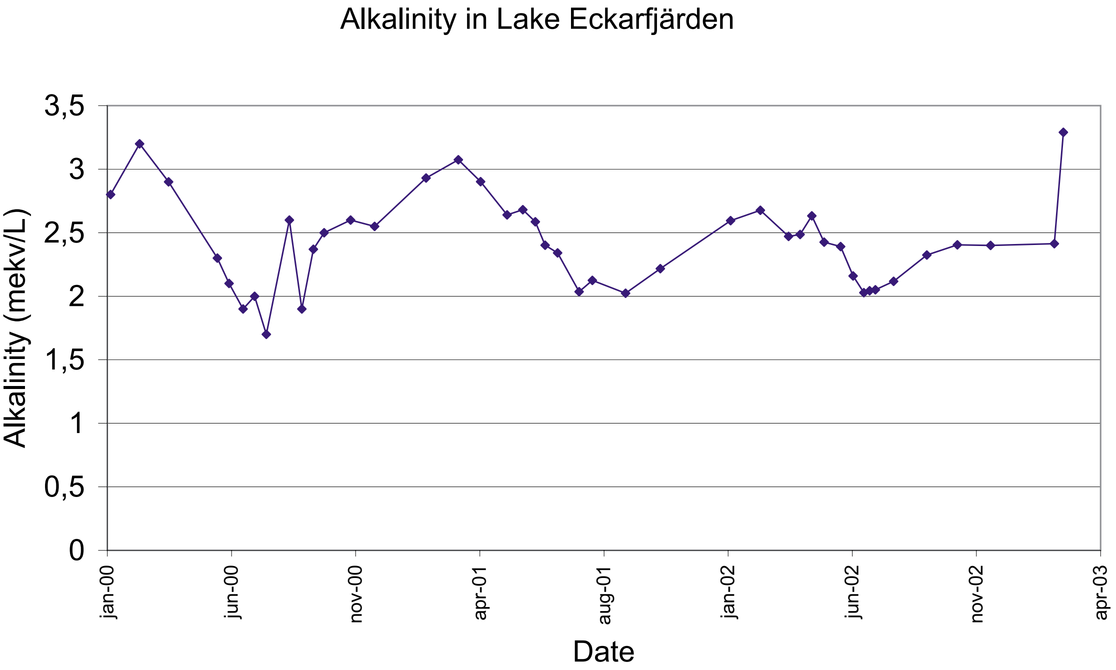
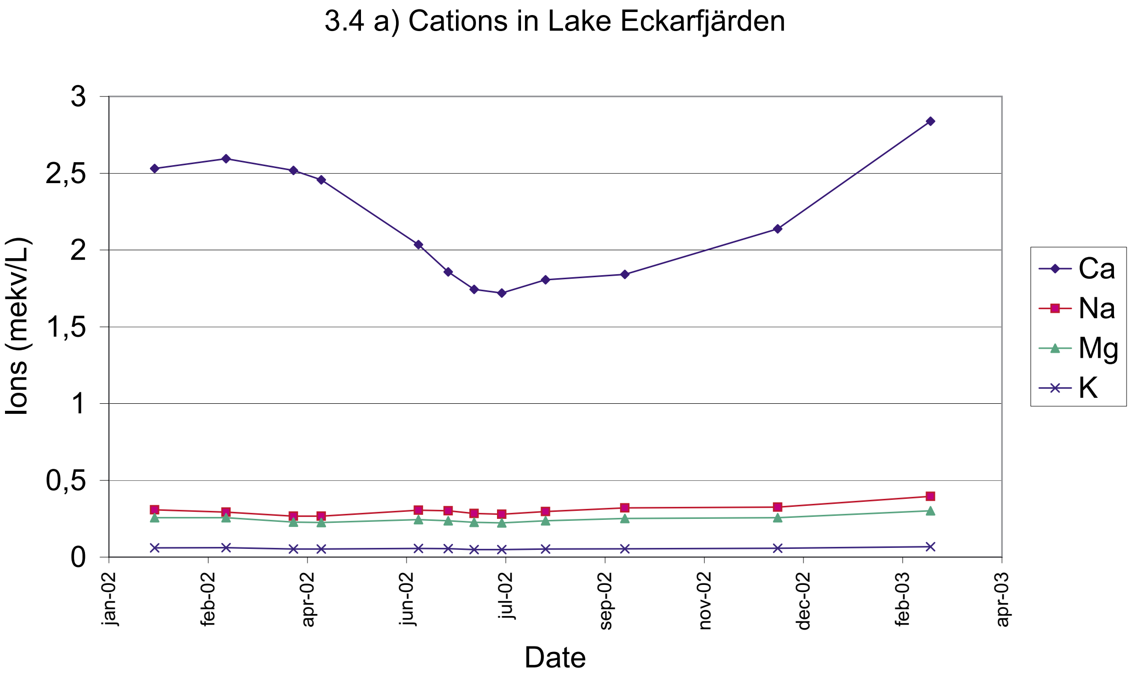


*Figure 3-3.* *Alkalinity in Lake Eckarfjärden during the period January 2000 to March 2003.*

Major inorganic constituents in the water were for the first time frequently measured during 2002. In accordance with the results of the sparse measurements from previous years, calcium was found to be by far the dominant cation in the water and bicarbonate the dominant anion. Both calcium and bicarbonate concentrations showed a pronounced seasonality with high values in winter and low values in summer (Figure 3-4 a and b).



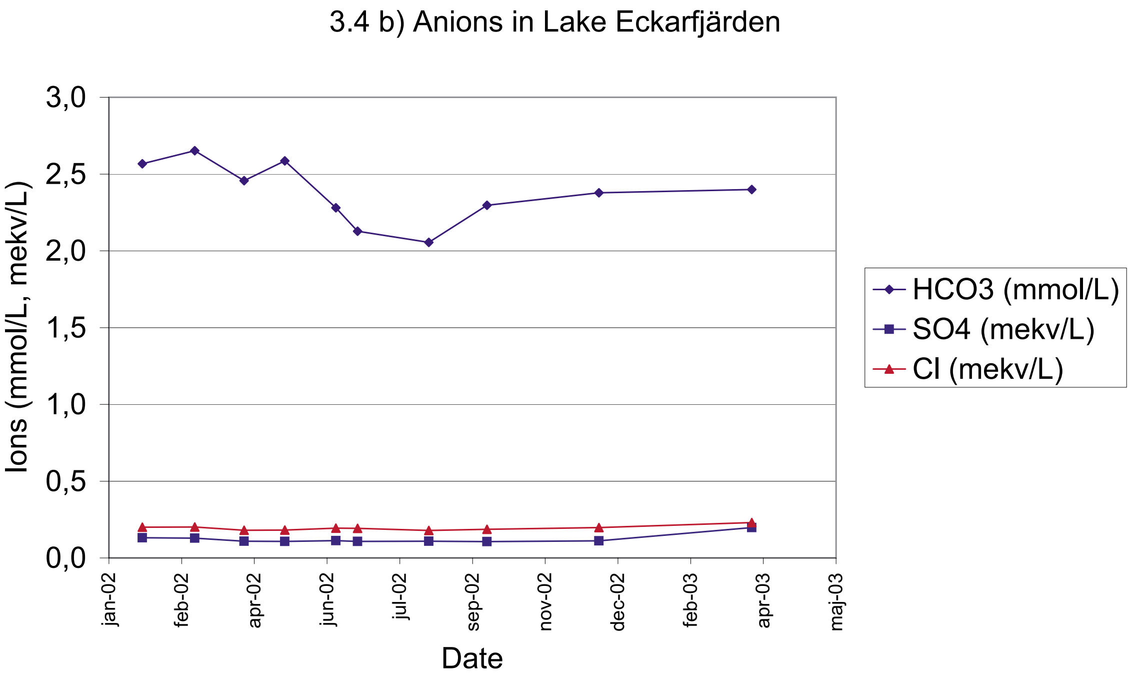


***Figure 3-4.*** *a) Cations in Lake Eckarfjärden during 2002, and b) anions in Lake Eckarfjärden during 2002. Note the different units for $HCO_3$ (mmol/L) and $SO_4$ and Cl (mekv/L).*

The concentrations of silica were high and of the same order of magnitude as during previous years (Figure 3-5). Silica showed a seasonal trend with low summer concentrations and high winter concentrations.

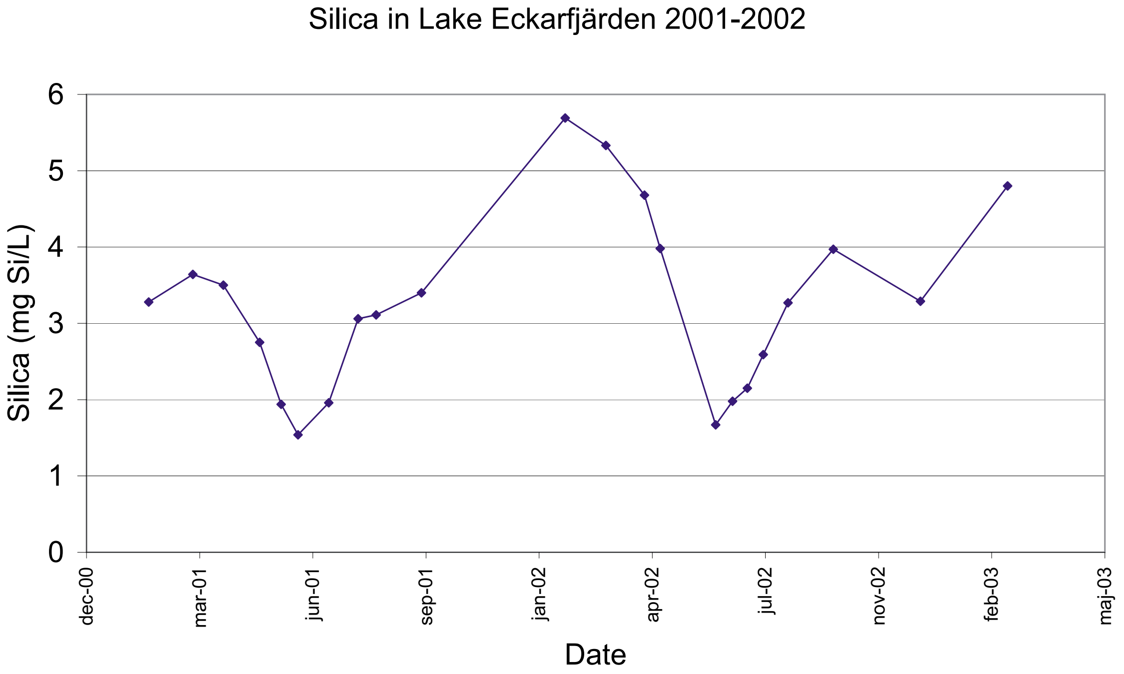


***Figure 3-5.*** *Concentration of silica in Lake Eckarfjärden during the period January 2000 to March 2003.*

The concentrations of total phosphorus were low, with an average of 6.9 µg P $L^{-1}$ (range 3–14 µg P $L^{-1}$), and showed little seasonal variation. The concentrations were considerably lower than during previous years, when total phosphorus averaged 16 µg P $L^{-1}$ and showed a range between 8 and 48 µg P $L^{-1}$ (Figure 3-6). The concentrations of phosphate (molybdate-reactive phosphorus) were also low (range 0–6 µg P $L^{-1}$; mean 2.2 µg P $L^{-1}$), and were often below or close to the detection limit of the method (2 µg P $L^{-1}$). This is similar to the situation during the previous yetars when the range was 0–20 µg P $L^{-1}$ and the average was 1.8 µg P $L^{-1}$ (Figure 3-6). Notably, the maximum concentrations of both total phosphorus and phosphate were measured in February 2001 and coincided with oxygen depletion in the bottom water.

As during 2000 and 2001, total nitrogen concentrations during 2002 were high, varying between 746 and 1601 µg N $L^{-1}$ (mean 1009 µg N $L^{-1}$; range 746–1601 µg N $L^{-1}$). Total nitrogen was mainly made up by organic nitrogen (Figure 3-7). The mean concentration of organic nitrogen was 681 µg N $L^{-1}$ (range 464–859) which was somewhat lower than during previous years. Inorganic nitrogen concentrations were similar to previous years (Figure 3-8) and inorganic nitrogen was mainly made up by ammonium nitrogen (range 14–884 µg N $L^{-1}$; mean 317 µg N $L^{-1}$). Ammonium nitrogen showed a pronounced seasonal variation with peaks under the ice in the winter and low summer values. Nitrate and nitrite concentrations were always low with an average concentration of 37 µg N $L^{-1}$ (range 5–97 µg N $L^{-1}$). There were no signs of any major nitrification event during the winter of 2002 (cf winter of 2001, /Blomqvist et al, 2002/)

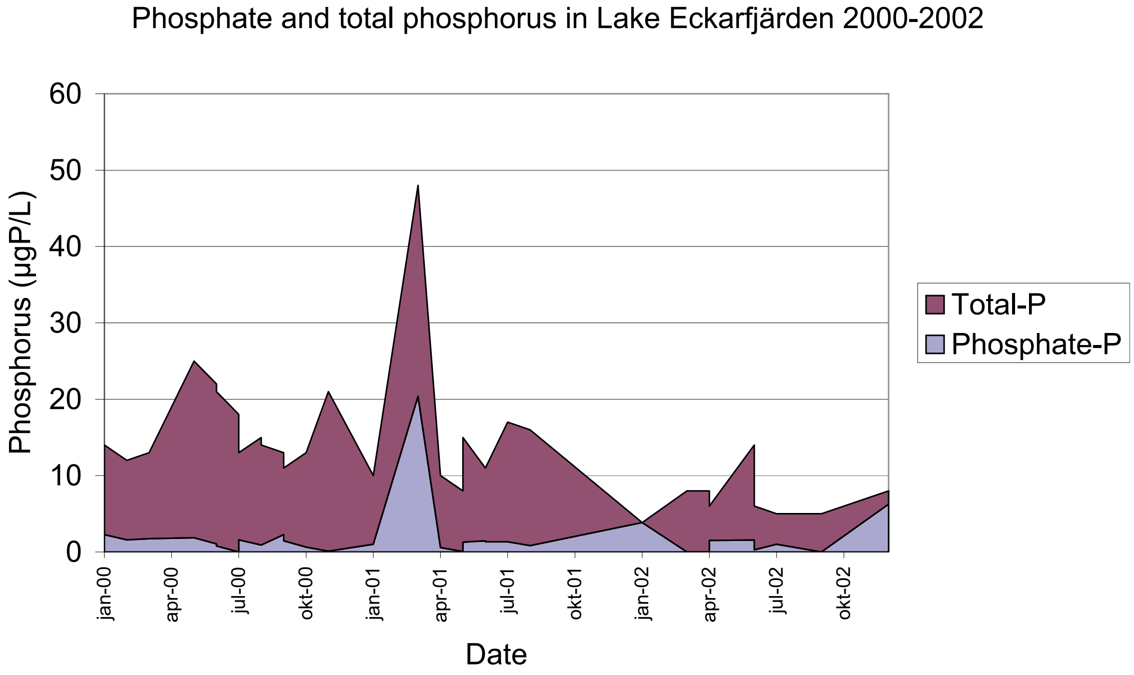


***Figure 3-6.** Concentration of phosphate and total phosphorus in Lake Eckarfjärden during the period January 2000 to March 2003.*

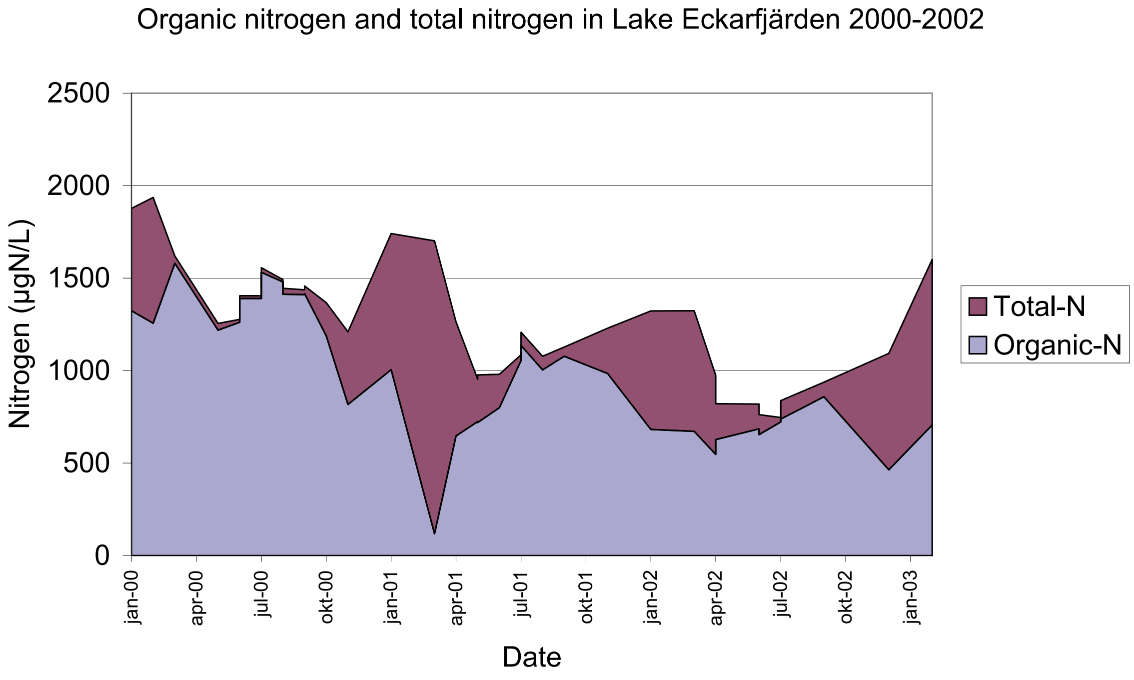


***Figure 3-7.** Concentration of organic and total nitrogen in Lake Eckarfjärden during the period January 2000 to December 2002.*

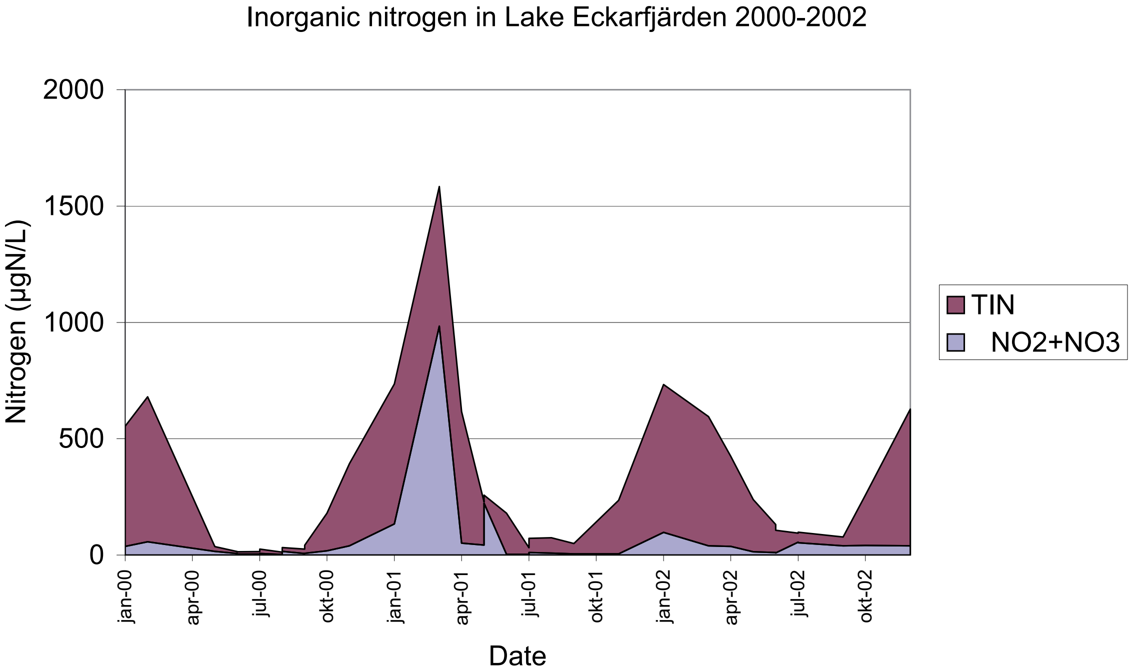
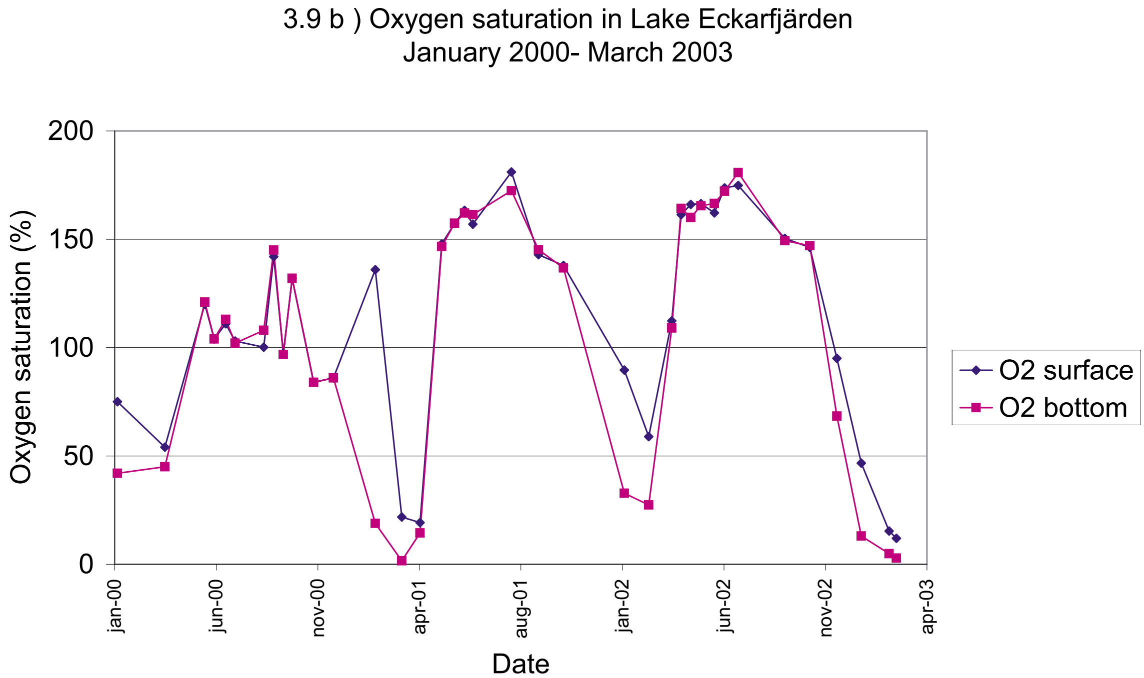


***Figure 3-8.*** *Concentration of nitrate, nitrite and total inorganic nitrogen in Lake Eckarfjärden during the period January 2000 to March 2002.*

The concentrations of dissolved oxygen showed the same pattern as during previous years with considerable over-saturation during summer and very low concentrations in late winter under the ice (Figure 3-9 a, b). During winter, bottom values were always lower than surface values. During the period January 2002–March 2003, minima at both depths were recorded in March 2003 but there was still some dissolved oxygen left so no state of anoxia was reached this period.

The concentrations of total organic carbon (TOC) were extremely high and showed little seasonal variation (range 20.2–23.7 mgC $L^{-1}$; mean 22.1 mgC $L^{-1}$). As during previous years, TOC was almost exclusively made up by dissolved organic carbon and the particulate organic carbon was always very low (Figure 3-10). The water colour, as indicated by the absorbance at 420 nm, was low; ranging from 0.08 to 0.178 (mean 0.127) and was very similar to previous years (range 0.08–0.26; mean 0.16). There was a tendency for higher values in spring and autumn and lower values in the summer but this trend was very weak.


3.9 b ) Oxygen saturation in Lake Eckarfjärden
January 2000- March 2003

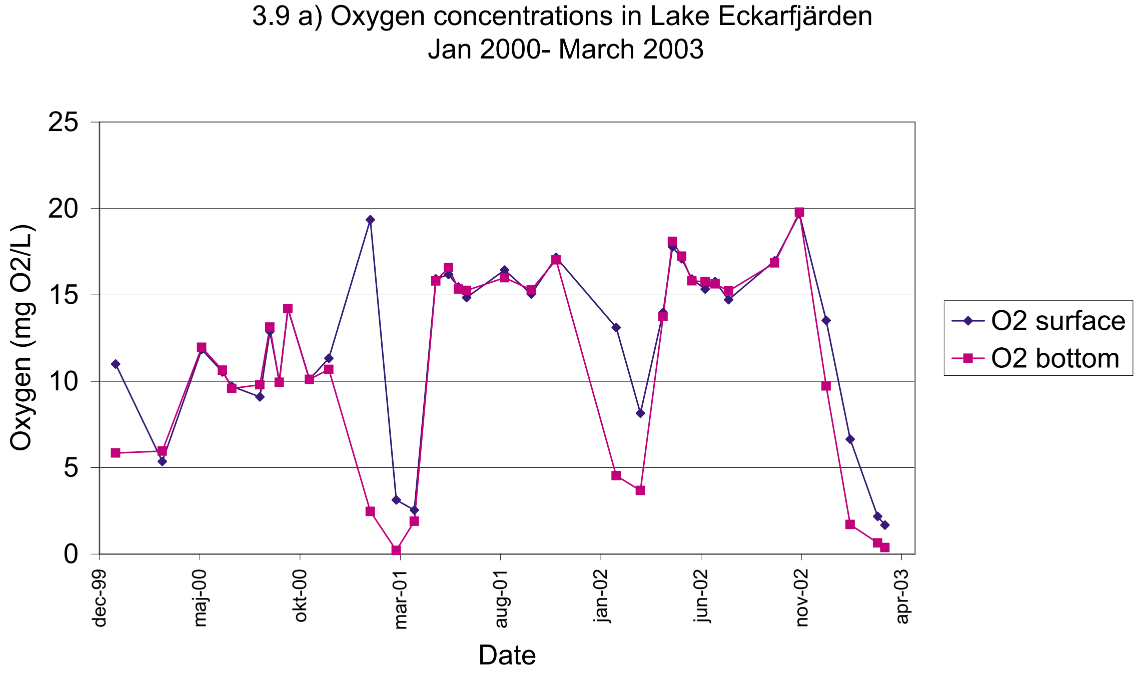

3.9 a) Oxygen concentrations in Lake Eckarfjärden
Jan 2000- March 2003

***Figure 3-9.*** *a) Oxygen concentration and b) oxygen saturation in the surface and bottom water of Lake Eckarfjärden during the period January 2000 to March 2003.*

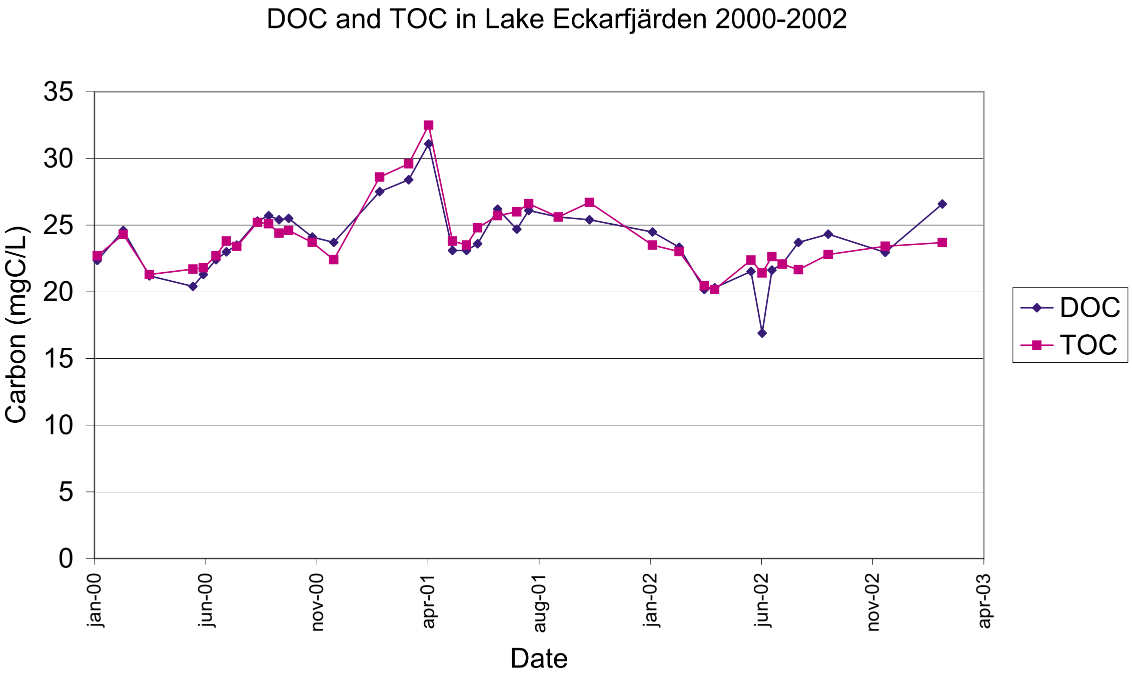


*Figure 3-10. Concentration of dissolved organic carbon (DOC) and total organic carbon (TOC) in Lake Eckarfjärden during the period January 2000 to March 2003.*

## 3.2 Biomass and community composition of pelagic and benthic biota

All measurements of the community composition, biomass, and production of different groups of pelagic and benthic biota are presented in Appendix B.

Total biomass of phytoplankton and heterotrophic (not photosynthesising) nanoflagellates in the pelagial ranged between 4 and 177 μgC $L^{-1}$ (74 ±53, mean ±SD). The biomass was higher than during 2001 but similar to that during 2000 (Figure 3-11). In terms of functional groups, mixotrophic flagellates (i.e. both photosynthesising and utilizing bacteria), and autotrophic non-flagellates dominated the phytoplankton community. With respect to seasonal dynamics, the phytoplankton community showed a pronounced seasonality with maxima during the ice-free season and minima under the ice in winter (Figure 3-11). Mixotrophic flagellates, mostly chrysophytes, dominated in early summer and autotrophic non-flagellates, mostly non nitrogen-fixing cyanobacteria, dominated in late summer. The biomass of heterotrophic nanoflagellates was usually small compared to that of mixotrophic flagellates.

Bacterioplankton biomass ranged between 11 and 35 μg C $L^{-1}$ (24 ±9, mean ±SD). In terms of seasonal development there was a summer maximum but the concentration was lower than during previous years (Figure 3-12).

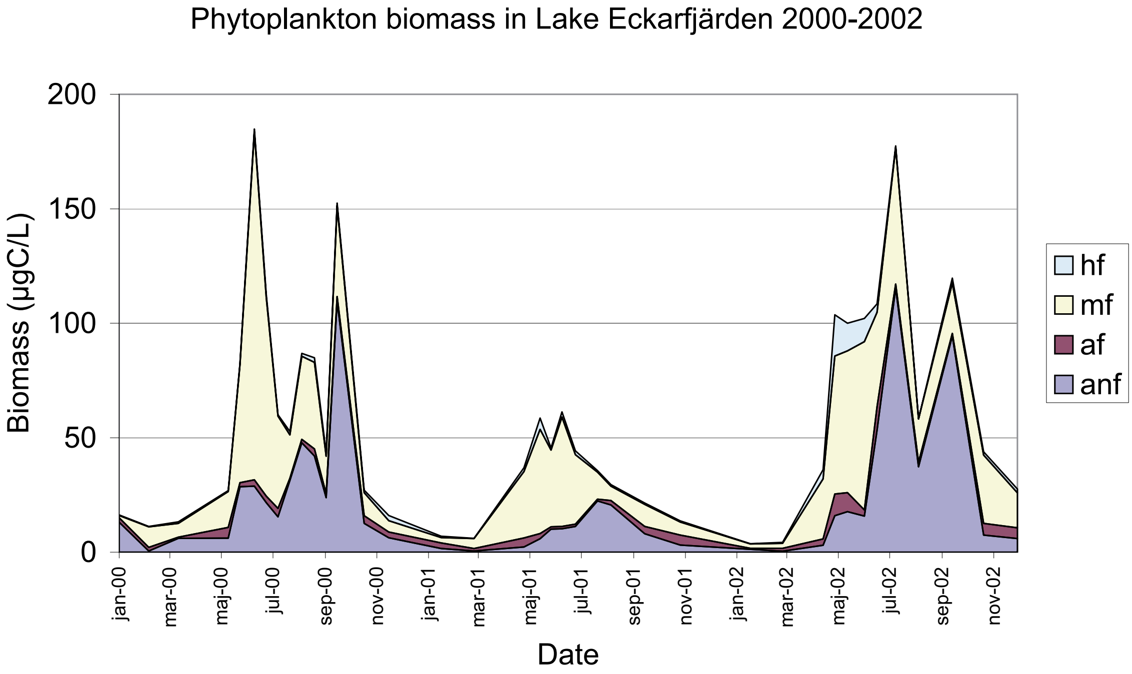


*Figure 3-11. Biomass of functional groups of phytoplankton in Lake Eckarfjärden during the period January 2000 to December 2002. Hf = heterotrophic flagellates, mf = mixotrophic flagellates, af = autotrophic flagellates, and anf = autotrophic non-flagellates.*

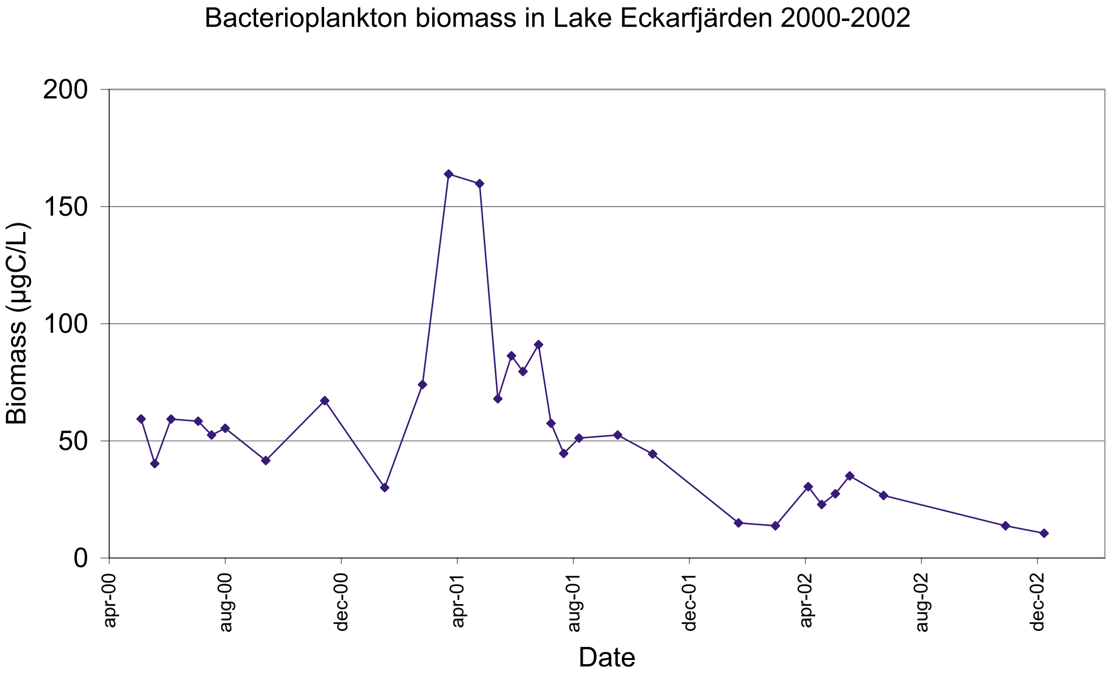


*Figure 3-12. Biomass of bacterioplankton in Lake Eckarfjärden during the period May 2000 to December 2002.*

Zooplankton biomass ranged between 7 and 144 µg C $L^{-1}$. The zooplankton community was dominated by copepods except for the summer period when rotifers dominated (Figure 3-13). The biomass of copepods was made up by equal amounts of cyclopoid and calanoid copepods. The copepods showed a clear seasonal variation with higher biomass during winter, spring, and autumn and lower biomass in the summer time (biomass range 3–142 µgC $L^{-1}$). Rotifers showed opposite seasonal variation to copepods with low biomass during winter, spring, and autumn but with a substantial summer maximum of 25 µgC $L^{-1}$ on 26th of July. The summer maximum was almost exclusively made up by *Polyarthra sp*. which was common at all times of the year. Cladocerans only made a small contribution to the total zooplankton biomass, varying from 1 to 13 µgC $L^{-1}$. Cladocerans were almost exclusively made up by *Bosmina sp.* except for 7th of May when *Daphnia* was the dominating Cladoceran.

The microphytobenthos community of the microbial mat on the illuminated soft sediment habitat was, in accordance with previous years, dominated by cyanobacteria, followed by diatoms and purple sulphur bacteria. The biomass was high (3.1 ±1.1 gC $m^{-2}$, mean ±SD) and in the same order of magnitude as in year 2000, but lower than 2001 (Figure 3-14). On an areal basis, the biomass of microphytobenthos was always much higher (14–410, average 110 times higher) than the biomass of phytoplankton in the water column above (Figure 3-15).

The biomass of heterotrophic bacteria in the sediment showed a considerable variation over the year but no evident seasonal patterns (Figure 3-16). The mean biomass was 3.8 gC $m^{-2}$ and this was 83–296 times higher than the bacterioplankton biomass in the water column above.

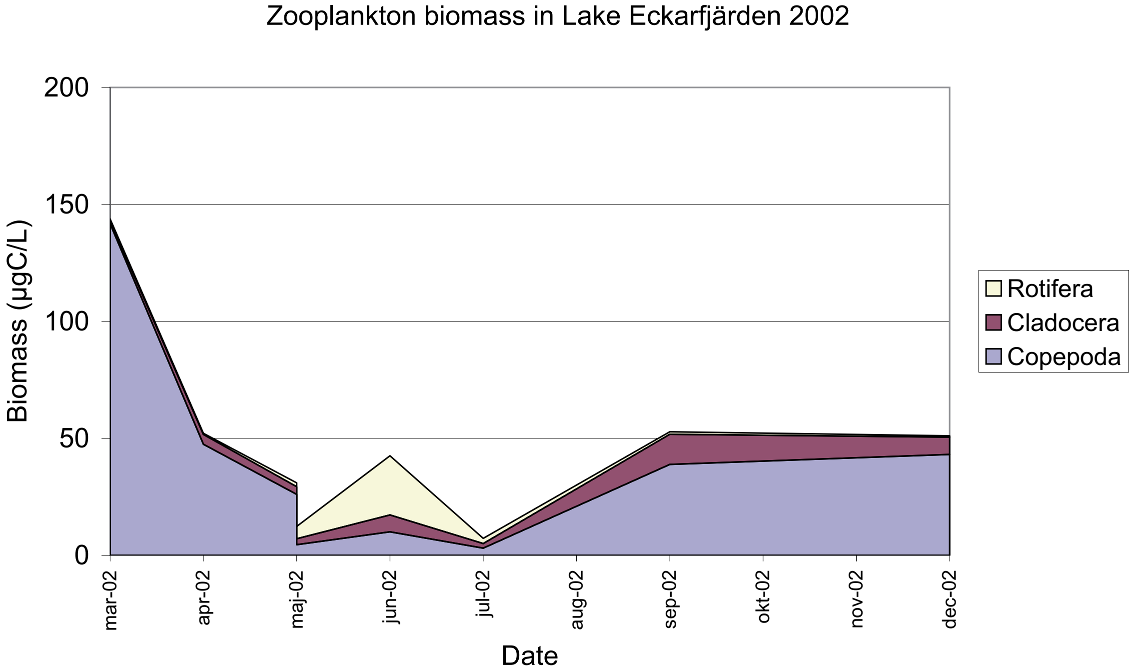


***Figure 3-13.*** *Biomass of zooplankton in Lake Eckarfjärden during the period March 2002 to December 2002.*

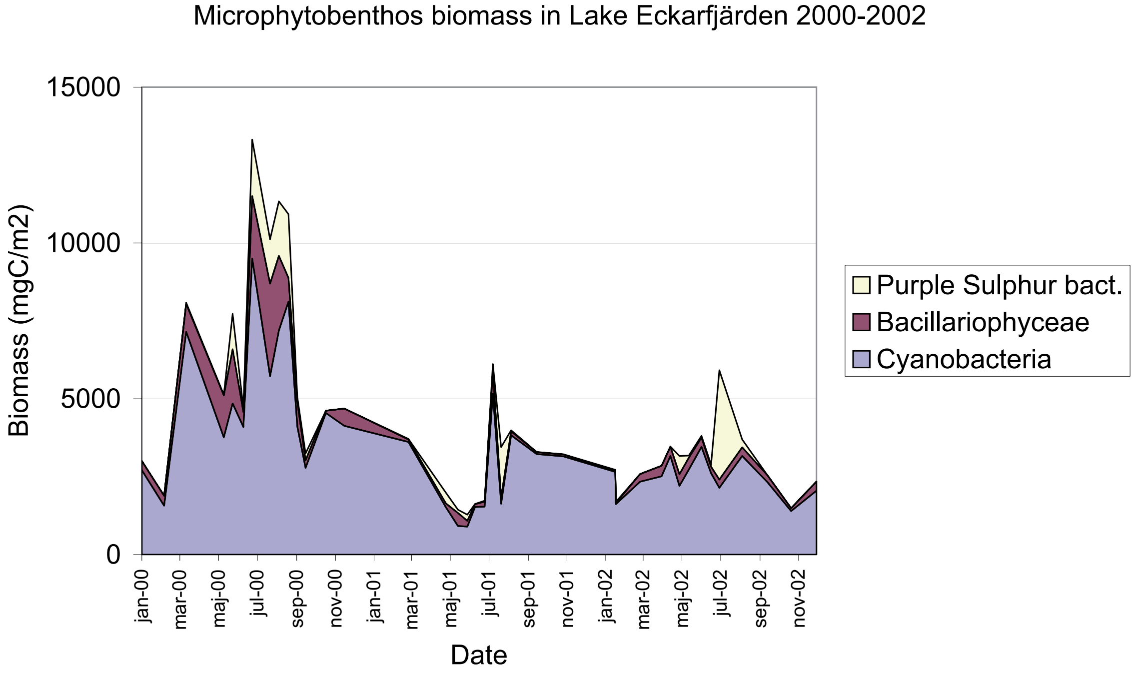


***Figure 3-14.** Biomass of microphytobenthos in the top 5 cm of the microbial mat in Lake Eckarfjärden during the period January 2000 to December 2002.*

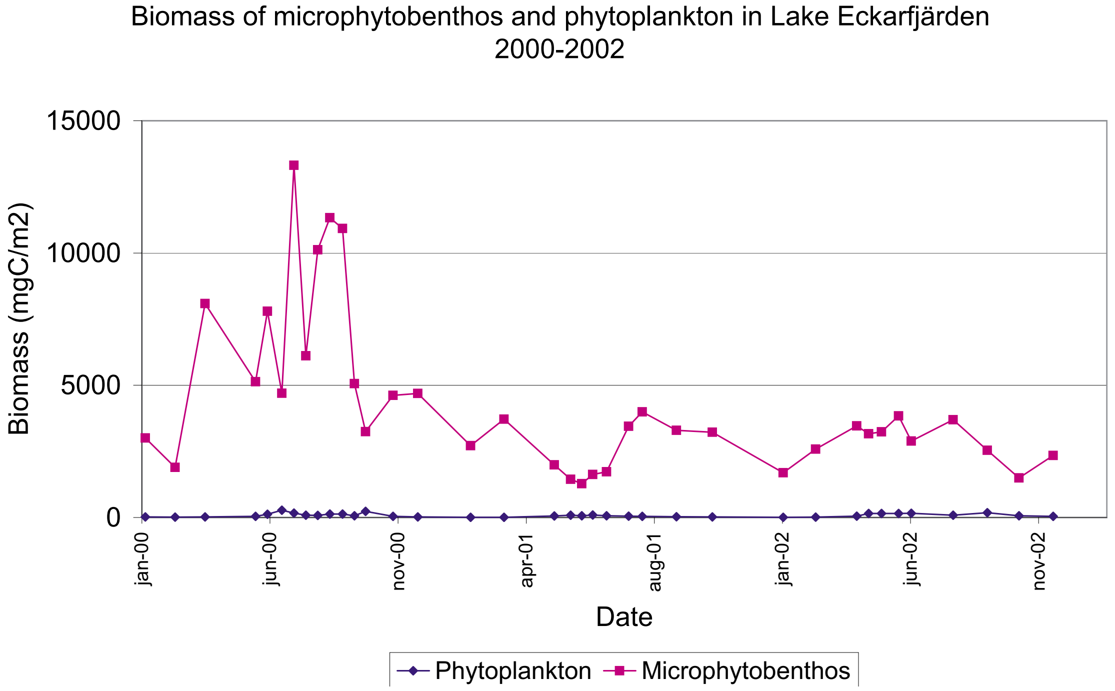


***Figure 3-15.** Biomass of phytoplankton and microphytobenthos, estimated on an areal basis in/below a water column of 1.5 m, in Lake Eckarfjärden during the period January 2000 to December 2002.*

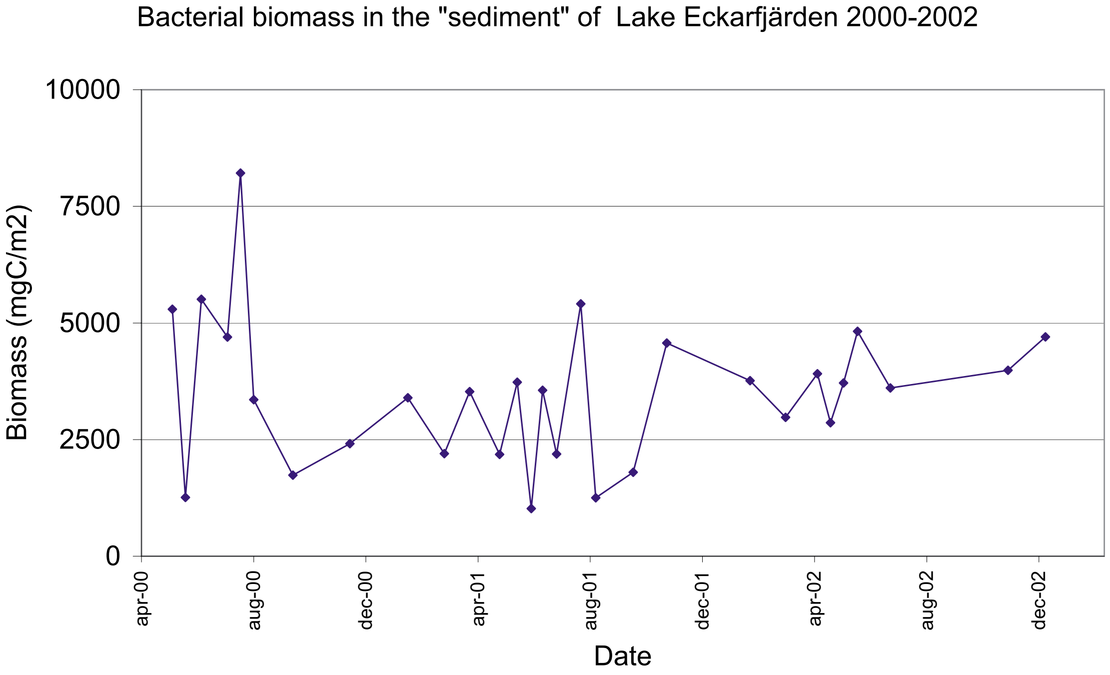
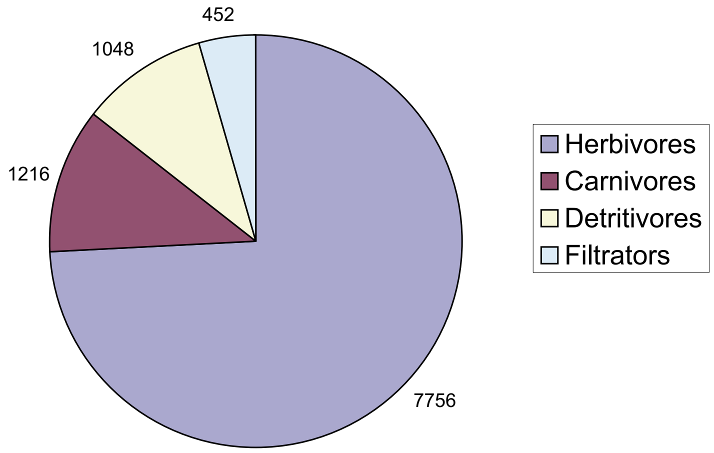


***Figure 3-16.*** *Bacterial biomass in the top 5 cm of the microbial mat in Lake Eckarfjärden during the period May 2000 to March 2002.*

The biomass of benthic fauna was low. Considering number of individuals, herbivores (principally *Chironomidae* and *Ephemeroptera*) was by far the dominating functional group with over 7000 indiviuals m$^{-2}$ (Figure 3-17a). Also in terms of biomass herbivores dominated, but in this case *Gastropoda*, with only 32 individuals m$^{-2}$, was the dominant group with 853 mg ww m$^{-2}$, while other herbivores made up 667mg ww m$^{-2}$, filtrators 484 mg ww m$^{-2}$ and detrivores 395 mg ww m$^{-2}$ (Figure 3-17b). There was a high diversity of carnivores and together these taxa had an abundance of 1200 individuals m$^{-2}$, but their biomass was low (261 mg ww m$^{-2}$, Figure 3-17a and b).

The dominating macrophyte (the macroalga Chara was not included in macrophytes) in Lake Eckarfjärden was by far *Phragmites australiensis*, covering 31% of the lake area with a total weight of more than 25 000 kg (Figure 3-18). The *Phragmites* stands were dense with an average of 50 straws m$^{-2}$, and mean dry weight of 296 g m$^{-2}$. There was also a large quantity of dead *Phragmites*, on average 80 straws m$^{-2}$. *Typha sp.* the second most common macrophyte, which covered 29% of the lake area, but was less dense with 18 straws m$^{-2}$ and a mean dry weight of 184 g m$^{-2}$. *Schoenoplectus lacustris* and *Equisetum fluviatile* covered only 3 and 1% of the lake area respectively and was quite sparse with a dry weight of 54 and 34 g m$^{-2}$, respectively.

3.17a) Benthic fauna in Lake Eckarfjärden
(no of individuals/m2)



3.17b) Benthic fauna in Lake Eckarfjärden (mg ww/m2)

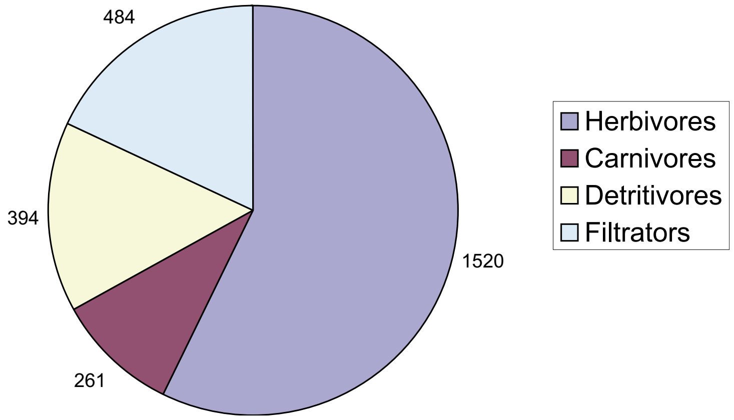


***Figure 3-17.*** *Benthic fauna in Lake Eckarfjärden in March 2002 in* ***a)*** *no of individuals /m$^2$ and* ***b)*** *mg wet weight /m$^2$.*

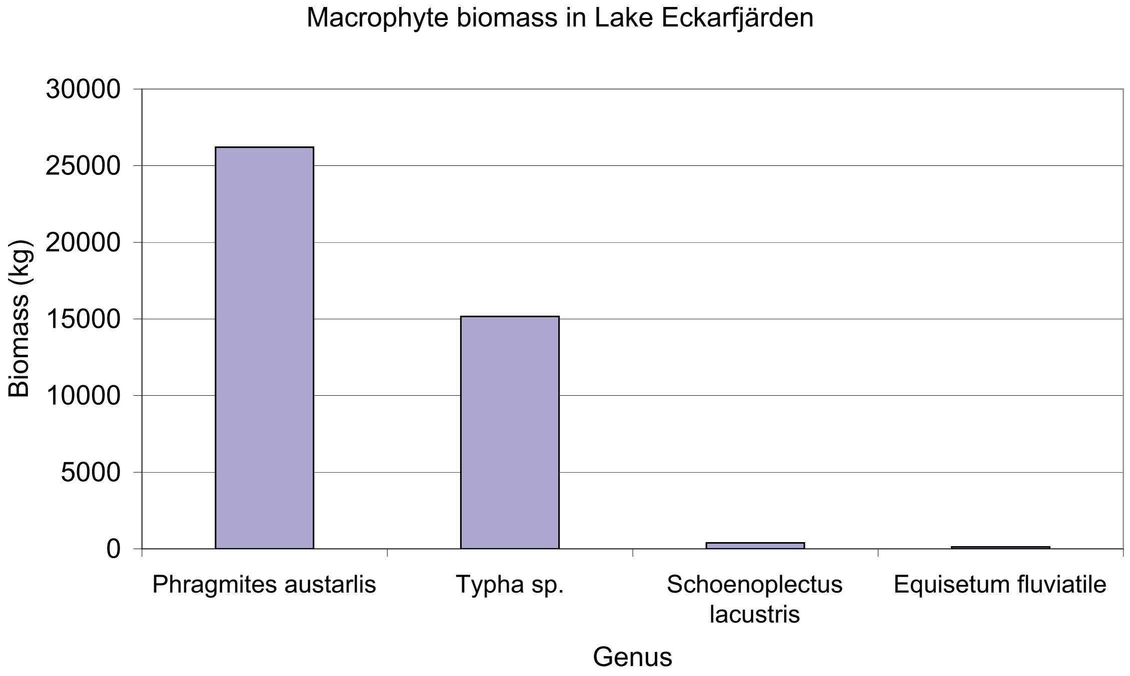


***Figure 3-18.*** *Total biomass of macrophytes in Lake Eckarfjärden 2002.*

## 3.3 Production of pelagic and benthic microbiota

All single measurements of production of microbiota are presented in Appendix C.

Phytoplankton production ranged from close to 0 to 27 mgC $m^{-2}$ $h^{-1}$ (on an areal basis in a water column of 1.5 m, which is the mean depth), with the lowest values in winter and the highest values in summer (Figure 3-19, Table 3-1). Calculated for the entire lake, the production ranged between 0.15 and 5 kgC per hour.

Primary production by microphytobenthos was high in summer, however, production was lower during 2002 than during 2001. The maximum value noted during 2002 was 39 mgC $m^{-2}$ $h^{-1}$, whereas the maximum during 2001 was 144 mgC $m^{-2}$ $h^{-1}$. At a water depth of 1.5 m the areal primary production of microphytobenthos was close to that of phytoplankton (Figure 3-19, Table 3-1). At three occasions the primary production of microphytobenthos was measured at three different depths. On the 14th of August the primary production was much lower at 1.5 m depth than at 0.5 and 1 m depth (Figure 3-20). However on the 23rd of September the primary production was higher at 1.5m depth than at 0.5 and 1 m depth. In October there were no clear differences in the production between the depths.

Bacterioplankton production showed a pronounced seasonal variation with highest values in the summer and lower values in the winter. The bacterial production in the pelagic varied between 0.4–8.8 µgC $L^{-1}$ $h^{-1}$ during 2002 (Figure 3-21). This is in the same order of magnitude as during 2001. The maximum during 2001 was somewhat higher, (11 µgC $L^{-1}$ $h^{-1}$), and coincided with a nitrification event under the ice. During 2002, the production by planktonic bacteria on an areal basis in a water column of 1.5m, varied between 0.3 and 12 mgC $L^{-1}$ $h^{-1}$ (Figure 3-22, Table 3-1).

Production of sediment bacteria was low, compared to that in other lake sediments, but higher than the production by bacterioplankton below a water column of 1.5 m (Figure 3-21, Table 3-1). The production varied over the year with highest values during summer and low values in winter and spring.

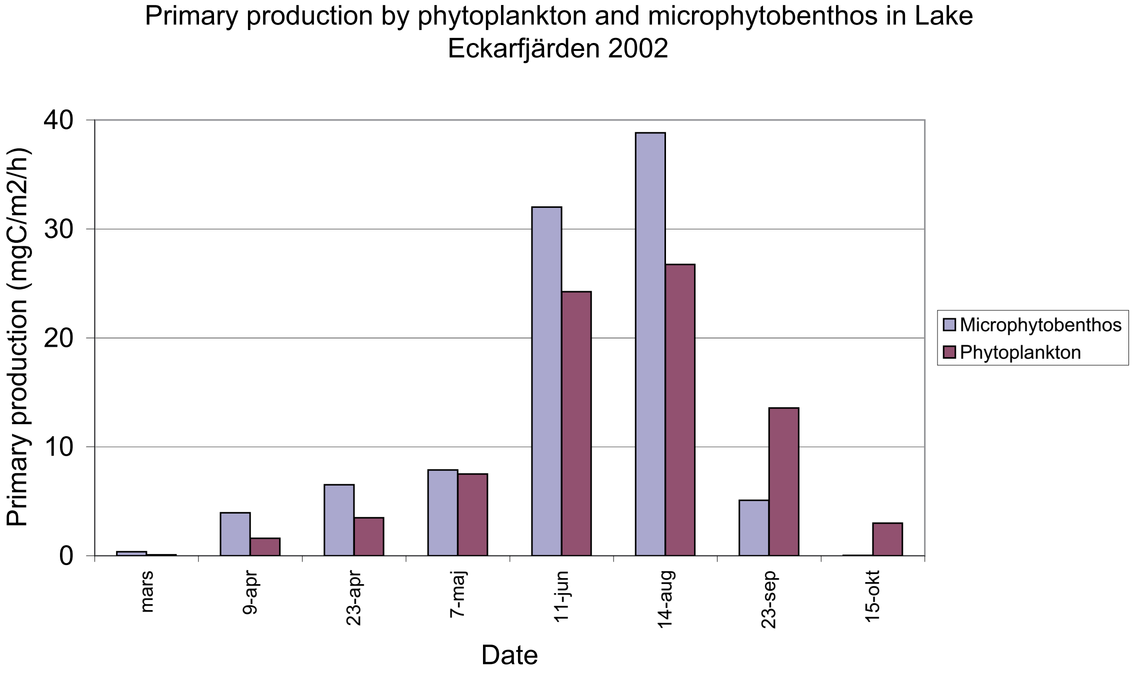


***Figure 3-19.*** *Primary production by phytoplankton and microphytobenthos, estimated on an areal basis in/below a water column of 1.5 m, in Lake Eckarfjärden 2002.*

**Table 3-1. Average biomass and production values of microbiota, estimated on an areal basis in/below a water column of 1.5 m, in Lake Eckarfjärden during 2002.**

| | **Biomass mgC m$^{-2}$** | **Production (mgC m$^{2-1}$ h$^{-1}$)** |
|---|---|---|
| Phytoplankton | 74 ± 53 | 11 ± 11 |
| Microphytobenthos | 3056 ± 1100 | 12 ±15 |
| Bacterioplankton | 36 ± 13 | 4 ± 4 |
| Benthic bacteria | 3848 ± 605 | 6 ± 5 |

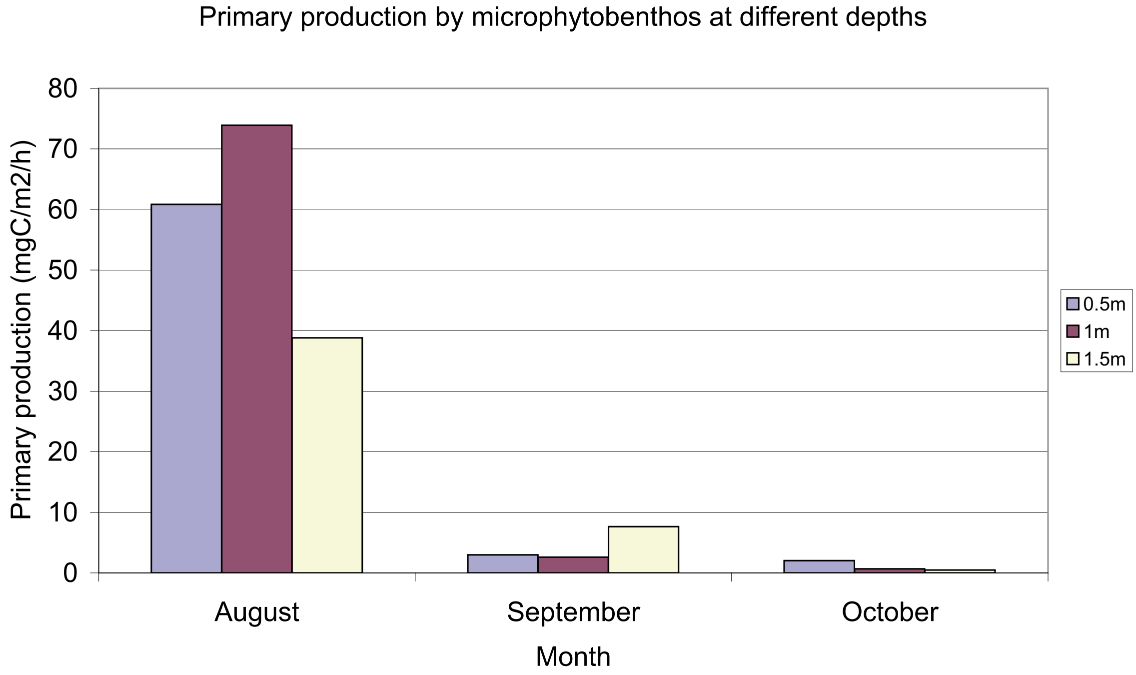


*Figure 3-20. Primary production by microphytobenthos at three different depths in Lake Eckarfjärden during 2002.*

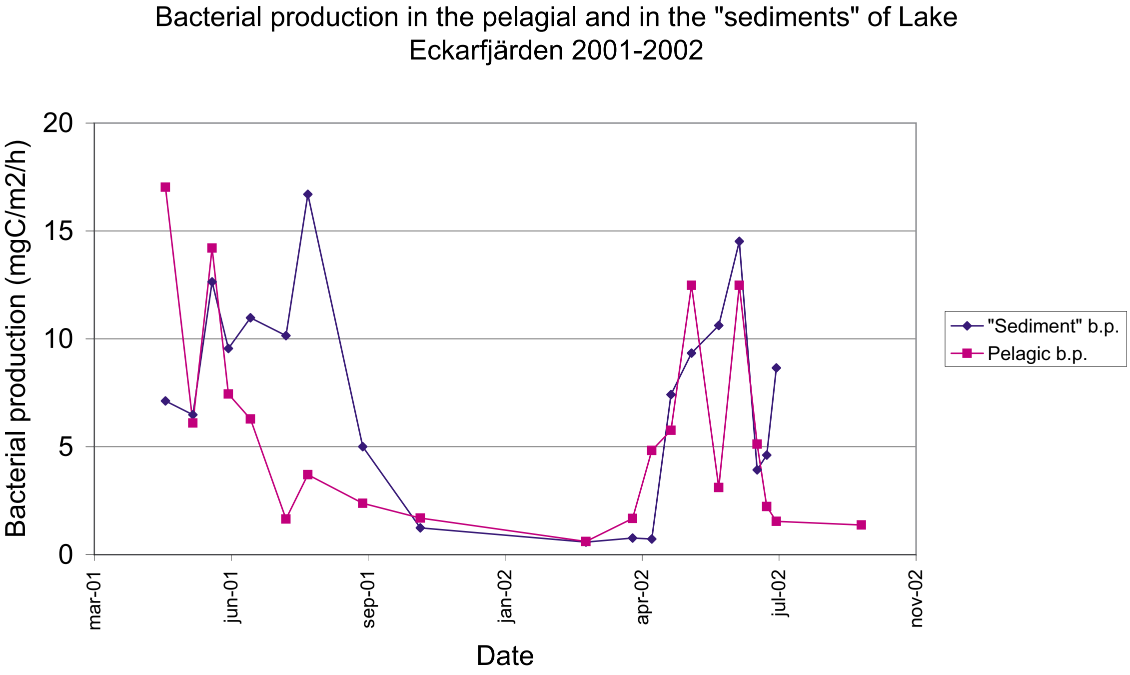


*Figure 3-21. Bacterial production (b.p.) in the pelagic and in the top 5 cm of the microbial mat, estimated on an areal basis in/below a water column of 1.5 m, in Lake Eckarfjärden during 2001 and 2002.*

# 4 Discussion

Our studies of the ecosystem in Lake Eckarfjärden during 2002 further strengthens the conclusion /Blomqvist et al, 2002/ that the microbial mat on the illuminated soft sediment habitat has a key role in the metabolism of organic matter in the system. The biomass of microbiota is heavily concentrated to the benthic microbial mat and the production by microbiota in the mat is high, also when compared to the pelagic production in the entire water column above.

The high metabolic activity of the mat also affects the overlaying water chemically, leading to precipitation of $CaCO_3$ and subsequent co-precipitation of phosphorus. This phenomenon results in the seemingly odd water chemistry of the lake with very high concentrations of virtually all other inorganic constituents of the water but phosphorus. The chemistry data from 2002 were in most respects identical to those from the previous years (with exception of total phosphorus which was lower) and indicates that the chemical characteristics of the open water have been reasonably established.

Total phosphorus was lower during 2002 than during previous years. This coincided with lower bacterial biomass and one explanation to the lower phosphorus concentrations may therefore be that less phosphorus was stored in bacteria (bacteria make up part of the particulate phosphorus fraction and hence also the total phosphorus). There can be several reasons why bacterial biomass was lower than during previous years. One reason could be higher grazing pressure by mixotrophic plankton although that does not explain the lowered phosphorus concentrations, since plankton are also included in the total phosphorus. Furthermore, although the biomass of mixotrophic flagellates was higher during 2002 it was not higher than in year 2000. A more reasonable explanation for the lower bacterial biomass could be lower production rates due to lower nutrient availability. However, despite the low bacterial biomass, the production by planktonic bacteria was high and of the same order of magnitude as during 2001. Therefore, it seems that there were enough nutrients available for growth. The lower phosphorus concentrations were most probably caused by increased losses to the sediments.

Although high, the primary production by microphytobenthos was lower during 2002 than 2001. One reason for this could be that the light availability was lower during 2002 than during previous years. The phytoplankton biomass was larger during 2002 than 2001 and hence the light availability lower down in the water column was most probably lower 2002 than during previous years. The measurements of the primary production by microphytobenthos at three different depths showed that measurements at only one depth could lead to seriously under- or overestimations of the total primary production in the lake. The fact that some areas of the lake are shallower and other are deeper than the depth of 1.5 m that were frequently used for measuring the primary production could lead to that the over- and underestimation of primary production at different depths evens out each other. However, to be certain, further studies are needed to establish the overall lake primary production by microphytobenthos.

Although the biomass of bacteria in the microbial mat was rather high, 3.8 gC $m^{-2}$, the bacterial production was rather low compared to that in other littoral sediments /Wetzel, 2001/. However, in contrast to other lake sediments, the microbial mat consists to a large part of living cyanobacteria. The bacterial production has only been measured during daytime when cyanobacteria ought to be most active due to sunlight and the low bacterial production values could very well be due to competition for nutrients with the cyanobacteria. One could speculate that the bacterial production on a daily basis could be higher and have a larger impact on the total production in the lake than shown in this study.

The zooplankton community, for the first time studied in 2002, showed an almost inverse seasonal development to that of many other lakes /e.g. Sommer et al, 1986/, with maximum during winter and minima during summer. Total biomass of zooplankton was also low /Hessen et al, 2003/, and dominated by copepods, which made up the bulk biomass during the winter maximum. This may reflect that these organisms usually stay in or close to the microbial mat on the bottoms and only leave this habitat in connection with low oxygen concentrations during winter. Another unusual feature of the zooplankton community was the dominance, in terms of biomass, of Rotatoria during summer. This observation, together with the fact that Cladocera were almost absent from the lake and that the few that were there were mostly very small species, clearly indicates that the predation pressure on zooplankton from fish may be a major controlling factor in the pelagic zone. Fish surveys in the county Uppland show that the amount of fish in Lake Eckarfjärden is somewhat smaller than in other lakes of equal size /Nyberg, 1999/. However, during field sampling large amounts of small yearlings of fish, which would be too small to be caught in a fish survey net have been observed by eye. The lake has a connection with the Baltic Sea through the nearby Lake Bolundsfjärden. Its reasonable to believe that fish from the Baltic Sea use Lake Eckarfjärden to spawn and that the juveniles stay there and feed from the zooplankton community until they are large enough to move out to the Baltic Sea. This hypothesis of migrating fish as an important factor in the lake food web merits further investigation.

In comparison with the very high biomass of microphytobenthos on the sediments, the benthic fauna community was weakly developed. In terms of number of individuals, the benthic fauna community was dominated by herbivorous species of *Chironomidae*. The overall biomass was low compared to that in other types of lakes /Wetzel, 2001/, indicating that the microbial mat was of low nutritional value to the animals. Another explanation may be that the microbial mat (water content > 95%) is too soft and unstable for animals (e.g. scrapers) to exploit.

Altogether our study clearly shows the allocation of biota and production to the microbial mat of Lake Eckarfjärden. The production in the microbial mat clearly affects the overlaying water and gives rise to this very unusual lake type.

# 5 Acknowledgements

This study was financially supported by the Swedish Nuclear Fuel and Waste Management Company. We thank Department of Miljöanalys, SLU, for providing chemical analysis of total nitrogen, nitrate, nitrite and ions. Jan Johansson counted bacterial biomass and fieldwork assistance by Ina Franzén and Therese Carlsson is also appreciated.

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# Appendix A

**Table A-1. Water chemistry of Lake Eckarfjärden January 2002–March 2003. "-" indicates missing value.**

| Date | PH-value | Conductivity (mS $m^{-1}$) | Alkalinity (mekv $L^{-1}$) | Temperature surface (°C) | Temperature bottom (°C) |
|---|---|---|---|---|---|
| 29 Jan -02 | 8.0 | 29 | 2.6 | 0 | 2 |
| 06 Mar -02 | 7.9 | 29 | 2.7 | 2 | 3 |
| 09 Apr -02 | 7.7 | 28 | 2.5 | 6 | 6 |
| 23 Apr -02 | 8.2 | 27 | 2.5 | 11 | 11 |
| 07 May -02 | 8.2 | 27 | 2.6 | 14 | 12 |
| 22 May -02 | 8.4 | 26 | 2.4 | 18 | 17 |
| 11 Jun -02 | 8.6 | 24 | 2.4 | 18 | 18 |
| 26 Jun -02 | 8.1 | 20 | 2.2 | 20 | 20 |
| 09 Jul -02 | 8.0 | 21 | 2.0 | 22 | 22 |
| 16 Jul -02 | 8.4 | 22 | 2.0 | 24 | 24 |
| 23 Jul -02 | 8.1 | 20 | 2.1 | 24 | 24 |
| 14 Aug -02 | 8.5 | 23 | 2.1 | 20 | 20 |
| 23 Sep -02 | 8.1 | 19 | 2.3 | 10 | 10 |
| 30 Oct -02 | 8.2 | 25 | 2.4 | 3 | 3 |
| 09 Dec -02 | 7.9 | 31 | 2.4 | 1 | 4 |
| 14 Jan -03 | - | - | - | 1 | 4 |
| 24 Feb -03 | 7.7 | 31 | 2.4 | 1 | 4 |
| 07 Mar -03 | 7.5 | 35 | 3.3 | 2 | 3 |
| **Mean** | **8.1** | **25.7** | **2.4** | | |
| **Stdev** | **0.3** | **4.5** | **0.3** | | |
| **No of obs** | **17** | **17** | **17** | **18** | **18** |
| **Minimum** | **7.5** | **19** | **2.0** | **0** | **2** |
| **Maximum** | **8.6** | **35** | **3.3** | **24** | **24** |

## Table A-1. Continued.

| | HCO3 mmol $L^{-1}$ | SO4 mekv $L^{-1}$ | Cl mekv $L^{-1}$ |
|---|---|---|---|
| 29 Jan -02 | 2.6 | 0.131 | 0.200 |
| 06 Mar -02 | 2.7 | 0.129 | 0.202 |
| 09 Apr -02 | 2.5 | 0.109 | 0.180 |
| 23 Apr -02 | 2.4 | - | - |
| 07 May -02 | 2.6 | 0.108 | 0.182 |
| 22 May -02 | 2.4 | - | - |
| 11 Jun -02 | 2.3 | 0.113 | 0.194 |
| 26 Jun -02 | 2.1 | - | - |
| 09 Jul -02 | 2.0 | 0.108 | 0.193 |
| 16 Jul -02 | 1.9 | - | - |
| 23 Jul -02 | 2.1 | - | - |
| 14 Aug -02 | 2.1 | 0.109 | 0.179 |
| 23 Sep -02 | 2.3 | 0.107 | 0.187 |
| 30 Oct -02 | 2.4 | - | - |
| 09 Dec -02 | 2.4 | 0.112 | 0.198 |
| 24 Feb -03 | 2.4 | - | - |
| 07 Mar -03 | 3.3 | 0.198 | 0.230 |
| **Average** | **2.367** | **0.122** | **0.195** |
| **Stdev** | **0.315** | **0.028** | **0.015** |
| **No of obs** | **17** | **10** | **10** |
| **Minimum** | **1.9** | **0.107** | **0.18** |
| **Maximum** | **3.3** | **0.198** | **0.23** |

## Table A-1. Continued.

| Date | Colour Abs420 | TOC (mg $L^{-1}$) | DOC (mg $L^{-1}$) | TOC/ Colour |
|---|---|---|---|---|
| 29 Jan -02 | 0.149 | 23.5 | 24.5 | 158 |
| 06 Mar -02 | 0.178 | 23.0 | 23.4 | 129 |
| 09 Apr -02 | 0.162 | 20.5 | 20.2 | 126 |
| 23 Apr -02 | 0.159 | 20.2 | 20.3 | 127 |
| 22 May -02 | 0.124 | 20.7 | - | 167 |
| 11 Jun -02 | 0.103 | 22.4 | 21.5 | 217 |
| 26 Jun -02 | 0.087 | 21.4 | 16.9 | 246 |
| 09 Jul -02 | - | 22.6 | 21.6 | - |
| 23 Jul -02 | - | 22.1 | 22.1 | - |
| 14 Aug -02 | 0.115 | 21.7 | 23.7 | 188 |
| 23 Sep -02 | - | 22.8 | 24.3 | - |
| 09 Dec -02 | 0.080 | 23.4 | 23.0 | 293 |
| 24 Feb -03 | 0.114 | 23.7 | 26.6 | 208 |
| **Mean** | **0.127** | **22.1** | **22.3** | **186** |
| **Stdev** | **0.03** | **1.2** | **2.5** | **56** |
| **No of obs** | **10** | **13** | **12** | **10** |
| **Minimum** | **0.080** | **20.2** | **16.9** | **126** |
| **Maximum** | **0.178** | **23.7** | **26.6** | **293** |

**Table A-1. Continued.**

| | $NH_4$-N (µgN $L^{-1}$) | $\sum NO_2+NO_3$ (µgN $L^{-1}$) | TIN (µgN $L^{-1}$) | Organic nitrogen (µgN $L^{-1}$) | Tot-N (µgN $L^{-1}$) |
|---|---|---|---|---|---|
| 29 Jan -02 | 636 | 5 | 641 | 682 | 1323 |
| 06 Mar -02 | 555 | 97 | 652 | 672 | 1324 |
| 09 Apr -02 | 387 | 40 | 427 | 547 | 974 |
| 23 Apr -02 | 157 | 37 | 194 | 627 | 821 |
| 07 May -02 | 214 | - | - | - | - |
| 22 May -02 | 225 | - | - | - | - |
| 11 Jun -02 | 121 | 14 | 135 | 685 | 820 |
| 26 Jun -02 | 97 | 11 | 108 | 654 | 762 |
| 09 Jul -02 | 14 | 9 | 23 | 723 | 746 |
| 16 Jul -02 | 39 | - | - | - | - |
| 23 Jul -02 | 46 | 55 | 101 | 738 | 839 |
| 14 Aug -02 | - | 53 | 53 | 819 | 872 |
| 23 Sep -02 | 38 | 40 | 78 | 859 | 937 |
| 30 Oct -02 | 216 | - | - | - | - |
| 09 Dec -02 | 588 | 41 | 629 | 464 | 1093 |
| 24 Feb -03 | 855 | 40 | 895 | 706 | 1601 |
| 07 Mar -03 | 884 | - | - | - | - |
| **Mean** | **317** | **37** | **328** | **681** | **1009** |
| **Stdev** | **295** | **26** | **303** | **107** | **271** |
| **No of obs** | **16** | **12** | **12** | **12** | **12** |
| **Minimum** | **14** | **5** | **23** | **464** | **746** |
| **Maximum** | **884** | **97** | **895** | **859** | **1601** |

**Table A-1. Continued.**

| | PO4-P (µgP $L^{-1}$) | Residual P (µgP $L^{-1}$) | tot-P (µgP $L^{-1}$) | Tot-N/ Tot-P |
|---|---|---|---|---|
| 29 Jan -02 | 3.9 | 0.0 | 3 | 441 |
| 06 Mar -02 | 0.0 | 8.0 | 8 | 166 |
| 09 Apr -02 | 0.0 | 8.0 | 8 | 122 |
| 23 Apr -02 | 1.5 | 4.5 | 6 | 137 |
| 07 May -02 | - | - | - | - |
| 22 May -02 | 1.6 | - | - | - |
| 11 Jun -02 | 1.6 | 12.4 | 14 | 59 |
| 26 Jun -02 | 0.3 | 5.7 | 6 | 127 |
| 09 Jul -02 | - | - | 6 | 124 |
| 16 Jul -02 | - | - | - | - |
| 23 Jul -02 | 1 | 4.0 | 5 | 168 |
| 14 Aug -02 | - | - | 9 | 97 |
| 23 Sep -02 | 0.0 | 5.0 | 5 | 187 |
| 30 Oct -02 | 1.4 | - | - | - |
| 09 Dec -02 | 6.3 | 1.7 | 8 | 137 |
| 24 Feb -03 | - | - | 5 | 320 |
| 07 Mar -03 | 0.9 | - | - | - |
| **Mean** | **1.5** | **5.4** | **7** | **174** |
| **Stdev** | **1.8** | **3.7** | **3** | **105** |
| **No of obs** | **12** | **9** | **12** | **12** |
| **Minimum** | **0** | **0** | **3** | **59** |
| **Maximum** | **6.3** | **12.4** | **14** | **441** |

**Table A-1. Continued.**

| | $O_2$ surface mg $O_2$ $L^{-1}$ | $O_2$ bottom mg $O_2$ $L^{-1}$ | $O_2$-saturation surface % | $O_2$-saturation bottom % |
|---|---|---|---|---|
| 29 Jan -02 | 13.1 | 4.5 | 90 | 33 |
| 06 Mar -02 | 8.2 | 3.7 | 59 | 27 |
| 09 Apr -02 | 14.0 | 13.7 | 112 | 109 |
| 23 Apr -02 | 17.8 | 18.1 | 161 | 164 |
| 07 May -02 | 17.1 | 17.2 | 166 | 160 |
| 22 May -02 | 15.9 | 15.8 | 166 | 165 |
| 11 Jun -02 | 15.3 | 15.8 | 162 | 167 |
| 26 Jun -02 | 15.8 | 15.6 | 174 | 172 |
| 16 Jul -02 | 14.7 | 15.2 | 175 | 181 |
| 23 Sep -02 | 17.0 | 16.8 | 150 | 149 |
| 30 Oct -02 | 19.7 | 19.8 | 146 | 147 |
| 09 Dec -02 | 13.5 | 9.7 | 95 | 68 |
| 14 Jan -03 | 6.6 | 1.7 | 47 | 13 |
| 24 Feb -03 | 2.2 | 0.6 | 15 | 5 |
| 07 Mar -03 | 1.7 | 0.4 | 12 | 3 |
| **Medel** | **12.8** | **11.3** | **115** | **104** |
| **Stdev** | **5.6** | **7.0** | **59** | **70** |
| **No of obs** | **15** | **15** | **15** | **15** |
| **Minimum** | **1.7** | **0.4** | **12** | **3** |
| **Maximum** | **19.7** | **19.8** | **175** | **181** |

**Table A-1. Continued.**

| mg L$^{-1}$ | Si<br>mekv L$^{-1}$ | Ca<br>mekv L$^{-1}$ | Na<br>mekv L$^{-1}$ | Mg<br>mekv L$^{-1}$ | K<br>µg L$^{-1}$ | Fe<br>µg L$^{-1}$ | Mn |
|---|---|---|---|---|---|---|---|
| 29 Jan -02 | 5.7 | 2.5 | 0.308 | 0.256 | 0.06 | 45.0 | 39.0 |
| 06 Mar -02 | 5.3 | 2.6 | 0.293 | 0.257 | 0.061 | 61.0 | 72.0 |
| 09 Apr -02 | 4.7 | 2.5 | 0.266 | 0.228 | 0.052 | 60.0 | 73.0 |
| 23 Apr -02 | 4.0 | 2.5 | 0.267 | 0.225 | 0.052 | 42.0 | 27.0 |
| 11 Jun -02 | 1.7 | 2.0 | 0.305 | 0.244 | 0.056 | 6.0 | 2.9 |
| 26 Jun -02 | 2.0 | 1.9 | 0.302 | 0.237 | 0.055 | 4.3 | 0.9 |
| 09 Jul -02 | 2.2 | 1.7 | 0.284 | 0.227 | 0.049 | 9.5 | 1.9 |
| 23 Jul -02 | 2.6 | 1.7 | 0.279 | 0.223 | 0.049 | 37.0 | 5.2 |
| 14 Aug -02 | 3.3 | 1.8 | 0.297 | 0.237 | 0.052 | 28.0 | 1.8 |
| 23 Sep -02 | 4.0 | 1.8 | 0.321 | 0.251 | 0.054 | 31.0 | 1.7 |
| 09 Dec -02 | 3.3 | 2.1 | 0.326 | 0.257 | 0.058 | 28.0 | 26.0 |
| 24 Feb -03 | 4.8 | 2.8 | 0.40 | 0.302 | 0.068 | 47.0 | 102.0 |
| **Mean** | **3.6** | **2.2** | **0.30** | **0.25** | **0.06** | **33.2** | **29.5** |
| **Stdev** | **1.3** | **0.4** | **0.03** | **0.02** | **0.01** | **19.3** | **35.0** |
| **No of obs** | **12** | **12** | **12** | **12** | **12** | **12** | **12** |
| **Minimum** | **1.7** | **2.8** | **0.40** | **0.30** | **0.07** | **4.3** | **0.9** |
| **Maximum** | **5.7** | **1.7** | **0.23** | **0.22** | **0.05** | **61.0** | **0.0** |

**Table A-1. Continued.**

| | Water colour (Abs620) | Water colour (Abs420) | Water colour (Abs436) | Water colour (Abs525) |
|---|---|---|---|---|
| 29 Jan -02 | 0.149 | 0.111 | 0.029 | 0.009 |
| 06 Mar -02 | 0.178 | 0.138 | 0.041 | 0.015 |
| 09 Apr -02 | 0.162 | 0.123 | 0.037 | 0.014 |
| 23 Apr -02 | 0.159 | 0.121 | 0.034 | 0.012 |
| 22 May -02 | 0.124 | 0.094 | 0.025 | 0.008 |
| 11 Jun -02 | 0.103 | 0.076 | 0.019 | 0.005 |
| 26 Jun -02 | 0.087 | 0.065 | 0.017 | 0.001 |
| 14 Aug -02 | 0.115 | 0.08 | 0.020 | 0.006 |
| 09 Dec -02 | 0.08 | 0.059 | 0.016 | 0.006 |
| 24 Feb -03 | 0.114 | 0.085 | 0.023 | 0.007 |
| 07 Mar -03 | 0.116 | 0.086 | 0.025 | 0.008 |
| **Mean** | **0.126** | **0.094** | **0.026** | **0.008** |
| **stdev** | **0.032** | **0.026** | **0.008** | **0.004** |
| **No of obs** | **11** | **11** | **11** | **11** |
| **Minimum** | **0.08** | **0.059** | **0.016** | **0.001** |
| **Maximum** | **0.178** | **0.138** | **0.041** | **0.015** |

# Appendix B

**Table B-1. Phytoplankton biomass in terms of functional groups in Lake Eckarfjärden 2002 (µgC $L^{-1}$).**

| | Autotrophic non-flagellates | Autotrophic flagellates | Mixotrophic flagellates | Hetero-trophic flagellates | Total |
|---|---|---|---|---|---|
| 27 Jan -02 | 1 | 0 | 2 | 0 | **4** |
| 6 Mar -02 | 0 | 1 | 2 | 0 | **4** |
| 23 Apr -02 | 3 | 3 | 26 | 4 | **36** |
| 7 May -02 | 16 | 10 | 60 | 18 | **104** |
| 22 May -02 | 18 | 8 | 62 | 12 | **100** |
| 11 Jun -02 | 16 | 3 | 73 | 10 | **102** |
| 26 Jun -02 | 53 | 10 | 41 | 4 | **108** |
| 16 July -02 | 115 | 2 | 60 | 1 | **177** |
| 14 Aug -02 | 37 | 2 | 19 | 0 | **58** |
| 23 Sep -02 | 94 | 1 | 22 | 2 | **120** |
| 15 Oct -02 | 7 | 5 | 30 | 1 | **44** |
| 9 Dec -02 | 6 | 5 | 15 | 2 | **28** |
| **Mean** | **31** | **4** | **34** | **5** | **74** |
| **Stdev** | **38** | **3** | **24** | **6** | **53** |
| **No of obs** | **12** | **12** | **12** | **12** | **12** |
| **Minimum** | **0** | **0** | **2** | **0** | **4** |
| **Maximum** | **115** | **10** | **73** | **18** | **177** |

**Table B-2. Phytoplankton biomass in terms of taxonomical classes in Lake Eckarfjärden 2002 (µgC $L^{-1}$).**

| | Cyano-phyceae | Chryso-physeae | Bacillario-phyceae | Chloro-phyceae | Crypto-phyceae | Dino-phyceae |
|---|---|---|---|---|---|---|
| 27 Jan -02 | 1 | 2 | 0 | 0 | 0 | 0 |
| 6 Mar -02 | 0 | 2 | 0 | 0 | 1 | 1 |
| 23 Apr -02 | 0 | 23 | 2 | 1 | 7 | 3 |
| 7 May -02 | 4 | 59 | 12 | 0 | 28 | 1 |
| 22 May -02 | 4 | 52 | 10 | 3 | 20 | 10 |
| 11 Jun -02 | 11 | 51 | 0 | 4 | 13 | 22 |
| 26 Jun -02 | 48 | 26 | 0 | 5 | 14 | 15 |
| 16 Jul -02 | 109 | 34 | 0 | 7 | 2 | 25 |
| 14 Aug -02 | 32 | 11 | 0 | 5 | 2 | 8 |
| 23 Sep -02 | 88 | 22 | 0 | 6 | 3 | 0 |
| 30 Oct -02 | 5 | 30 | 0 | 2 | 7 | 0 |
| 9 Dec -02 | 0 | 15 | 0 | 6 | 6 | 0 |
| **Mean** | **25** | **27** | **2** | **3** | **9** | **7** |
| **Stdev** | **37** | **19** | **4** | **3** | **8** | **9** |
| **No of obs** | **12** | **12** | **12** | **12** | **12** | **12** |
| **Minimum** | **0** | **2** | **0** | **0** | **0** | **0** |
| **Maximum** | **109** | **59** | **12** | **7** | **28** | **25** |

## Table B-3. Microphytobenthos biomass in terms of taxonomical classes in Lake Eckarfjärden during 2002 (mgC m$^{-2}$).

| | Cyano-phyceae | Bacillario-phyceae | Dino-phyceae | Chloro-phyceae | Purple Sulphur bacteria |
|---|---|---|---|---|---|
| 27 Jan -02 | 1619 | 40 | 0 | 0 | 34 |
| 06 Mar -02 | 2337 | 247 | 0 | 0 | 0 |
| 09 Apr -02 | 2514 | 340 | 0 | 0 | 0 |
| 23 Apr -02 | 3168 | 299 | 0 | 0 | 0 |
| 07 May –02 | 2203 | 375 | 0 | 0 | 588 |
| 22 May -02 | 2730 | 380 | 19 | 41 | 68 |
| 11 Jun -02 | 3454 | 304 | 0 | 23 | 57 |
| 26 Jun -02 | 2610 | 213 | 0 | 0 | 68 |
| 09 Jul -02 | 2145 | 264 | 0 | 0 | 3509 |
| 14 Aug -02 | 3168 | 273 | 0 | 0 | 253 |
| 23 Sep -02 | 2319 | 223 | 0 | 0 | 0 |
| 30 Oct -02 | 1397 | 96 | 0 | 0 | 0 |
| 09 Dec -02 | 2053 | 292 | 0 | 0 | 292 |
| **Mean** | **2490** | **257** | **1** | **5** | **352** |
| **Stdev** | **598** | **99** | **5** | **12** | **963** |
| **No of obs** | **13** | **13** | **13** | **13** | **13** |
| **Minimum** | **1397** | **40** | **0** | **0** | **0** |
| **Maximum** | **3454** | **380** | **19** | **41** | **3509** |

## Table B-4. Microphytobenthos biomass in terms of functional groups in Lake Eckarfjärden during 2002 (mgC m$^{-2}$).

| | Autotrophic non-flagellates | Mixotrophic flagellates | Purple Sulphur bacteria | Total |
|---|---|---|---|---|
| **27 Jan -02** | 1660 | 0 | 34 | 1694 |
| **06 Mar -02** | 2584 | 0 | 0 | 2584 |
| **09 Apr -02** | 2854 | 0 | 0 | 2854 |
| **23 Apr -02** | 3467 | 0 | 0 | 3467 |
| **07 May -02** | 2578 | 0 | 588 | 3166 |
| **22 May -02** | 3151 | 19 | 68 | 3237 |
| **11 Jun -02** | 3781 | 0 | 57 | 3838 |
| **26 Jun -02** | 2823 | 0 | 68 | 2891 |
| **09 Jul -02** | 2410 | 0 | 3509 | 5918 |
| **14 Aug -02** | 3441 | 0 | 253 | 3694 |
| **23 Sep -02** | 2542 | 0 | 0 | 2542 |
| **30 Oct -02** | 1493 | 0 | - | 1493 |
| **09 Dec - 02** | 2345 | 0 | 0 | 2345 |
| **Mean** | **2702** | **1** | **352** | **3056** |
| **Stdev** | **668** | **5** | **963** | **1110** |
| **No of obs** | **13** | **13** | **13** | **13** |
| **Minimum** | **1493** | **0** | **0** | **1493** |
| **Maximum** | **3782** | **19** | **3509** | **3838** |

**Table B-5. Bacterial biomass in Lake Eckarfjärden 2002. “-“ indicates missing value**

| | **Bacterioplankton µgC $L^{-1}$** | **Bacterioplankton mgC $m^{-2}$** | **Sediment bacteria mgC $m^{-2}$** |
|---|---|---|---|
| 27 Jan -02 | - | - | 3761 |
| 6 Mar -02 | - | - | 2977 |
| 9 Apr -02 | 30 | 46 | 3910 |
| 23 Apr -02 | 23 | 34 | 2862 |
| 7 May -02 | 27 | 41 | 3713 |
| 22 May -02 | 35 | 53 | 4820 |
| 11 Jun -02 | - | - | 4226 |
| 26 Jun -02 | 27 | 40 | 3607 |
| 23 Sep -02 | - | - | 3768 |
| 30 Oct -02 | 14 | 21 | 3986 |
| 9 Dec -02 | 11 | 16 | 4701 |
| **Mean** | **24** | **36** | **3848** |
| **Stdev** | **9** | **13** | **605** |
| **No of obs** | **7** | **7** | **11** |
| **Minimum value** | **11** | **16** | **2862** |
| **Maximum value** | **35** | **53** | **4820** |

**Table B-6. Zooplankton biomass in terms of taxonomical classes in Lake Eckarfjärden during 2002 (µgC $L^{-1}$). Samples were filtered through 40 um mesh size. ”-” indicates no individuals found, whereas ”0” indicates that individuals were found but at lower biomass than 0.000 µgC $L^{-1}$.**

| **Taxa / Date** | 6 March | 23 April | 7 May | 22 May | 26 June | 18 July | 23 September | 9 December |
|---|---|---|---|---|---|---|---|---|
| **Coepepods** | **141.7** | **47.5** | **26.0** | **4.6** | **10.0** | **3.1** | **38.9** | **43.1** |
| Calanoida | | | | | | | | |
| *-nauplie* | - | 4.7 | 3.4 | 0.2 | 0.1 | 0.2 | 0.4 | - |
| *-copepodit* | 1.7 | - | 10.1 | 0.4 | 2.1 | 0.4 | 3.6 | - |
| *-adult male* | 24.9 | 15.0 | 3.1 | - | - | - | 2.7 | 24.1 |
| *-adult female* | 41.2 | 15.3 | - | 2.6 | - | - | 5.0 | 16.1 |
| Cyclopoida | | | | | | | | |
| *-nauplie* | 0.4 | 2.0 | 1.1 | 0.9 | 2.8 | 0.9 | 0.03 | - |
| *-copepodit* | 1.5 | 6.8 | 4.9 | 0.5 | 4.2 | 1.1 | 21.3 | 3.0 |
| *-adult male* | 12.0 | 3.6 | 1.3 | - | 0.07 | 0.1 | - | - |
| *-adult female* | 60.0 | - | - | - | - | 0.4 | - | - |
| **Cladocerans** | **1.2** | **4.2** | **3.3** | **2.5** | **7.2** | **1.9** | **12.8** | **7.4** |
| *Acoperus* | - | - | - | - | - | - | 0.1 | 1.4 |
| *Bosmina* | 1.2 | 3.9 | 0.9 | 2.2 | 1.6 | 1.1 | 8.1 | 5.5 |
| *Ceriodaphnia* | - | 0.04 | - | 0.1 | 0.2 | 0.3 | 4.4 | - |
| *Chydorus* | - | - | 0.4 | - | - | - | 0.03 | 0.4 |
| *Daphnia* | - | 0.3 | 2.0 | 0.2 | 0.1 | 0.1 | - | - |
| *Diaphanosoma* | - | - | - | - | 0.2 | 0.4 | 0.2 | - |
| *Leptodora* | - | - | - | - | 5.1 | - | - | - |
| **Rotifers** | **0.8** | **0.5** | **1.6** | **5.2** | **25.3** | **2.2** | **1.1** | **0.6** |
| *Ascomorpha* | - | - | 0.03 | 0.02 | 0.02 | 0.2 | 0.01 | 0 |
| *Asplanchna* | - | - | 0.03 | 0.002 | 0 | - | - | - |
| *Collotheca* | - | 0.001 | 0.03 | 0.2 | 0.04 | 0.1 | 0.1 | - |
| *Conochilus* | 0.02 | - | - | - | - | - | - | - |
| *Euchlanis* | - | - | 0.1 | - | - | - | - | - |
| *Kellicottia longispina* | 0.01 | 0.02 | 0.03 | 0.5 | 0.01 | 0.02 | 0.004 | 0.07 |
| *Keratella cochlearis* | 0.01 | 0.01 | 0.02 | 3.8 | 1.1 | 0.7 | 0.8 | 0.2 |
| *Lecane* | - | 0 | 0.03 | 0 | 0 | - | 0 | - |
| *Ploesoma* | - | - | - | - | 0 | - | - | - |
| *Polyarthra* | 0.76 | 0.2 | 1.3 | 0.6 | 24.2 | 1.2 | 0.2 | 0.3 |
| *Pompholyx* | - | - | 0.002 | - | - | - | - | - |
| *Synchaeta* | - | 0.2 | - | - | - | - | 0 | - |
| *Trichocerca* | - | 0.01 | - | 0.01 | - | - | 0.004 | - |
| *Trichotria* | - | - | - | - | - | - | 0 | - |
| **Total** | **144** | **52** | **31** | **12** | **42** | **6** | **49** | **51** |

**Table B-7. Biomass of benthic fauna in terms of functional groups in the microbial mat in Lake Eckarfjärden 2002. Sampling was performed on the 11th of March 2002.**

| Benthic fauna | mg ww $m^{-2}$ | Individuals $m^{-2}$ |
|---|---|---|
| **Detritivores** | | |
| *Isopoda* | 372 | 212 |
| *Nematoda* | 2 | 120 |
| *Oligochaeta* | 11 | 96 |
| *Ostracoda* | 10 | 620 |
| **Herbivores** | | |
| Chironomidae | 493 | 5 920 |
| *Ephemeroptera* | 171 | 1 760 |
| *Trichoptera* | 3 | 44 |
| *Gastropoda* | 853 | 32 |
| **Filtrators** | | |
| Pisidiidae | 484 | 452 |
| **Carnivores** | | |
| Acarina | 27 | 336 |
| *Ceratopogonidae* | 21 | 192 |
| *Chaoboridae* | 3 | 4 |
| *Chironomidae* | 124 | 580 |
| *Coleoptera* | 9 | 12 |
| *Hirudinea* | 15 | 12 |
| *Odonata* | 13 | 16 |
| *Trichoptera* | 51 | 64 |
| **Total** | **2659** | **10 472** |

**Table B-8. Biomass of the macrophyte *Phragmites australis* per m$^2$ in Lake Eckarfjärden. Number of straws was estimated by randomly placing a frame within the *Phragmites* belt and counting the straws. Biomass was measured for the live *Phragmites* only, which were cut off and taken to lab where they were weighted and dried.**

| *Square* | **No of living *Phragmites* m$^{-2}$** | **No of dead *Phragmites* m$^{-2}$** | **Wet weight (g m$^{-2}$)** | **Dry weight (g m$^{-2}$)** |
|---|---|---|---|---|
| 1 | 48 | 32 | 730 | 332 |
| 2 | 80 | 48 | 1126 | 542 |
| 3 | 48 | 32 | 587 | 297 |
| 4 | 16 | 32 | 0 | 0 |
| 5 | 80 | 160 | 561 | 242 |
| 6 | 160 | 96 | 1171 | 497 |
| 7 | 80 | 16 | 490 | 236 |
| 8 | 80 | 240 | 3237 | 1478 |
| 9 | 80 | 0 | 290 | 138 |
| 10 | 0 | 80 | 0 | 0 |
| 11 | 16 | 48 | 248 | 95 |
| 12 | 80 | 112 | 1476 | 648 |
| 13 | 0 | 0 | 0 | 0 |
| 14 | 0 | 48 | 0 | 0 |
| 15 | 128 | 256 | 1718 | 774 |
| 16 | 32 | 96 | 755 | 339 |
| 17 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 78 | 34 |
| 19 | 32 | 0 | 1321 | 495 |
| 20 | 0 | 0 | 0 | 0 |
| 21 | 32 | 64 | 983 | 359 |
| 22 | 48 | 80 | 712 | 300 |
| 23 | 32 | 32 | 636 | 283 |
| 24 | 48 | 48 | 515 | 220 |
| 25 | 224 | 784 | 1043 | 461 |
| 26 | 0 | 0 | 0 | 0 |
| 27 | 16 | 0 | 449 | 194 |
| 28 | 32 | 0 | 682 | 338 |
| **Average** | **50** | **82** | **672** | **296** |
| **Stdev** | **53** | **153** | **705** | **316** |
| **No of obs** | **28** | **28** | **28** | **28** |
| **Minimum** | **0** | **0** | **0** | **0** |
| **Maximum** | **224** | **784** | **3237** | **1478** |

**Table B-9. Biomass of the macrophyte *Typha sp.* per m$^2$ in Lake Eckarfjärden. Number of straws was estimated by randomly placing a frame within the *Typha* belt and counting the straws. Biomass was measured for the live *Typha* only, which were cut off and taken to lab where they were weighted and dried.**

| square | No of living *Typha* m$^{-2}$ | No of dead *Typha* m$^{-2}$ | Wet weight (g m$^{-2}$) | Dry weight g (g m$^{-2}$) |
|---|---|---|---|---|
| 1 | 16 | 0 | 1407 | 312 |
| 2 | 16 | 0 | 846 | 221 |
| 3 | 16 | 0 | 1096 | 303 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 |
| 6 | 32 | 0 | 942 | 257 |
| 7 | 64 | 0 | 1761 | 576 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 |
| 10 | 48 | 0 | 2685 | 672 |
| 11 | 48 | 0 | 926 | 287 |
| 12 | 96 | 0 | 1143 | 363 |
| 13 | 64 | 0 | 3692 | 921 |
| 14 | 16 | 0 | 1549 | 388 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 32 | 0 | 708 | 315 |
| 18 | 16 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 |
| 20 | 16 | 16 | 111 | 36 |
| 21 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 |
| 26 | 0 | 16 | 0 | 0 |
| 27 | 16 | 0 | 1806 | 414 |
| 28 | 16 | 0 | 315 | 96 |
| **Average** | **18** | **1** | **678** | **184** |
| **stdev** | **25** | **4** | **949** | **246** |
| **No of obs** | **28** | **28** | **28** | **28** |
| **Minima** | **0** | **0** | **0** | **0** |
| **Maxima** | **96** | **16** | **3692** | **921** |

**Table B-10. Biomass per m$^2$ of the macrophytes *Equisetum fluviatile* and *Schoenoplectus lacustris*. in Lake Eckarfjärden. Number of straws was estimated by randomly placing a frame within the stands of the macrophytes and counting the straws.**

| Square | *Equisetum fluviatile* (straws m$^{-2}$) | *Schoenoplectus lacustris* (straws m$^{-2}$) |
|---|---|---|
| 1 | 36 | 16 |
| 2 | 80 | 16 |
| 3 | 72 | 8 |
| 4 | 12 | 4 |
| 5 | 52 | 40 |
| 6 | 24 | 12 |
| 7 | 36 | 24 |
| 8 | 8 | 4 |
| 9 | 20 | 16 |
| 10 | 76 | 4 |
| **Average** | **42** | **14** |
| **Wet weight m$^{-2}$ (g)** | **197** | **279** |
| **Dry weight m$^{-2}$ (g)** | **34** | **54** |

# Appendix C

**Table C-1. Primary production by phytoplankton and microphytobenthos in Lake Eckarfjärden 2002. “-“ indicates missing values.**

| | Microphytobenthos gC * $m^{-2}$ * $h^{-1}$ (1.5 m depth) | Phytoplankton mgC * $m^{-2}$ * $h^{-1}$ (1.5 m depth) |
|---|---|---|
| 06 Mar – 02 | 0 | 0 |
| 09 Apr – 02 | 4 | 2 |
| 23 Apr – 02 | 7 | 3 |
| 07 May – 02 | 8 | 8 |
| 22 May – 02 | - | 10 |
| 11 Jun – 02 | 32 | 24 |
| 26 Jun – 02 | - | 9 |
| 14 Aug – 02 | 24 | 27 |
| 23 Sep – 02 | 5 | 14 |
| 15 Oct – 02 | 0 | 3 |
| **Mean** | **10** | **10** |
| **Stdev** | **12** | **9** |
| **No of obs** | **8** | **10** |
| **Minima** | **0** | **0** |
| **Maxima** | **32** | **27** |

**Table C-2. Primary production in mgC $m^{-2}$ $h^{-1}$ by microphytobenthos at three different depths in Lake Eckarfjärden 2002.**

| Date/Depth 0.5 m | Depth 1 m | Depth 1.5 m | Depth | Mean | Stdev |
|---|---|---|---|---|---|
| 14 Aug - 02 | 61 | 74 | 39 | 58 | 18 |
| 23 Sep - 02 | 3 | 3 | 8 | 4 | 3 |
| 15 Oct - 02 | 2 | 1 | 0 | 1 | 1 |
| **Mean** | **22** | **26** | **16** | | |
| **Stdev** | **34** | **42** | **20** | | |
| **No of obs** | **3** | **3** | **3** | | |
| **Minimum** | **2** | **1** | **0** | | |
| **Maximum** | **61** | **74** | **39** | | |

**Table C-3. Bacterial production (Bp) in the pelagial and in the microbial mat. Production is shown per volume (in 1 $cm^3$ of water or sediment) and on an areal basis (per $m^2$). The production on areal basis is calculated in a water column of 1.5 m for the pelagic, and in a 5 cm deep layer of the microbial mat below a water column of 1.5 m.**

| Date | Bp pelagial ngC $*cm^{-3} *h^{-1}$ | Bp microbial mat ngC $*cm^{-3} *h^{-1}$ | Bp pelagial mgC* $m^{-2} *h^{-1}$ (1.5 m depth) | Bp microbial mat mgC* $m^{-2} *h^{-1}$ |
|---|---|---|---|---|
| 06 Mar - 02 | 0 | 12 | 1 | 1 |
| 09 Apr - 02 | 1 | 15 | 2 | 1 |
| 23 Apr - 02 | 3 | 15 | 5 | 1 |
| 07 May - 02 | 4 | 148 | 6 | 7 |
| 22 May - 02 | 8 | 187 | 12 | 9 |
| 11 Jun - 02 | 2 | 212 | 3 | 11 |
| 26 Jun - 02 | 8 | 290 | 12 | 15 |
| 09 Jul - 02 | 3 | 79 | 5 | 4 |
| 16 Jul - 02 | 1 | 92 | 2 | 5 |
| 23 Jul - 02 | 1 | - | 2 | - |
| 23 Sep - 02 | 1 | 173 | 1 | 9 |
| 30 Oct - 02 | 1 | 41 | 1 | 2 |
| 09 Dec - 02 | 0 | 24 | 0 | 1 |
| **Mean** | **3** | **107** | **4** | **5** |
| **Stdev** | **3** | **93** | **4** | **5** |
| **No of obs** | **13** | **12** | **13** | **12** |
| **Minimum** | **0** | **12** | **1** | **1** |
| **Maximum** | **8** | **290** | **12** | **15** |