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THE INFLUENCE OF HERBIVOROUS CHIRONOMIDS ON THE EXCHANGE OF NUTRIENTS BETWEEN SEDIMENT AND WATER

The biotic role, particularly the role of benthic animals in the nutrients regeneration in the sedimentwater systems has not been emphasized. Several studies (PARCELLA et al 1970, KAMP-NIELSEN 1974, 1975 a, 1975 b) emphasized the importance of bacteria and algae in the exchange between sediment and water. According to EDWARDS (1958) the addition of Chironomus riparius larvae to sludge increased the concentration of ammonia and decreased the concentration of nitrate in water overlying sludge. Recently ANDERSON (1976) has reported that the addition of the larvae of C.plumosus to lake sediment increased the denitrification of nitrate added to the overlying water. However GRANELI (1979) reported that chironomids seem to have only minor effects on the exchange of nitrogen across the mud-water interface.

There are also only few studies which assessed the effects of chironomids on the phosphorus exchange in sedimentwater systems (GALLEP et al. 1978, GALLEP 1979, GRANELI 1979). According to those works the presence in sediment of chironomid larvae does increase the phosphorus concentration of overlying water.

The purpose of the present study was to determine the effects of herbivorous chironomids on the exchange of dissolved nutrients (nitrogen as well as phosphorus) across the sediment water interface under aerobic conditions.

Material and Methods

Sediment samples used in this experiments were taken from hypertrophic Keszthely basin in Lake Balaton. Lake Balaton is a shallow eutrophic lake (HERODEK 1977). The pH of the lake water is 8,3 to 8,7, the methylorange alkalinity is 4,0. The main ions are Ca^{++}, Mg^{++}, HCO_3^- and SO_4^{--} (DOBOLYI and HERODEK 1980). Mud samples were taken with an Ekman-Birge mud sampler and then sieved through a 1 mm mesh to eliminate animals present. Chironomid larvae used in experiments belong to the herbivorous Chironomus group (Dévai, pers. com.) and were collected from Keszthely basin between April and July 1981. The length of the larvae was between 15 - 20 mm (4-6 mg dry weight, 4th instar).

Sediment-water systems were constructed in glass tubes, 40 cm long and 4 cm in diameter, and in plastic boxes, 15 x 15 cm wide and 20 cm high. Four tubes, containing 5-7 cm sediment and about 450 ml of tap water were placed in spring-summer photoperiod (LD 14:10) at room temperature (about 20°C). While six boxes containing the same amount of sediment but about 2,5 l of tap water each were kept in a thermostate in light-dark (LD 12:12) and in darkness (LD 0:24) at 20 ± 0,5°C. The tubes and boxes were kept aerobic by bubbling the water with air. The water was thus mixed but did not disturbe the sediment surface. After the sediment-water systems were set up they were allowed to equilibrate for about 5-7 days before nutrients were measured and animals added. According to (HARGRAFE (1975) mixed sediment cores rapidly regain their physical, chemical and biological properties.

Tubes and boxes were populated with densities of 5,000; 10,000 and 20,000; and 500; 1,000; 2,000; 5,000 and 10,000 chironomids . m^{-2}, respectively.

Vessels were checked daily and the emerged or died larvae were removed and replaced. Despite this mortality occurred in the mud during experiments. Chironomids were not fed in the sediment-water systems.

Every 5-7 days the overlying water was analysed for the following parameters: ammonia (ChANEY & MARBACH 1962), nitrate (ELLIOTT & PORTER 1971), soluble reactive phosphorus (SRP) (STEPHENS 1963), total phosphorus (TB) (GALES et al. 1966), total nitrogen (TN) KOROLEFF 1972) and pH (ammonia and pH meter OP 264, RADELKIS).
The mean concentrations of SRP, TP and TN were used to calculate the mean daily release rates (mg m^{-2} day^{-1}).

Results

Experiment in tubes

Ammonia concentration was significantly higher in tubes containing larvae in contrast of controls, during first 20 days of experiment. After that the concentration of ammonia has decreased to extremely low values (Fig. 1). There was an inverse relationship between nitrate and ammonia concentration (Fig. 2). After larvae were introduced, nitrate increased while ammonia decreased. However the addition of chironomids had significant effect on the nitrate concentrations. SRP has increased after larvae were added but after 20 days the concentration dropped and than increased again (Fig. 3). SRP concentration of control remained lowered until the end of experiments.
The net TP release rates (TP release rate was lowered by TP release rate of control) related to chironomid densities, have increased as the density of larvae increases (Fig. 4). Median release rate of TP was above 15 mg $m^{-2}day^{-1}$ at larval density of 20,000 ind.m^{-2}.
The net TN release rates have increased up to density of 10,000 ind.m^{-2}, however median release rate decreased at 20,000 ind.$^{-2}$ (Fig.4).
The pH- of water was significantly higher in tubes with larvae as compared to that of control except tube 1, where the pH was unaffected by chironomids (Fig. 5).

Experiment in boxes

The median ammonia concentrations in boxes, set on LD 12:12 and LD 0:24 photoperiods, is shown on Figure 6. There was observed no marked difference in ammonia content between control and boxes with chironomids in light-dark.
The ammonia concentration in darkness first increased and then decreased with density of chironomids. Boxes 3,4 and 5 contained significantly more ammonia than the control.
In contrary to this nitrate content of boxes with larvae was significantly higher in light-dark than that of control. However no difference could be observed in darkness between control and boxes with chironomids (Fig. 6).
Chironomid larvae had significant effect on TN concentrations in sediment-water systems both in light-dark and in darkness as well (Fig. 7).
TN content were significantly greater in darkness than in light-dark, except box 5 where no difference could be observe. SRP concentrations were also higher in darkness than in light-dark (Fig. 8).
It means that algae can take up much of the released phosphorus since SRP levels in vessels with chironomids were greater in dark than in light. SRP contents increased with larval density at both illumination conditions. TP contents in light-dark were also significantly below those of their respective dark sets aside from box 4 (Fig. 8). This result can be explained by extensive wall growth in light-dark microcosms. Dark boxes had no visible wall growth.
Figure 9 shows the net SRP and TP release rates in light-dark and darkness related to chironomid densities. According to results the SRP and TP release rates were almost two times greater in darkness than in light-dark and increased with chironomid densities. Median release rates of SRP and TP in darkness ranged between 1,0-2,5 and 2,2-5,0 mg m^{-2} day^{-1}, respectively and that of in light-dark 0,2-1,4 and 0,8 - 3,5 mg m^{-2} day^{-1}, accordingly. These release rates maybe underestimated because of emergence and mortality of larvae occurred during experiments. Namely at the end of

measurements survivorship of chironomids amounted to, in average, 80-85 %. If densities had been maintained at their original levels, SRP and TP release rates might have been even higher.
The pH of overlying water in the boxes with larvae and in that of free of animals was significantly higher in light-dark and in darkness as well than pH of tap water used for set up microcosms (Fig. 10). The pH in the boxes with chironomids was markedly higher in darkness as compared to the control. However the pH value of control did not differ significantly in light-dark from that of boxes with chironomids.

Summary
Ammonia concentration was significantly higher in tubes with chironomids than that of controls only during first 20 days of the experiment. There was an inverse relationship between nitrate and ammonia concentration at natural light condition (LD 14:8). The addition of chironomids increased the nitrate and decreased the ammonia content of overlying water which maybe due to ammonification-dentrification processes. The addition of larvae had significant effect on the nitrate release rate from the sediment.
Soluble reactive phosphorus (SRP) conentrations in tubes with chironomids were higher as compared to the control until the end of experiment. Net release rate of total phosphorus (TP) has increased as the density of larvae increased. Net total nitrogen (TN) release rates were significant in tubes with chironomids. Chironomids had no any effect on ammonia release rate in light-dark (LD 12:12). In darkness (LD 0:24) ammonia content of overlying water was significantly greater only above density of 2000 ind m^{-2}.
In contrary to this nitrate content of boxes with larvae was significantly greater in light-dark than that of control. No difference could be observed in darkness between control and boxes with chironomids.

Chironomid larvae had markedly effect on TN concentration in sediment-water systems both in light-dark and in darkness as well.
SRP contents increased with larval density at both illumination conditions and was higher in darkness. It means that the algae can take up much of the released phosphorus.
TP contents in darkness were also significantly greater than those in light-dark sets which can be explained by extensive wall growth in light-dark microcosms.
Net SRP and TP release rates were almost two times higher in darkness than in light-dark and have increased with chironomid densities.
It is obvious from our data that herbivorous chironomids cause increases in phosphorus content of overlying water most of which was SRP.
The pH of overlying water was higher in darkness as compared to the control which maybe indicates once again the algal presence in light-dark sets.

References

ANDERSON, J.M. ,1976: Importance of the denitrification process for the rate of degradation of organic matter in lake sediments. In: Interations Between Sediments and Freshwater (ed. H.L. Golterman), pp. 357-362. Junk, Amsterdam.

CHANEY, A.L. & E.P. MARBACH, 1962: Modified reagents for the determination of urea and ammonia. Clin.Chem. 8.130-132.

EDWARDS, R.W., 1958: The effect of larvae of Chironomus riparius Meigen on the redox potentials of settled activated sludge. Ann.Appl.Biol. 46, 457-464.

ELLIOTT, R.J. & A.G. PORTER, 1971: A rapid cadmium reduction method for the determination of nitrate in bacon and curing brines. Analyst, Lond. 96, 522-527.

GALES, M.E., E.C. SULIAN & R.C.KRONER, 1966: Method for quantitative determination of total phosphorus in water. J.Am.Wat. Wks Ass. 58, 1363-1368.

GALLEPP, G.W. 1979: Chironomid influence on phosphorus release in sediment-water microcosms. Ecology 60, 547-556.

GALLEPP, G.W., J.F. KITCHELL & S.M.BARTELL, 1978: Phosphorus release from lake sediments as affected by chironomids. Verh.Int. Verein. Limnol. 20, 458-468.

GRANELI, W.C., 1979: The influence of Chironomus plumosus larvae on the exchange of dissolved substances between sediment and water. Hydrobiologia 66, 149-159.

HARGRAVE, B.T., 1975: Stability in structure and function of the mud-water interface. Verh.Int.Verein.Limnol. 19, 1073-1079.

KAMP-NIELSEN, L., 1974: Mud-water exchange of phosphate and other ions in undisturbed sediment cores and factors affecting the exchange rates. Arch. Hydrobiol. 73, 218-237.

KAMP-NIELSEN, L. 1975 a: A kinetic approach to the aerobic sediment-water exchange of phosphorus in Lake Esrom. - Ecol. Modelling 1, 153-160.

KAMP-NIELSEN, L., 1975 b: Seasonal variation in sediment-water exchange of nutrient ions in Lake Esrom. Verh.Internat. Verein.Limnol. 19, 1057-1065.

KOROLEFF, F., 1972: Determination of total nitrogen in natural waters by means of persulphate oxidation. In: New Baltic Mammal with Methods for Sampling and Analyses of Physical, Chemical and Biological Parameters (ed. S.R.Carlberg), pp. 73-78. Charlottenlund.

PARCELLA, D.B., J.S. KUMAGAI & E.J. MIDDLEBROOKS, 1970: Biological effects on sediment-water nutrient interchange. J.San Eug. Division, Proc. Amer. Soc. Civil Eng. 96, 911-926.

STEPHENS, K., 1963: Determination of low phosphate concentration in lake and marine waters. Limnol.Oceanogr. 8, 361-362.

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Figure 1. Changes in ammonia concentrations over time in tubes as a function of photoperiod and the presence of Chironomus sp. (Co= tap water, C=control).

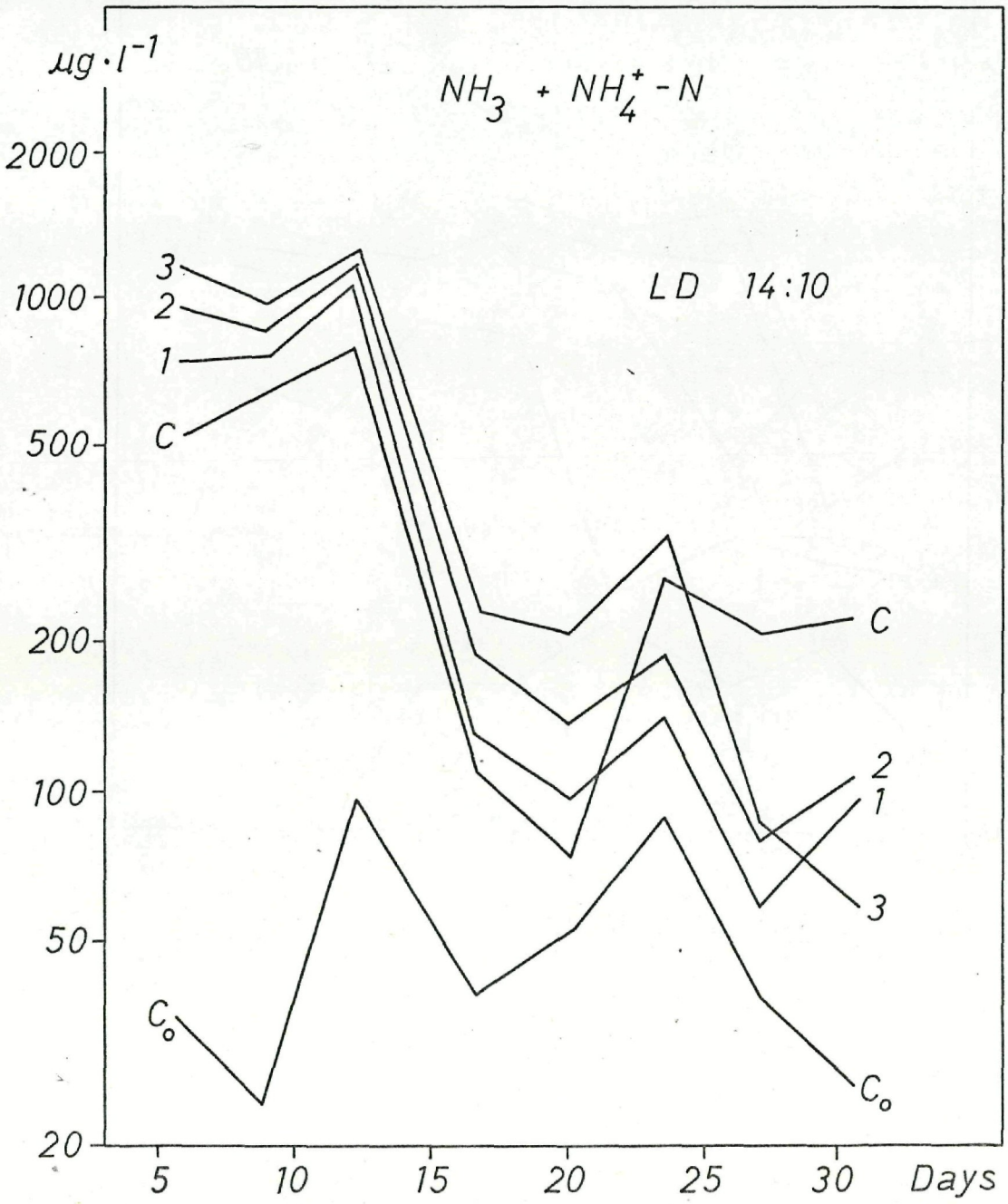


Figure 2. Changes in nitrate concentrations over time in tubes.

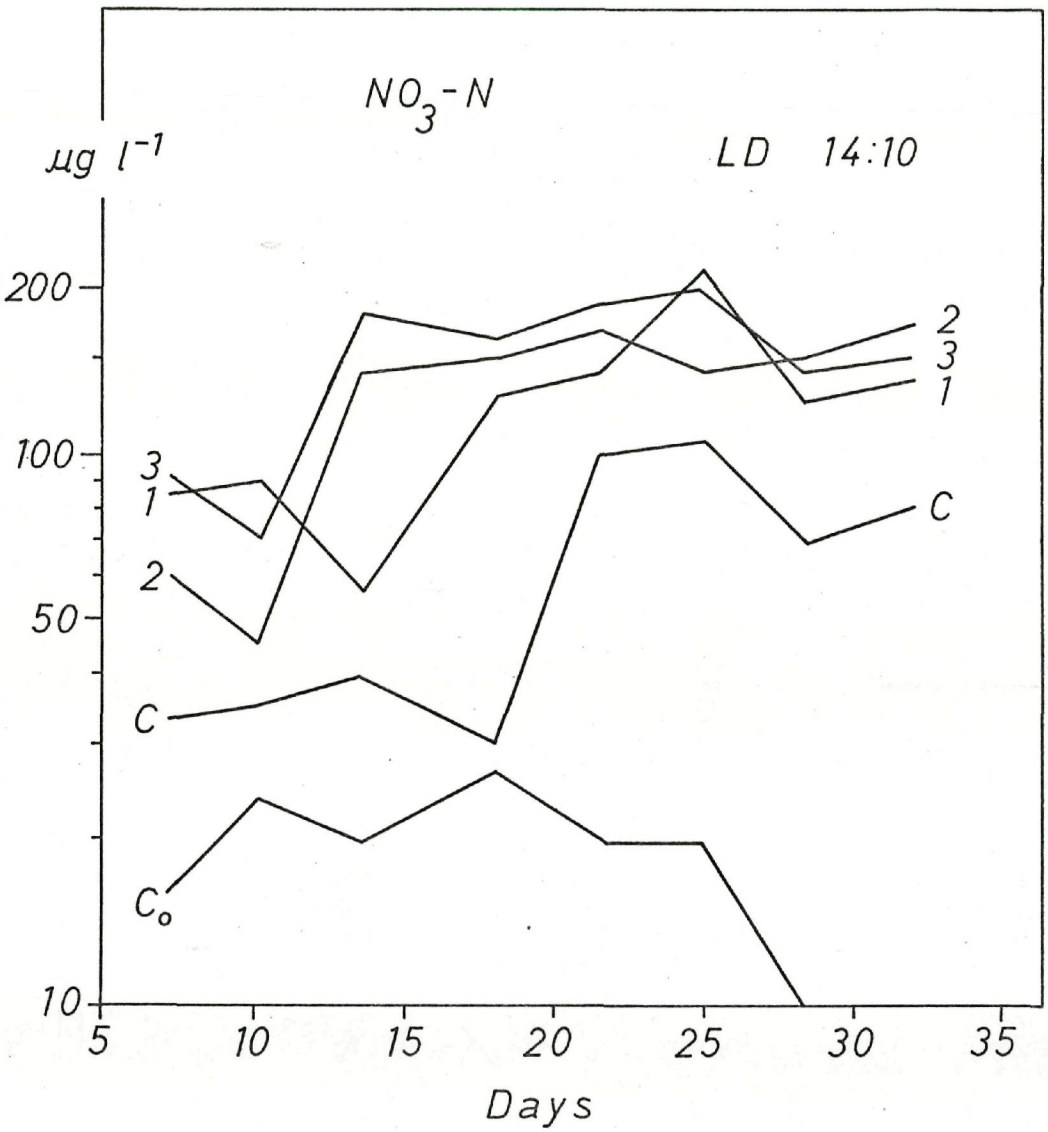


Figure 3. Changes in phosphate concentrations over time in tubes.

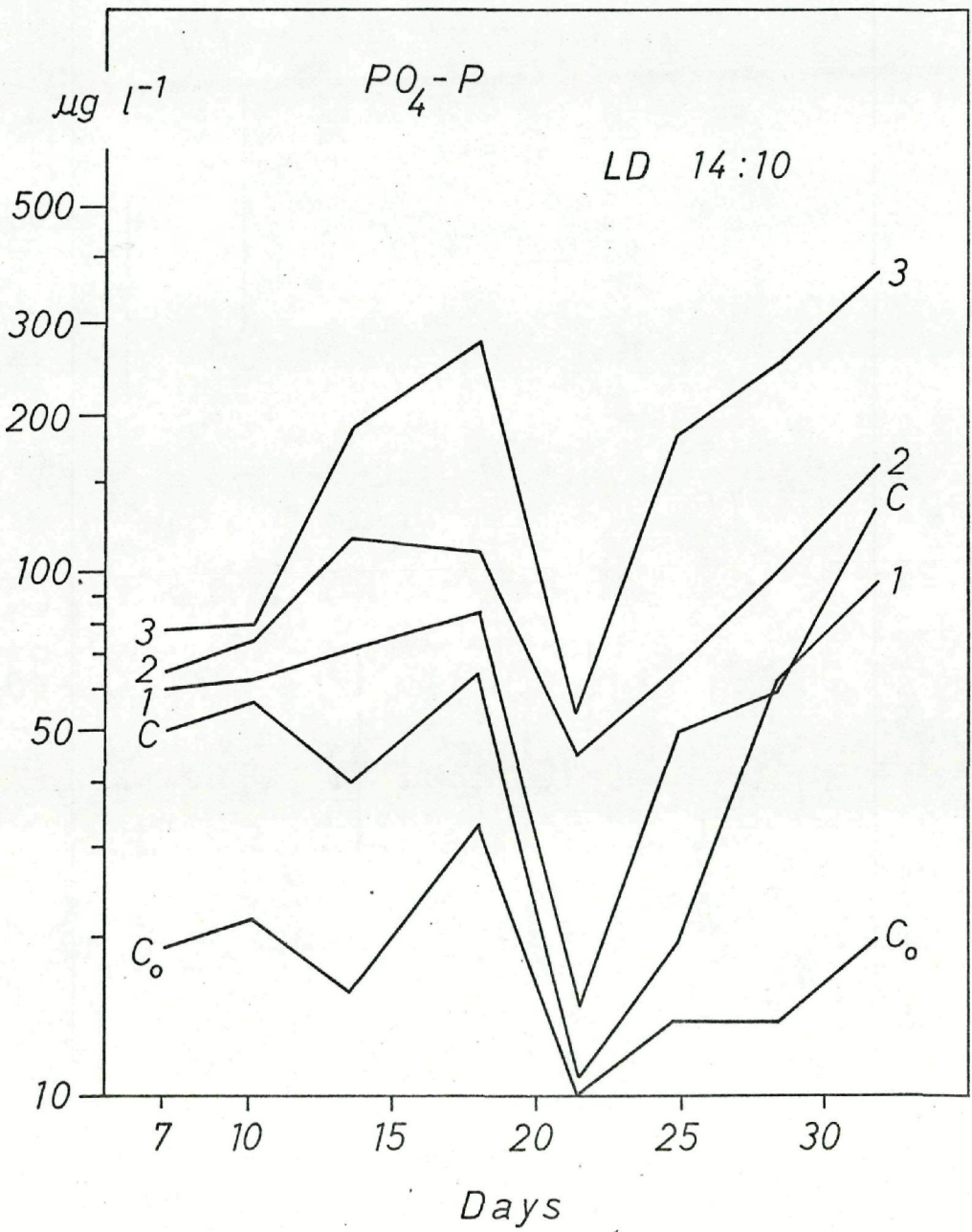


Figure 4. TP and TN release rates in tubes.

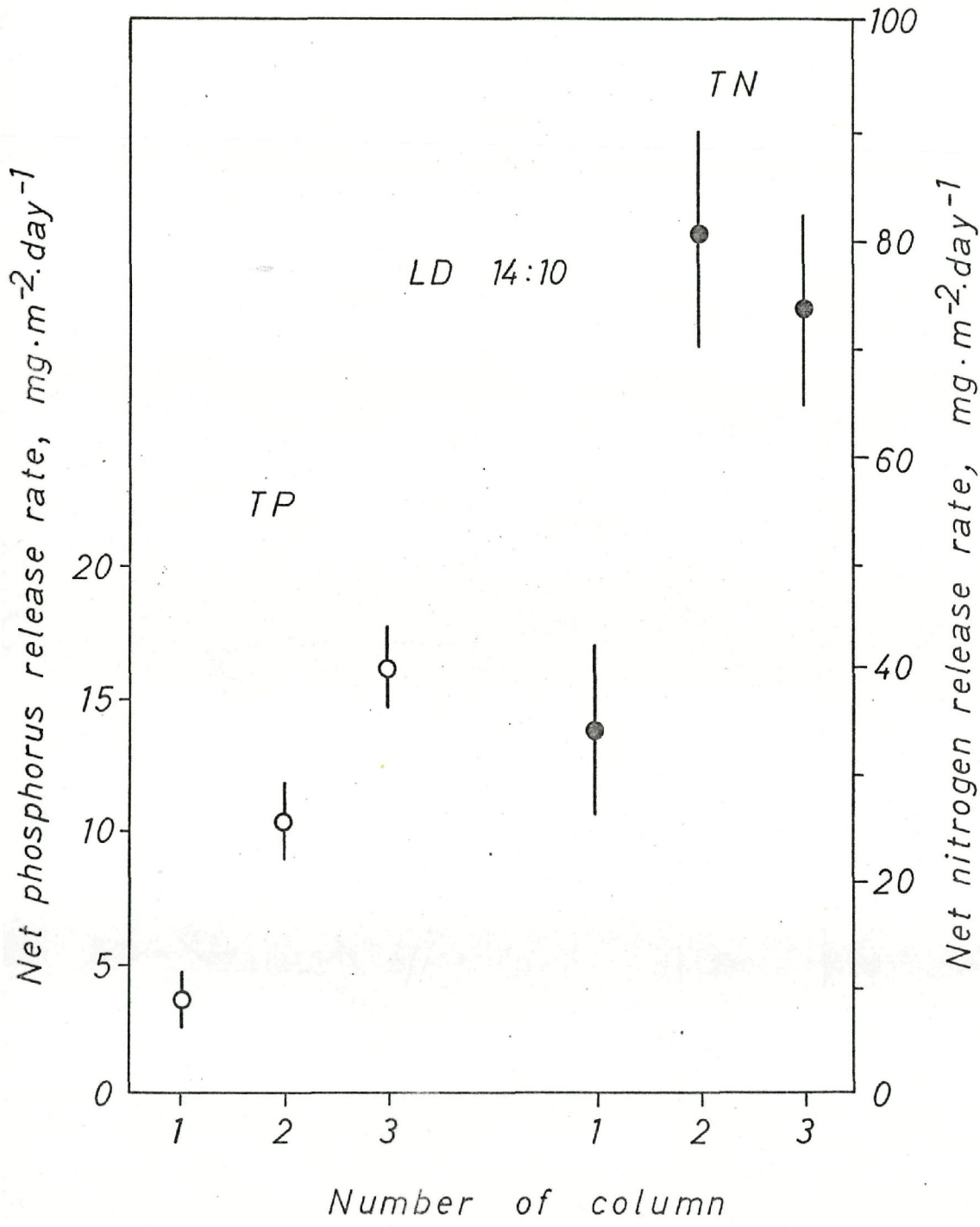


Figure 5. Changes of pH of overlying water in tubes.

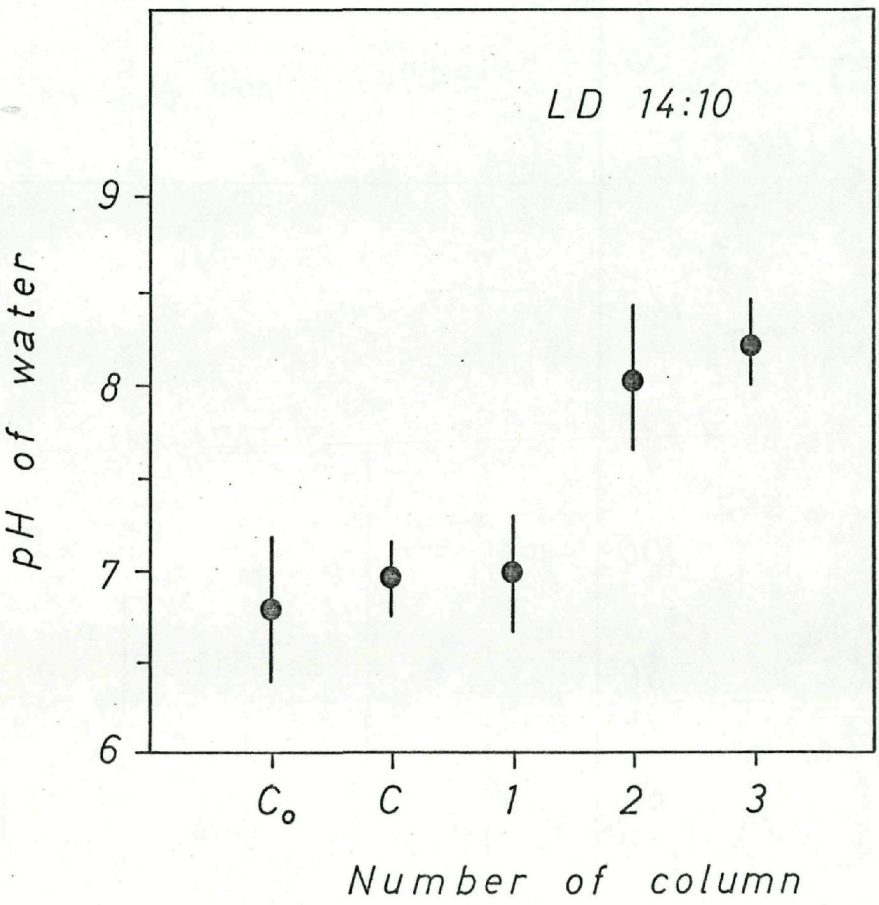


Figure 6. Concentrations of ammonia and nitrate in overlying water in boxes as a function of photoperiods and chironomid density (C= control).

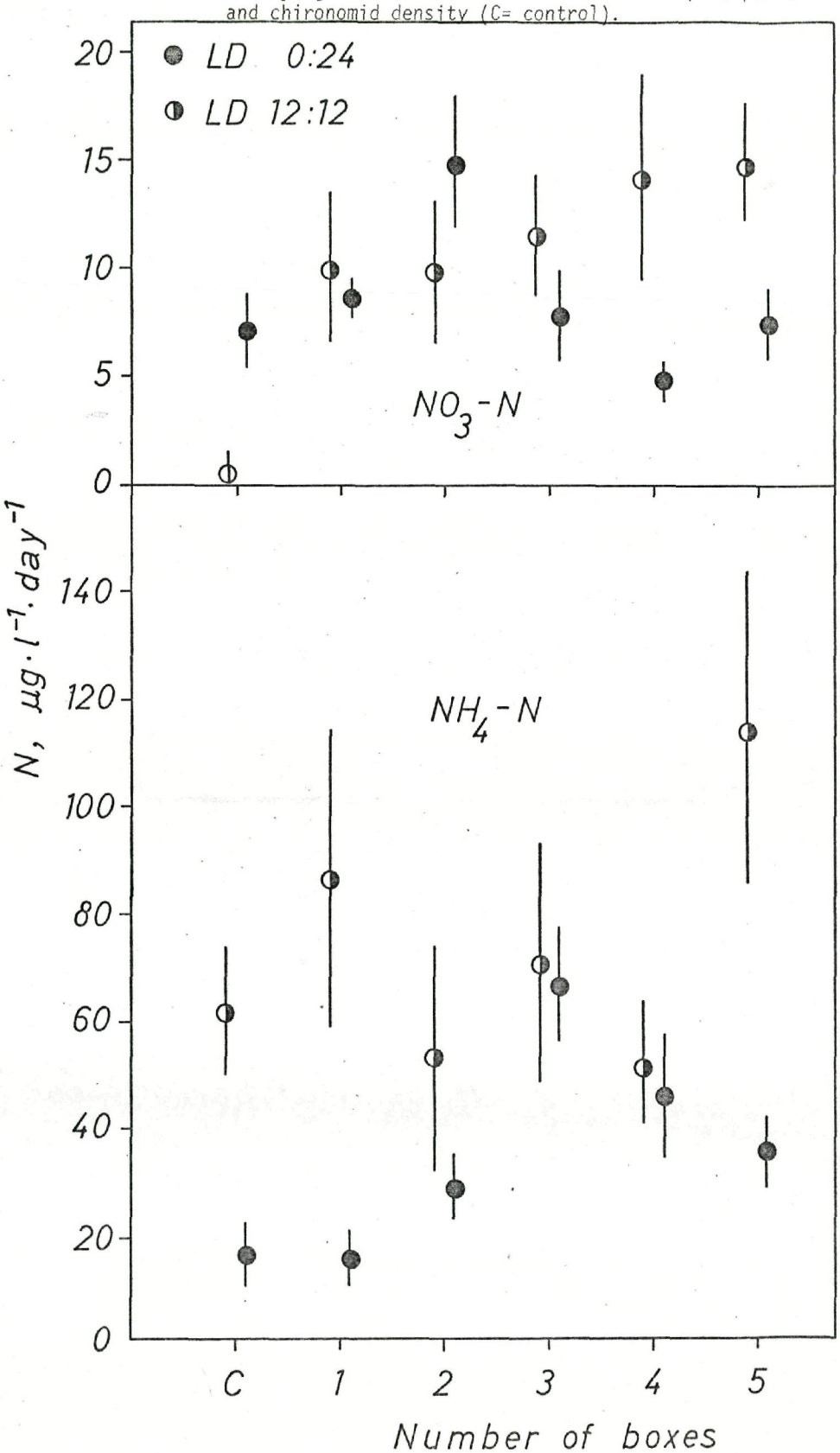


Figure 7. Concentrations of TN in the water in boxes.

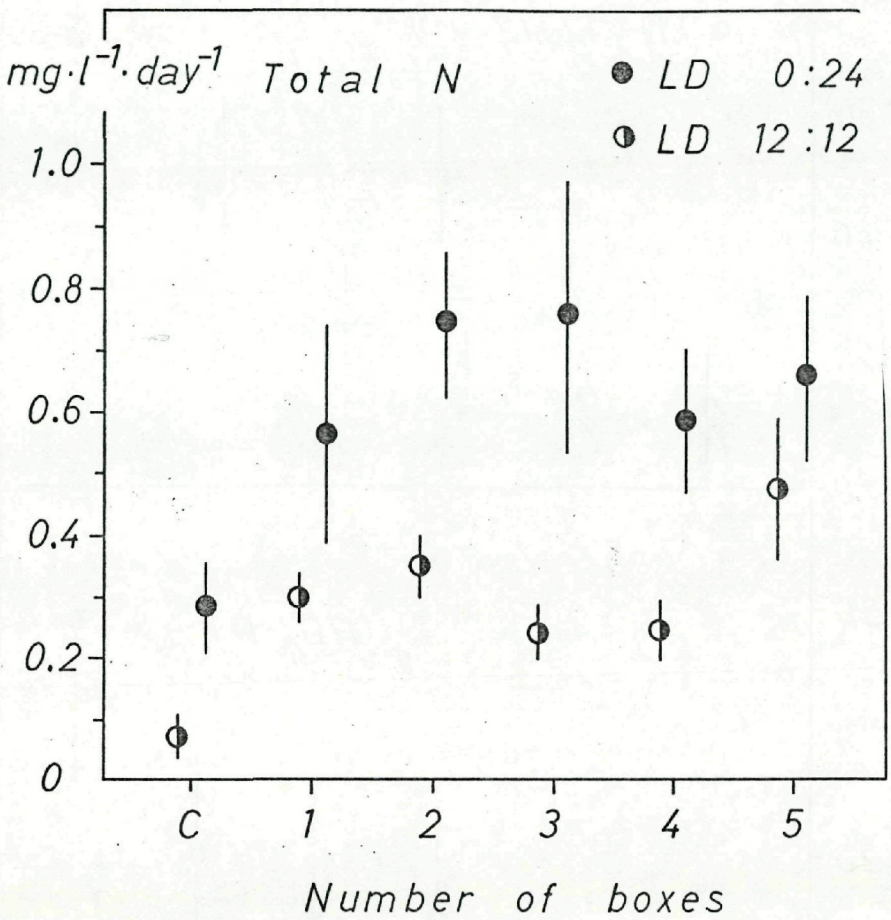
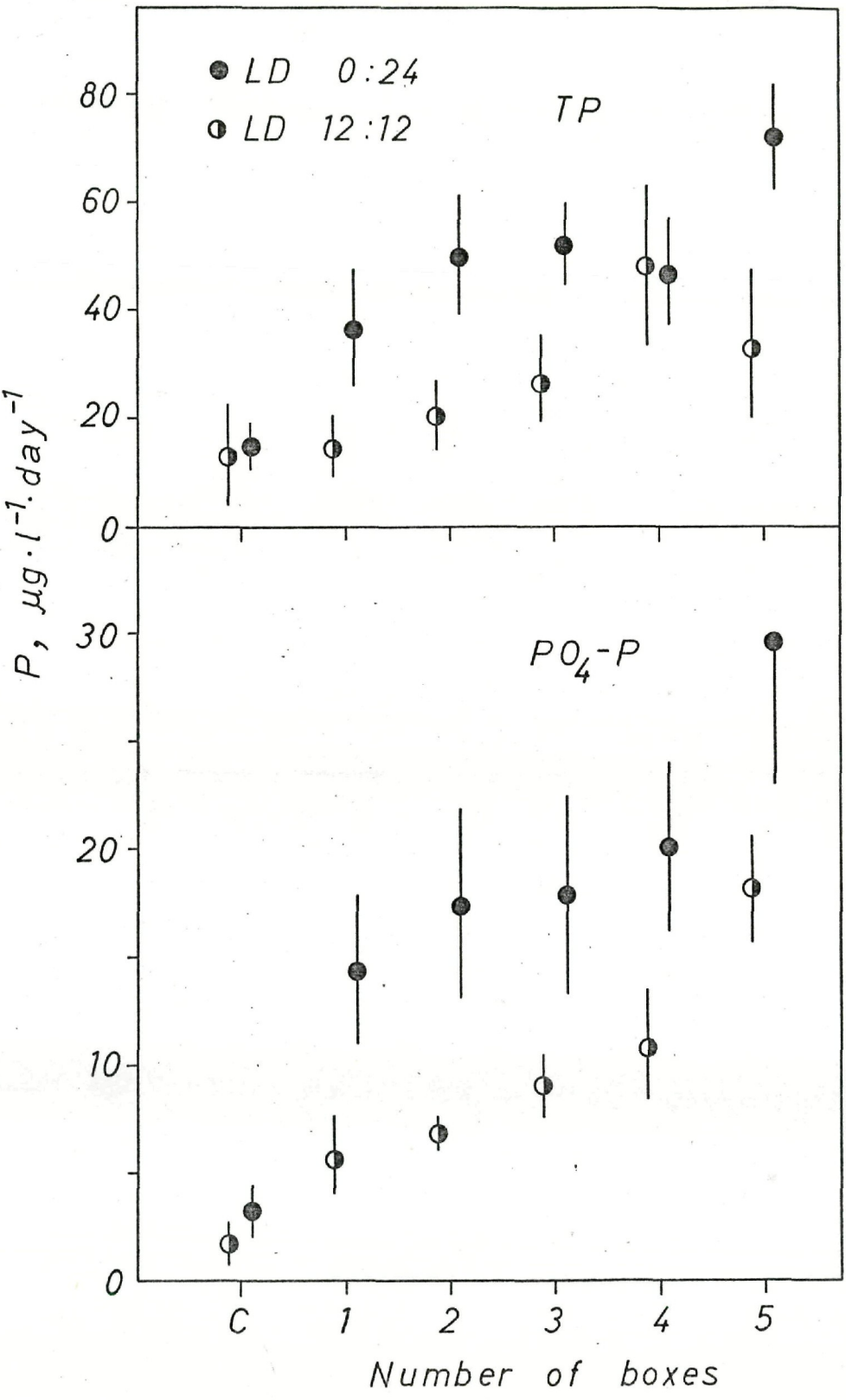


Figure 8.
Concentration of phosphate and TP in the water in boxes.



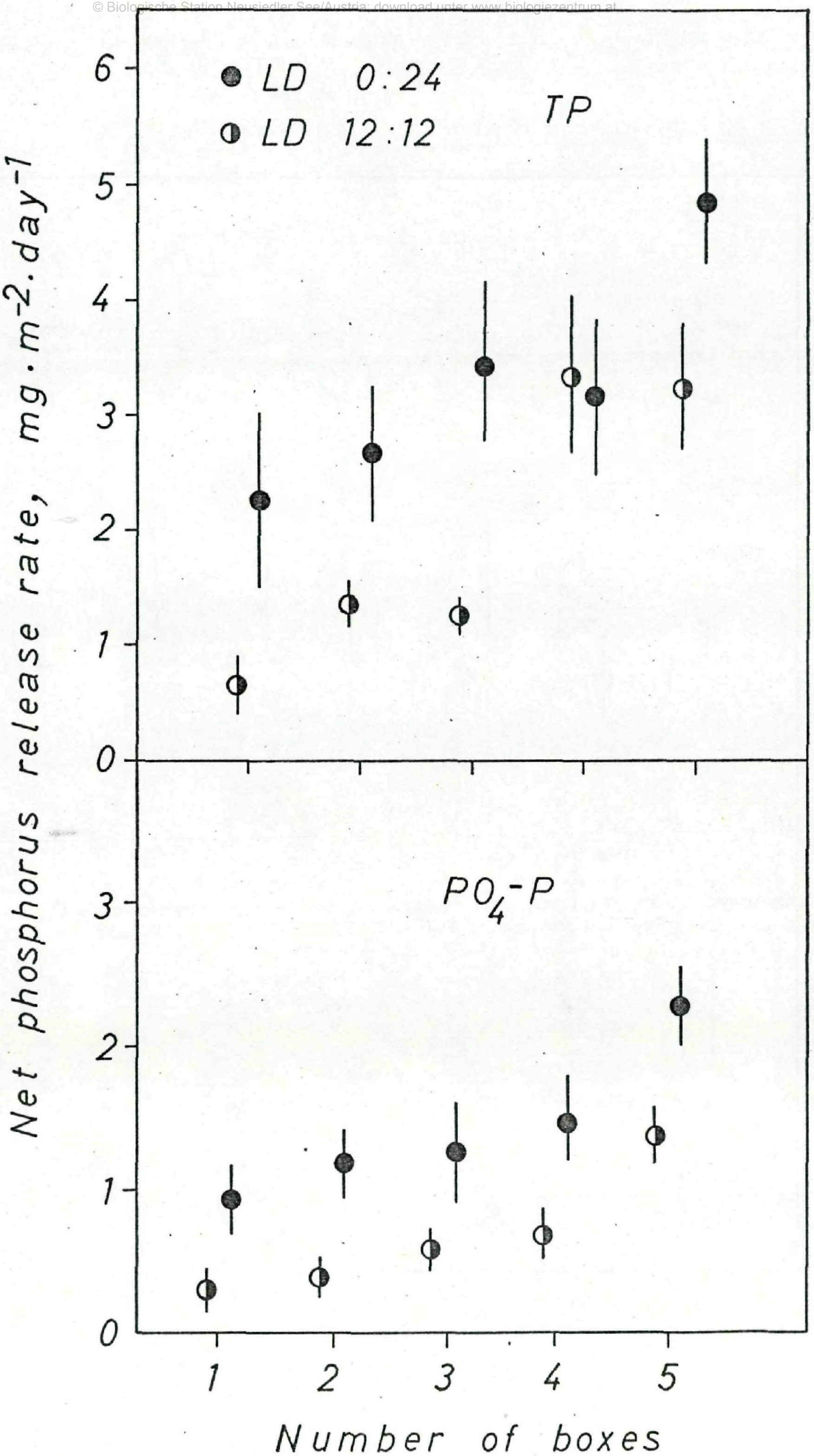


Figure 9. Phosphate and TP release rates in boxes.

Figure 10. Changes of pH of overlying water in boxes.