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THE ROLE OF FISHES IN THE PROCESSES OF EUTROPHICATION. ENCLOSURE EXPERIMENT IN LAKE BALATON.

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Abstract

The effects of bream on phytoplankton, zooplankton and water chemistry were studied experimentally in Lake Balaton using cylindrial enclosures. The presence of bream in the enclosure caused series of alterations at the primary producer level. The fish increased the primary production, induced an increased algal density, and decreased the biomass of algae. Predation of fish resulted in reduced abundance of crustaceans, mainly copepods. Fish had not any significant effect on the size of adult copepods while they lowered the mean size of adult cladocerans. There were also apparent changes concerning certain abiotic factors. The water in the enclosure with fish was characterized by higher pH, lower transparency and higher phosphorus and ammonia concentrations.

Introduction

Existing ecological theories imply that since predator population size (fish) is regulated by food, for example by zooplankton or benthos, the predator will cause changes (decrease or increase depending on feeding habits and density of predator) in the prey density (BROOKS & DODSON, 1965; HRBACEK, 1962; STENSON, 1976). As prey in turn is also regulated by food and also affects its food source (PORTER, 1977) it is obvious that factors influencing the prey density may also influence lower trophic levels including the producers.

It is now even more evident that planktivorous and benthivorous fish, through selective predation not only affect the species composition and biomass of their prey but also have via feedback mechanisms influence on phytoplankton productivity, nutrient regeneration and physical and chemical properties of the water that is factors used as trophic criteria (ANDERSSON et al., 1978; HENRIKSON et al., 1980).

In lake Balaton 47 fish species are known. The annual commerical fish yield amounts to more than 1200 tons. According to BIRO & GARADI, 1974, bream represents the majority, about 80 % of the annual catch. The annual biomass, in the sixties, was 160 and the annual net production 73 kg ha^{-1}. However, the biomass of bream has sharply increased recently and now it may reach more than 600 kg ha^{-1} (SZIPOLA pers.comm.).

To know about the effects of bream population on lower trophic levels and on physical and chemical properties of the lake water a short term experiment was carried out in enclosures installed in Lake Balaton.

Material and methods

Study area

Lake Balaton, where the experiment was carried out, with a surface area of 593^{-2} is the largest lake in Central Europe (length 77 km, max. width: northern part, 16 km, southern 8 km). The extensive surface covers, however, a shallow water body; its mean depth reaches 3.14 m and a wind velocity over 4 m s^{-1} is sufficient to stir the loose bottom layers and disperse sediment particles over the whole water body (ENTZ & FILLINGER, 1961). The trophic conditions in NE basin are mesotrophic and in the Keszthely basin they are hypertrophic (HERODEK, 1977) (Fig. 1)

Two cylindrical enclosures made of foil (polyethylene) were installed in the east basin of the lake on the 3rd of August, 1982, at a water depth of about 2.3 m (Fig. 1). The enclosures consisted of two sections. The upper part, consisting of inflatable blocks (polyurethan cells), was covered with and welded into foil. These blocks were joined to each other to form a circle by hose with heavy gauge wire in it. The bottom of the enclosure was made of a stainless steel ring (15 cm high and 1.5 mm thick) to which foil was folded by a metallic yoke. Eight spikes, also made of stainless steel, were screwed on to each metallic ring by which enclosures were secured on the bottom.
To prevent birds from lighting on the enclosures, bird scarers were installed at the top of each enclosure. The metallic drifts were pushed into polyurethane blocks, which were than joined with fishing line so that the birds were prevented from perching on to the top of the inflation collar.
The enclosures (3 m in diameter) were open to the sediment and to the atmosphere and contained about 15 m^3 of lake water. One enclosure was free of fish and the other densely stocked with bream (weighing from 23-240 g w.w., 100 g m^{-2}).
Mixed water samples for biological and chemical analyses were taken every 3-5 days at three stations, one in the lake and one in each enclosure, using surface-mud tube sampler. Subsamples were than taken out for chemical (PO_4-P, NH_4-N, pH) and chlorophyll-a and phytoplankton analyses. Mixed water samples were than filtered through a net (mesh size 60 μm) and the filtrates prserved in formalin for taxonomic and qualitative analyses of crustaceans.
Phytoplankton samples were preserved also in formalin and counted under an inverted microscope following Utermöhl's sedimentation technique. Five millimetres sedimentation chambers were used throughout. Primary production was measured with ^{14}C technique by V. ISTVANOVICS. Chlorophyll-a concentration was measured spectrophotometrically using methanol extractions and transparency with a 25 cm Secchi-disc. The following chemical analyses were done: ammonia with phenol-hypochlorite reaction (CHANEY & MARBACH, 1962), ortophosphate with molybdate reaction (MURPHY & RILEY, 1962) and pH on Automathic Titrimeter (OP-506, Radelkis, Hungary).
The results presented in this paper are based on observations made between the 3rd and 23 rd of August 1982.

Results

Phytoplankton

Altogether 90 species of algae were found in the three different water bodies. The most abundant species was Anabaenopsis raciborskii at all sampling stations. Considering the algal biomass, beside Anabaenopsis, species of diatoms (mainly Surirella, Gyrosygma, Amphora and Cymatopleura) dominated. These species, despite of their low abundance, had very great influence on the total biomass of algae. Primary production sharply increased from the 3 rd to 7 th day of experiment (up to 220 μg C $l^{-1}h^{-1}$) in all three water bodies: later on it hardly changed in the fish-free enclosure and in the lake, as well. Until the stocking of one enclosure with fish, there was only small difference in primary production between the two enclosure, but later on this difference became greater as there was a further increase observed in primary production in the fish enclosure (up to 250 μg C $l^{-1}h^{-1}$)(Fig.2) Both the total number and the biomass of algae changed similarly to primary production in the lake and in the enclosure with no fish. However, in the fish enclosure only,the density of algae followed the changes in primary production: the biomass decreased after the fish were introduced. If we compare the biomass of different branches of algae in two enclosures it can be seen that the biomass of blue-greens, Pyrrophyts, greens and Euglens was higher in the fish enclosure than in the fish-free one (Fig. 3). However, the biomass of diatoms, in the fish-free enclosure, manifold exceeded that of in the fish enclosure.
Chlorophyll-a concentrations are in good agreement with primary production (Fig. 1). The highest chlorophyll concentrations were measured in the fish enclosure (36 mg m^{-3}) and in the lake (28 mg m^{-3}) at the end of experiment. There was a difference by a factor of nearly two in chlorophyll concentration between the fish and fisch-free enclosures.

Zooplankton

During the experiment copepods, mainly Mesocyclops leuckarti, Eudiaptomus gracilis and Acanthocyclops robustus, were dominant in all water bodies (Fig. 5). At the same time the abundance of cladocerans was very low throughout the experiment.
After five days of experiment the total number of crustaceans, due to the higher number of copepods (mainly Mesocyclops leuckarti) increased in the lake and in the fish-free enclosure as well and reached a maximum of 40 and 65 ind l^{-1} respectively, by the end of experiment. However, the density of crustaceans continually decreased in the enclosure with fish (below 30 ind l^{-1}).
After fish introduction the mean size of adult cladocerans decreased significantly while that of copepods changed in the enclosure with fish (Fig.6). However, hardly no change in the mean size of crustaceans was observed in the enclosure with no fish nevertheless removal of fish caused an increase in the mean size of both cladocerans and copepods. The mean size of adult crustaceans varied most in the lake.

Water quality

The differences in primary production between different water bodies resulted in differences in pH (Fig. 7). The difference in pH between the two enclosures was not significant (0.2 units only). The pH in the fish enclosure exceeded 8.6 units by the end of experiment. Also the water in the fish enclosure was more turbid by the end of experiment, consequently, the Seechi-disc transparency was lower than in the fish-free enclosure or in the lake (Fig.8).
The orthophosphate concentration before the introduction of fish was the highest in the lake (about 7.5 $\mu g\ l^{-1}$) and later on, when the algal biomass started to increase, it decreased (below 1 $\mu g\ l^{-1}$) (Fig. 9). At the same time the phosphorus concentration were lower in the enclosure. After the fish were introduced the phosphorus concentration first increased and then decreased in the fish enclosure, by the end of experiment, the phosphorus concentration in the fish enclosure exceeded that of the fish-free one. Ammonia concentrations increased at all stations until introduction of fish: later on it decreased and by the end of experiment it was higher in the fish enclosure (about 100 $\mu g\ l^{-1}$) than in the fish-free one (65 $\mu g\ l^{-1}$) (Fig. 9).

Discussion

The presence of bream in the enclosure caused series of alterations at the primary producer level. The fish increased the primary production induced an increased algal density and decreased the biomass and diversity of phytoplankton. There were contradictions between algal density and biomass and chlorophyll concentration and biomass in the fish enclosure. First of all the decrease in algal biomass in the enclosure with fish was primarily due to a significant decrease in biomass of four most abundant and large diatoms (Amphora, Gymatopleura, Gyrosygma, Surirella) and/or to the error originating from the biomass estimation based on volumetric method (STRATHMANN, 1967; WINBERG, 1971). On the other hand since the abundance of crustaceans, owing partly to predation by fish, was very low it seems likely that fish probably ate those large diatoms. However, losses of algae, such as diatoms, by sedimentation also could occur (LACK & LUND, 1974) though it did not happen in the fish-free enclosure. The inconsistency between the biomass and chlorophyll concentration could be the result of differences in pigment content of different branches of algae (PARK & MILIUS, 1978; DESORTOVA, 1981). The biomass of blue-greens, with the higher chlorophyll-a content, was higher while the biomass of diatoms, with lower pigment content, was manifold lower in the fish enclosure where both the primary production and chlorophyll concentration were the highest.

In accordance with other investigations (SMYLY, 1976; ANDERSSON et al., 1978; HENRIKSON et al., 1980) intense predation of planktivorous fish resulted in reduced abundance of crustaceans while in the absence of fish crustaceans, mainly copepods, increased in abundance. Since abundance of cladocerans, because of Anabaenopsis bloom which occurred at that time in the lake (G.TOTH,pers.comm.), was very low during the experiment an intense grazing was observed on copepods and dietary choice of fish was certainly influenced by relative low density of cladocerans. It turned out that cladocerans were not preferred to copepods and that fish did not select clearly for larger species as it was observed by BROOKS, 1968 and WINFIELD et al.(1983)in aquaria. According to Henrikson at al., 1980 selective predation from fish has been shown to reduce the mean size of crustaceans and removal of fish may cause increased mean size of the zooplankton community. Relying upon our findings it may be true considering the mean size only but if we take into account the standard deviations it can be seen that fish had not any effect on the size of adult copepods while they lowered the mean size of adult cladocerans significantly. There were also apparent changes concerning certain abiotic factors. The water in enclosure with fish was charcterized by higher pH and lower transparency. At the same time enclosure without fish had lower pH and higher transparency. Considering the changes in biotic and abiotic factors being accomplished in the enclosures it can be seen that with a dense bream population some symptoms of eutrophication appeared, even during a short term experiment. That point under discussion maybe realistic and is supported by the results of some other studies (HRBACEK et al., 1961; ANDERSSON et al., 1978; HENRIKSON et al., 1980). Nutrients from the zooplankton probably are the most important source for the producers, at least during stagnant conditions (PETERS, 1975). There are however, also other sources. In recent years the importance of fish in nutrient cycling has been emphasized (LAMARRA, 1975; KITCHELL et al., 1975; SHAPIRO et al., 1975; STENSON et al., 1976). LAMARRA 1975 reported that presence of carp (Cyprinus carpio) increased phosphorus concentration in the lake water and by this enhanced primary production. ANDERSSON et al. 1978 described the changes caused by dense population of roach (Rutilus rutilus) in enclosures as being similar to eutrophication. However, KITCHELL et al. 1975 concluded that phosphorus release by the planktonic bluegill (Lepomis macrochirus) was not of decisive importance to the phytoplankton. FAAFENG & NILSSEN 1981 found that even a small roach biomass markedly enhanced the concentration of chlorophyll-a. Our experiments with bream showed considerable release of phosphorus. Significant amount of nitrogen is also reactivated by bream mainly in form of ammonia (TATRAI, 1981) which is easily taken up by algae. This study indicates that a large population of bream may be important in recycling of nutrients especially when their external supply is low. This confirms the suggestions of SHAPIRO et al. 1975 and ANDERSSON et al. 1978 that management of the fish population might be an efficient means to control the water quality.

Summary

The effects of bream on phytoplankton, zooplankton and water chemistry were studied experimentally in Lake Balaton using two cylindrical enclosures. One enclosure was free of fish and the other densely stocked with bream (100 g m^{-2}). Altogether 90 species of algae were found in the two enclosures and in the lake. The most abundant species were Anabaenopsis raciborskii and diatoms (Surirella, Gyrosygma, Cymatopleura). Primary production was the highest in fish enclosure (250 μg C $l^{-1}h^{-1}$). However, the total biomass of algae was the lowest in fish enclosure due to a decrease in the biomass of diatoms (Fig. 2). The highest chlorophyll concentration ammounted to 36 mg m^{-3} in the fish enclosure (Fig.4). During the experiment copepods, mainly Mesocyclops leuckarti were dominant. The total number of crustaceans increased in the fish-free enclosure and reached a maximum of 60 ind l^{-1} by the end of experiment (Fig.5). At the same time the total number of crustaceans continually fell in the fish enclosure (below 30 ind l^{-1}). The ph was higher and Secchi-disc transparency lower in the fish enclosure than in the fish-free one (Figs 7,8). Orthophosphate and ammonia concentrations were the highest in the fish enclosure by the end of experiment (4,5 and 100 μg l^{-1}, respectively) (Fig.9).

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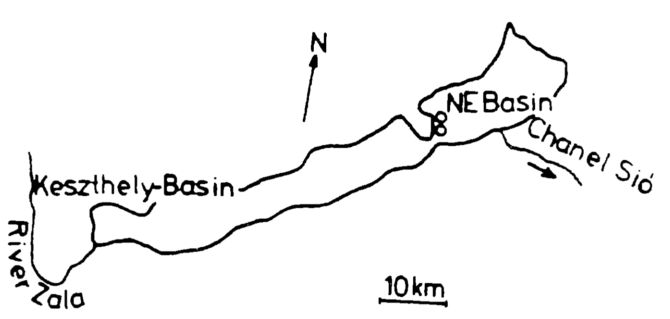

Figure 1: Main basins and the place of the enclosure experiment in Lake Balaton.

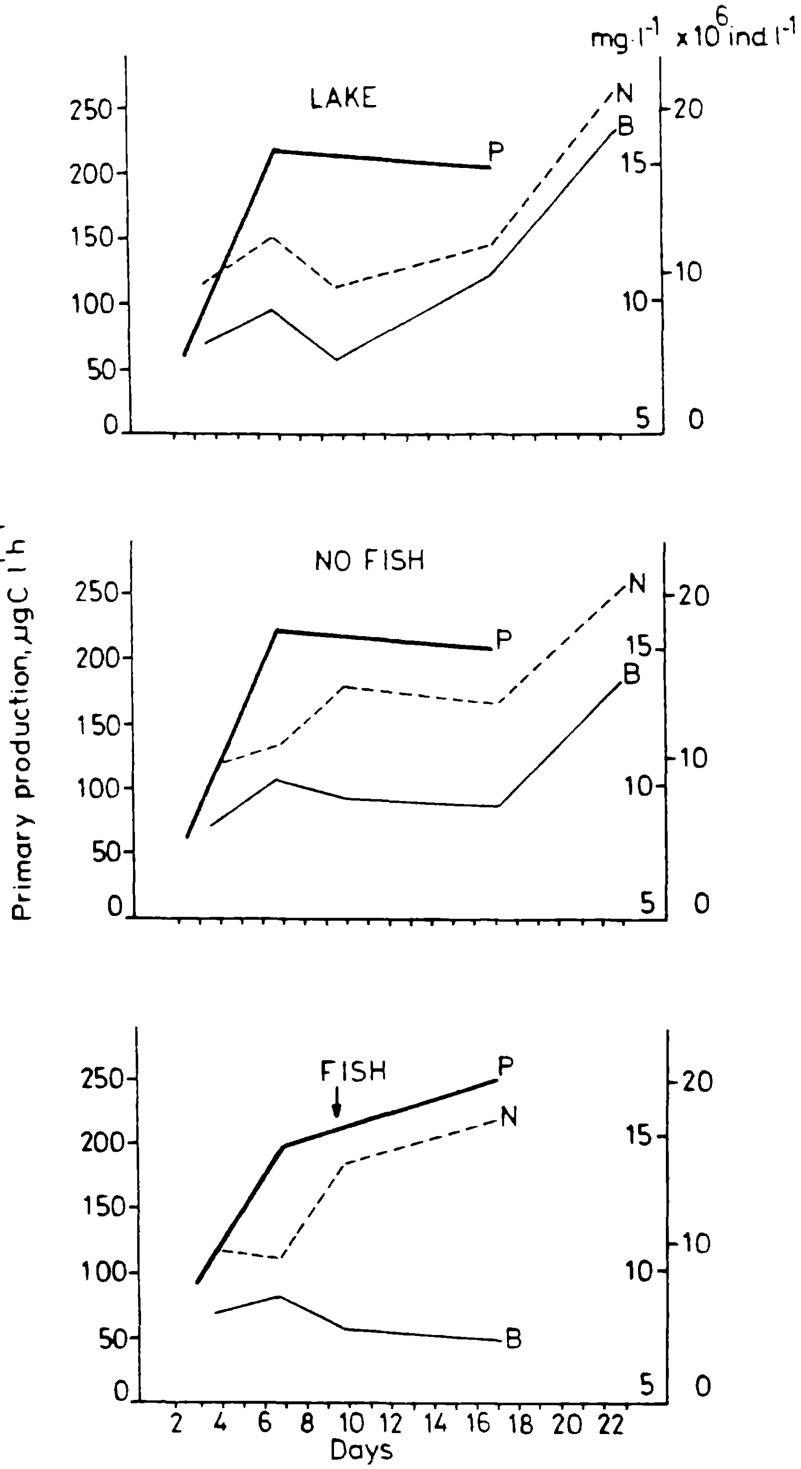

Figure 2: Primary production (P), number (N) and biomass (B) of algae in the enclosures and in Lake Balaton. The arrow indicates stocking of one of the enclosure with fish.

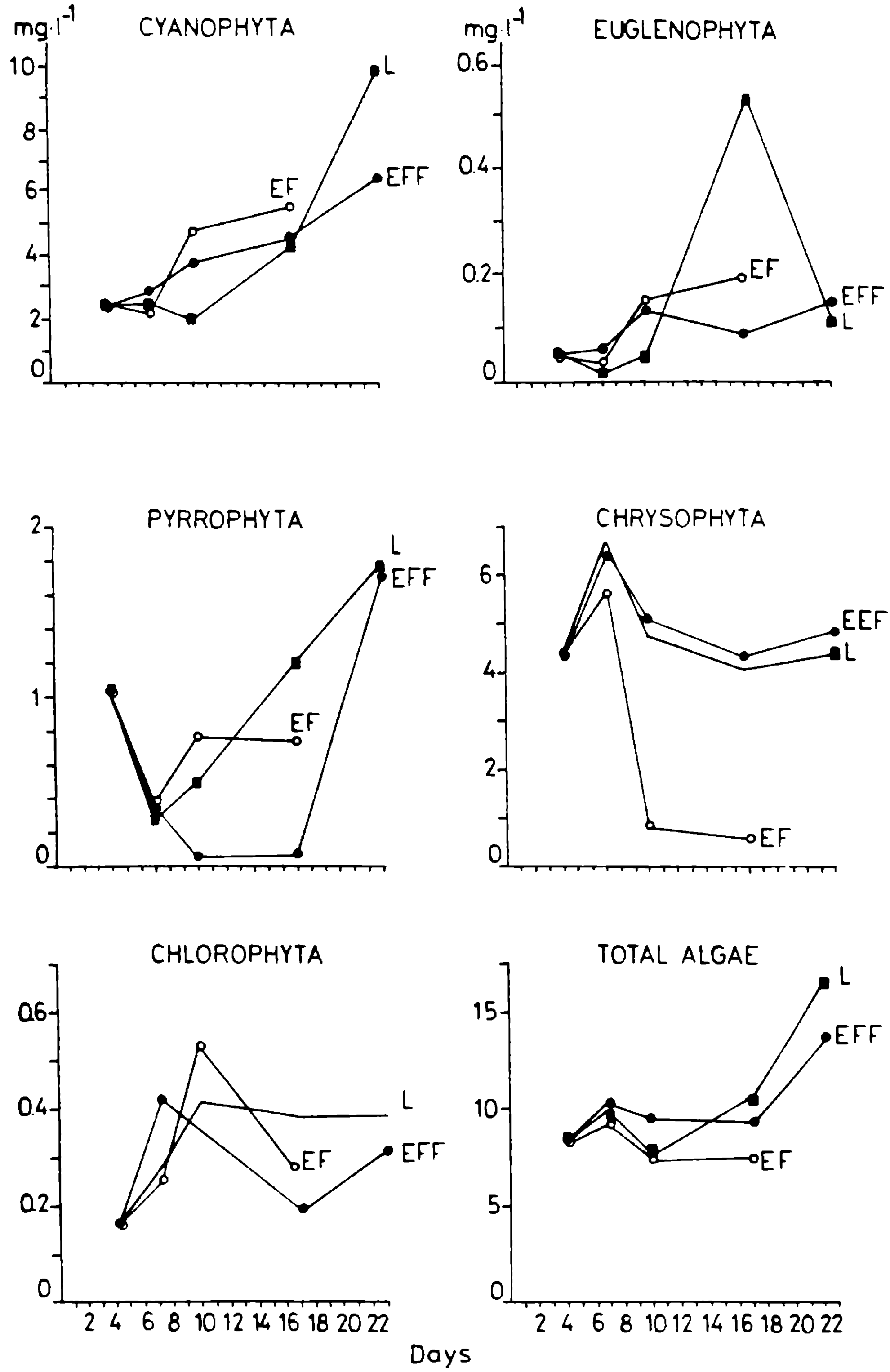

Figure 3: Biomass of different branches of algae in the enclosure with fish (EF), without fish (EFF) and in the lake (L).

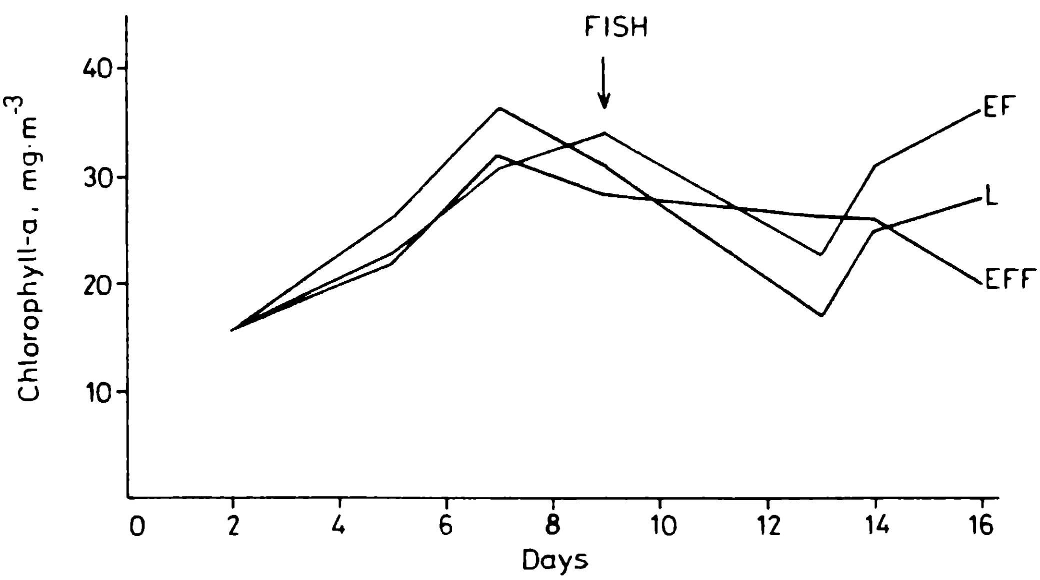

Figure 4: Chlorophyll-a concentrations in the enclosure with fish (EF), without fish (EFF) and in the lake (L).

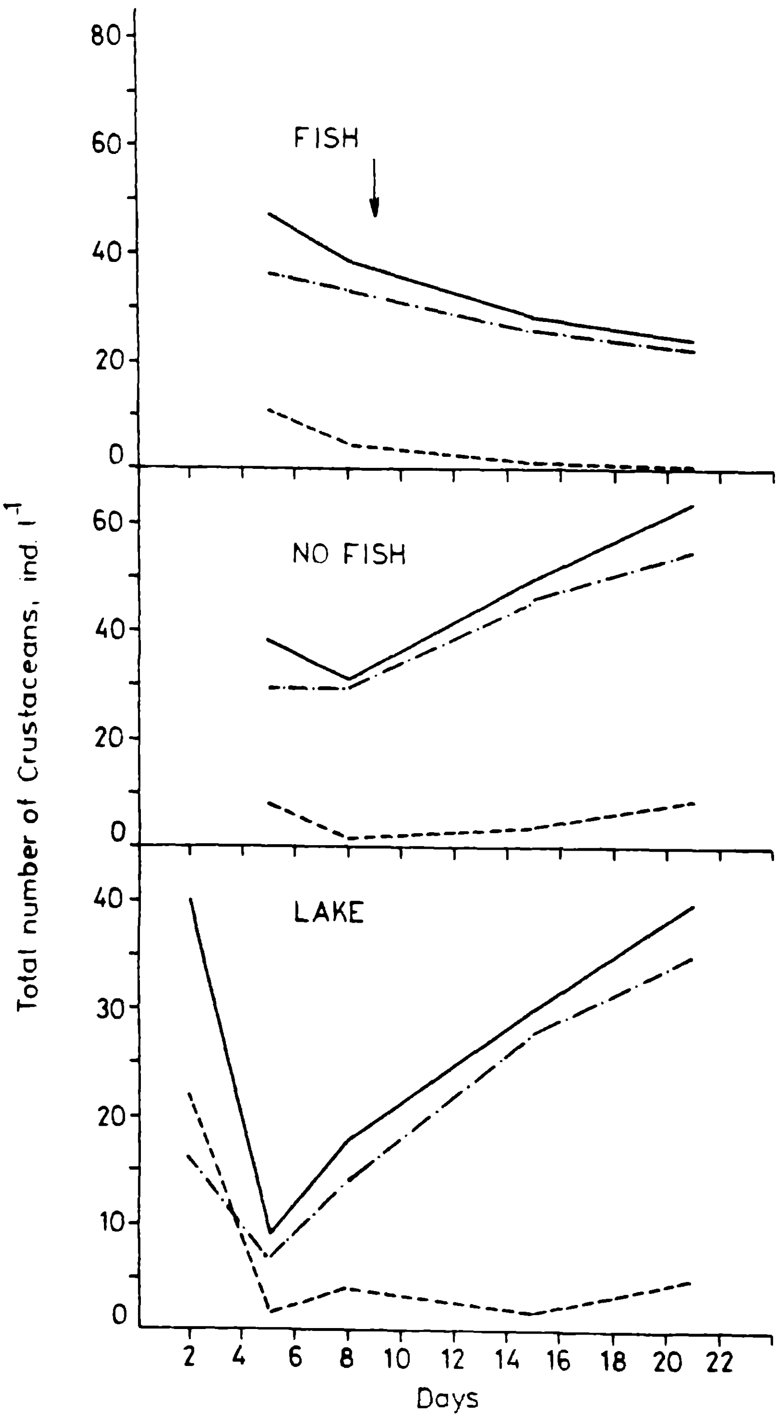

Figure 5: Abundance of copepods (-), cladocerans (-----) and total crustaceans (_____) in the enclosures and in the lake

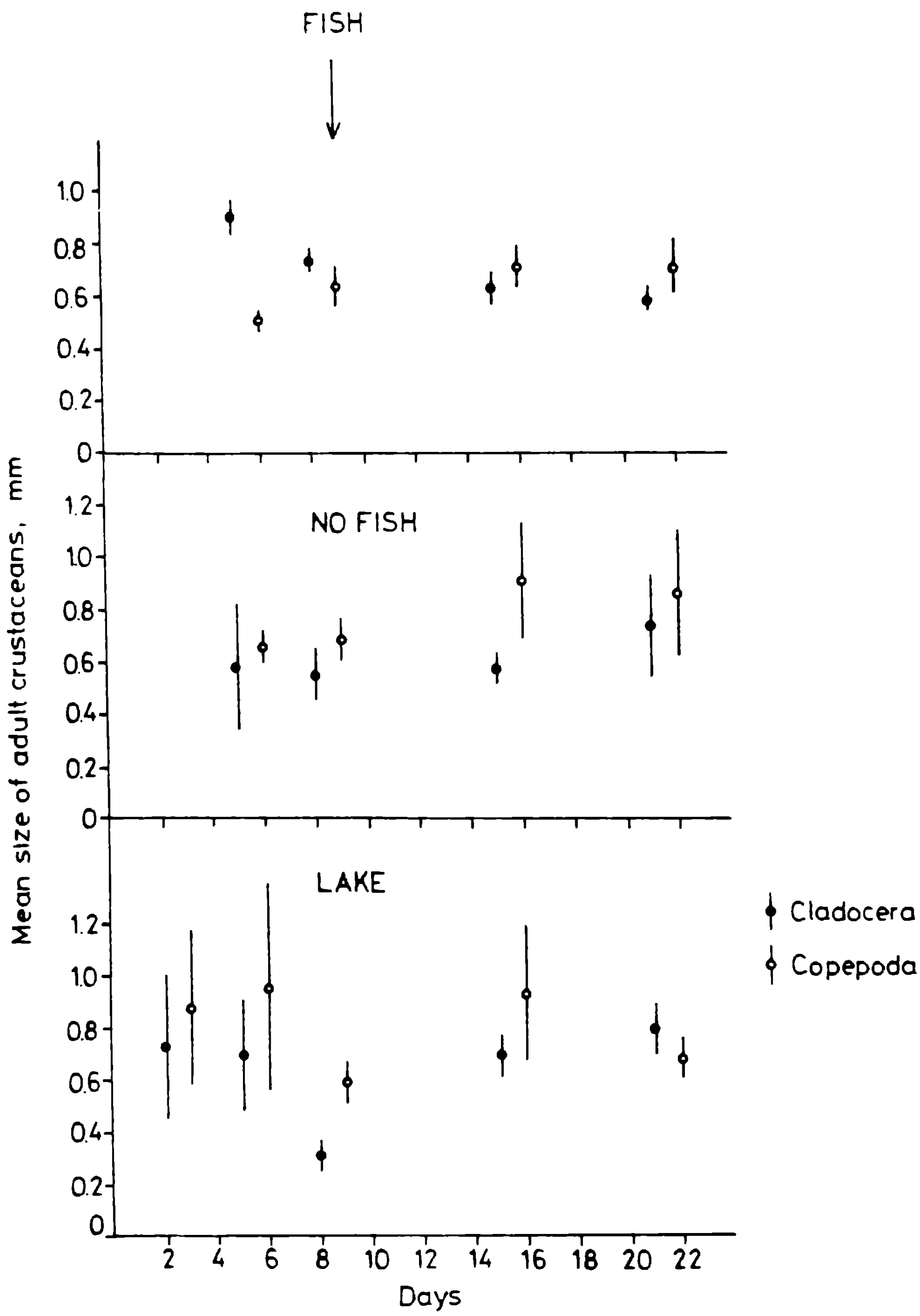

Figure 6: Mean size of adult crustaceans in the enclosures and in the lake (± 1SD is also indicated).

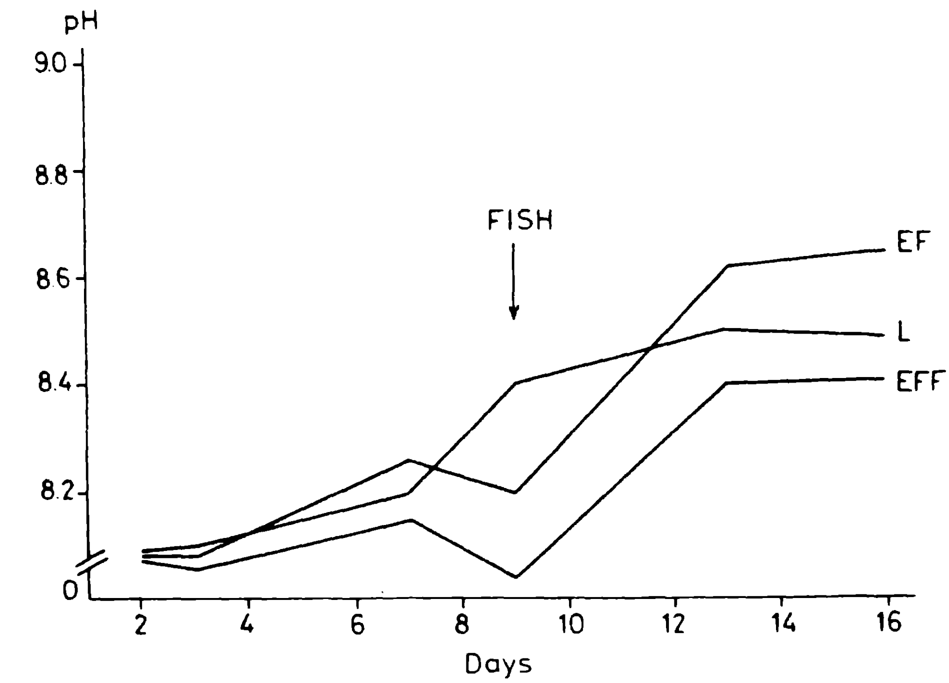

Figure 7: pH values in the enclosure with fish (EF), without fish (EFF) and in the lake (L).

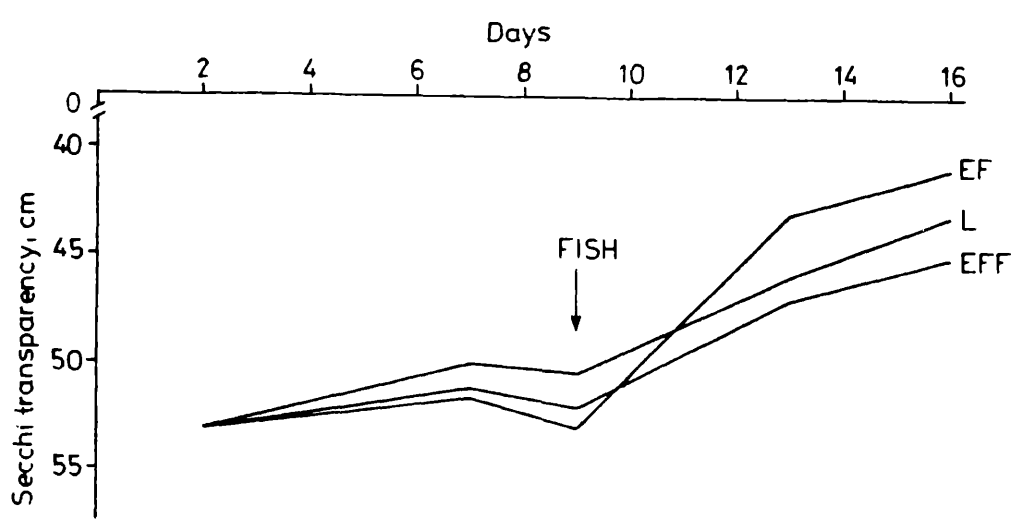

Figure 8: Secch-disc transparency in the enclosure with fish (EF), without fish (EFF) and
in the lake (L.).

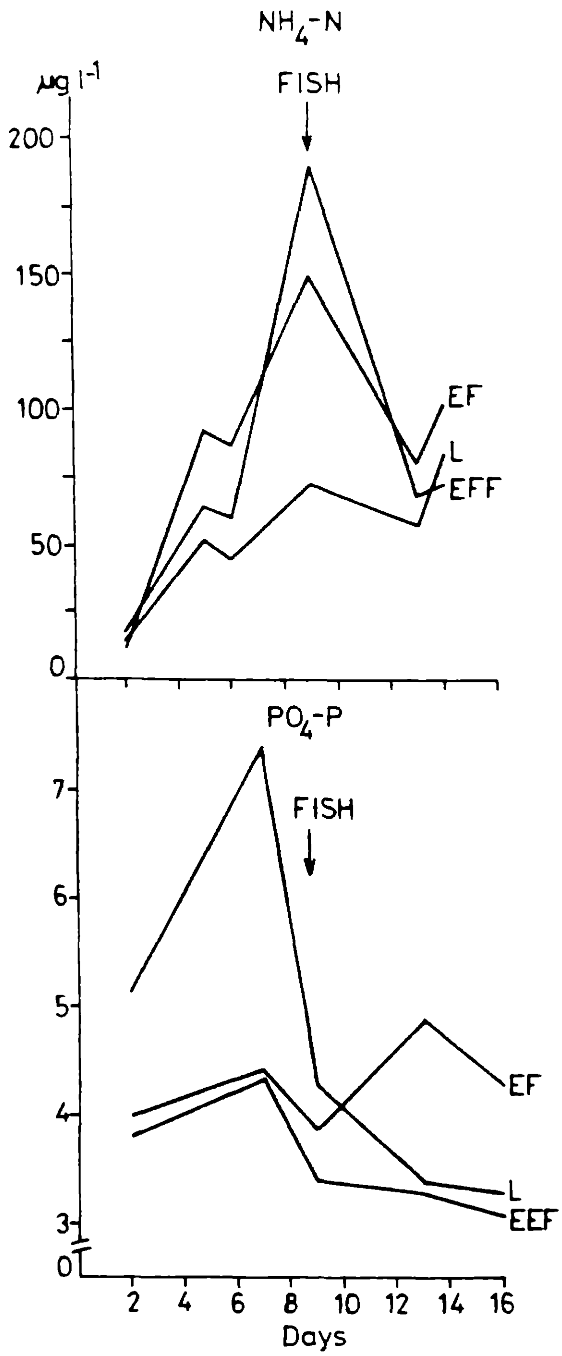

Figure 9: Concentrations of orthophosphate and ammonia in the enclosure with fish (EF), without fish (EFF) and in the lake (L).