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EFFECTS OF PARATHION ON THE ECOLOGY OF A EUTROPHIC
AQUATIC ECOSYSTEM: LIMNOCORRAL EXPERIMENT*

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ABSTRACT

Repetitive exposure of a eutrophic fish pond ecosystem, enclosed in limnocorrals to 30 ppb parathion resulted in elimination of the potentially dominant zooplankton species, Moina micrura. Consequently, the populations of the rotifers Brachionus and Asplanchna markedly increased. Changes in the zooplankton composition and abundance were followed by increased fluctuations in phytoplankton biomass, phytoplankton photosynthesis, plankton respiration and community metabolism. Similar responses to parathion treatment were observed in previous studies under fish pond conditions.

In the presence of fish the effect of parathion on the ecosystem was generally less pronounced and not uniform. The collapse of the zooplankton community and the rapid changes in limnological conditions in the control (untreated) limnocorrals severely limited the duration of the experiment. The results suggest that under eutrophic conditions, small enclosures may be useful for evaluation of the effect of toxicants on the ecosystem only in short term experiments with short lived chemicals.

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INTRODUCTION

A great deal of information is available on the effect of pesticides at the organismic level, mostly under laboratory-controlled conditions (Brown 1978, Khan 1977). Information on the consequences emanating from pesticides contamination at the community and ecosystem level under natural conditions is wanting. One of the reasons for this is the difficulty of experimental manipulation of natural aquatic ecosystems.

This consideration prompted us to undertake a research programme in which the fate of selected pesticides in the aquatic environment, their impact on the aquatic biota and on the metabolism in the ecosystem will be evaluated under conditions as close as possible to the natural environment.

In earlier experiments (Gasith and Perry 1980) 400 m² fish ponds were used as model aquatic systems. The experimental fishponds were large enough to represent a natural ecosystem of similar trophic conditions with regard to the environmental factors and biotic components, and could be manipulated for pesticide introduction. The fish pond system had an inherent practical limitation in prohibiting the use of radioactive-labelled pesticides which could simplify the evaluation of the fate of pesticides in the ecosystem.

The present investigation was designed to evaluate the effect of a short-lived organophosphorus pesticide, parathion, on the population dynamics and activity of bacteria, algae and zooplankton, under conditions of containment in relatively small limnocorrals of 1.4 m³ capacity which were placed in the fish pond. The advantage of using limnocorrals over a fish pond system is in the relative ease of experimental manipulation and duplication. However, enclosures usually have drawbacks in that they cause changes in the abiotic and biotic structure of the ecosystem. Therefore, their use is limited for short term experiments only. Hence, we initiated this study with limnocorrals to evaluate their usefulness in short term ecosystem experiments with short-lived pesticides. If proved ecologically sound, the utilization of small limnocorrals could facilitate the use of radioactive-labelled pesticides in studies of eutrophic aquatic systems.

Materials and Methods

The experiment was carried out in 1.2 x 1.2 x 1.0 m limnocorrals anchored in a fish pond (1000 m²) at the Dor Fish Research Station, Israel.

The experimental design was as follows:

Limnocorral	Constituents of the Medium		
	Pond water ^a	Fish ^b	Parathion
1	+	-	-
2	+	-	-
3	+	-	+
4	+	-	+
5	+	+	-
6	+	+	-
7	+	+	+
8	+	+	+

a. Fishpond water containing all biotic components excluding fish

b. Each limnocorral contained 12 Tilapia (10-15 cm long) and 10 carp (4-8 cm long).

The limnocorrals were filled with fish pond water on the day of the initiation of the experiment. The experiment lasted for 10 days. Parathion was introduced on days 0; 3 and 6. On the 1st treatment 100 mg of ethyl-parathion (47.6% emulsifiable concentrate, Machteshim, Beer-Sheva, Israel) was added to each of the treated limnocorrals. On the 2nd and 3rd treatment half of the above dose was added to each of the treated limnocorrals. The sampling frequency of the experimental system was on days 0; 1; 2; 3; 4; 7; and 10. The time of sampling was always between 10:00 and 15:00 hours. Water samples for the various analyses and bioassays were taken after thorough stirring of the water in each limnocorral. At least 15 minutes were allowed for settling of the heavy particulate matter prior to the sampling of water.

Parathion analysis: Duplicate water samples for determination of parathion residue in the water were taken from mid-depth in each limnocorral with a Van Dorn sampling bottle. The analytical procedure followed that described by Gasith and Perry (1980).

Population dynamics: Changes in algal biomass were determined by following the changes in chlorophyll a content. Chlorophyll a was measured spectrophotometrically in duplicate samples following filtration of 100 ml on Whatmann GF/C filters and extraction in absolute methanol (Marker 1972, Holm Hansen 1978).

The dynamics of the zooplankton population was determined by following the changes in number and composition of the various species. A 2 liter sample taken at mid-depth with a Van Dorn sampling bottle was sieved through a 212 micron net. The entire sample was preserved and counted.

The dynamics and activity of the bacterial population will be dealt with elsewhere.

Metabolism: The photosynthetic and respiratory activity of the plankton community was evaluated by the light and dark bottle method (Vollenweider 1969). Water samples taken at 10-30 cm depth and contained in 300 ml BOD bottles were incubated for 2-3 hours. The light bottles were suspended at 10 cm depth in each limnocorral respectively. The dark bottles were placed together in a dark container submerged in the fish pond. Changes in the oxygen concentration during the incubation period were measured with a polarographic electrode (YSI, BOD probe).

Measurements of the midday in situ oxygen profile were taken for comparative evaluation of the overall community metabolism. The oxygen profile was measured with a polarographic oxygen electrode (YSI).

Measurements of the secchi disc transparency were used for comparative evaluation of the changes in the content of suspended particulate matter and the relative light conditions. At the end of the experiment the relative light conditions as reflected by the secchi disc transparency were compared with direct measurements of the vertical light attenuation taken by an underwater photometer (LI-COR Model LI-185A).

Results

The limnological characteristics of the water in the fish pond and the experimental limnocorrals were typical of a highly eutrophic system in summer. The midday temperature regime of the limnocorrals was similar to that of the fish pond throughout the experimental period, within half a degree. The overall midday temperature range varied between maximum of 32.8°C at the surface and 28.0°C at the bottom (100 cm). The overall mid day pH range was 7.8-8.3.

The secchi disc transparency (SDT) in the fish pond and the limnocorrals was typical of eutrophic systems. As shown in fig. 1 the SDT in the fish pond was relatively constant over the experimental period (11 cm \pm 6%). In the limnocorrals the SDT continuously increased with time (fig. 1). Within 24 hours of the initiation of the experiment the SDT in the untreated limnocorrals devoid of fish (Nos. 1; 2) nearly doubled. In the other limnocorrals it increased by about 50%. During the rest of the experimental period the SDT was greatest in the parathion-treated, fish-free limnocorrals (Nos. 3; 4). During the second half of the experimental period the SDT was lowest in 3 of the 4 limnocorrals containing fish.

Secchi disc transparency values (SDT) and the vertical light attenuation coefficient (K) and percent light transmission per meter ($T = 100 e^{-K}$) calculated from direct measurement of the underwater light condition at the end of the experiment are shown in Table 1.

Regression analysis of the results indicated a direct relationship between the SDT and percent light transmission in the limnocorrals and the fish pond ($r = 0.99$, $n = 6$). This result supports the assumption that SDT values may be used for determination of the light conditions in the fish pond and the limnocorrals.

Parathion residue in the water

The residue concentration of parathion in the treated limnocorrals is shown in table 2. The initial concentration of parathion after its introduction averaged 25-30 ppb. In the interim periods between applications the concentration of parathion in the water declined rapidly. Following each application the parathion concentration in the water declined to 40%, 11-21%, and 23% of the initial concentration after the 1st, 2nd and 3rd introductions, respectively.

Zooplankton composition and dynamics

During the experimental period the zooplankton population in the fish pond and in the limnocorrals consisted of 5 species, i.e. Moina micrura (Cladocera) Eucyclops serrulatus (Copepoda) Asplanchna brightwelli, Asplanchna priodonda and Brachionus caldiflorus (Rotifera). The two Asplanchna species were placed in a single category.

The composition and relative abundance of the zooplankton community in the fish pond is shown in fig. 2. The dominant species throughout the experimental period was the cladocera M. micrura. Analysis of the number of individuals per sample indicated a general increase of the zooplankton populations of each of the four genera present during the first 2-3 days. Thereafter, the zooplankton population declined with two of the genera (Eucyclops and Brachionus) disappearing 3 days later.

In the parathion-free limnocorrals and in the absence or presence of fish (Nos. 1; 2; and 5; 6 respectively) the population of the cladoceran species increased by 4-10 fold within the first 24 hours (figs. 3; 4). During this period the other genera completely disappeared. The resulting single species community finally collapsed within 6 days in the limnocorrals devoid of fish (Nos. 1; 2), and within 9 days in the presence of fish (Nos. 5; 6). The disappearance of the cladoceran species in the latter coincided with reappearance of a rotifer (Asplanchna) population. In the absence of fish none of the zooplankton species reappeared till the end of the experiment.

Treatment with parathion resulted in a population decline of the cladoceran species and a sharp increase in the rotifers populations within 24 hours, either in the absence or in the presence of fish (limnocorrals 3; 4 and 7; 8 respectively, figs. 3; 4). Whereas in the absence of fish the population of the cladoceran species was completely eliminated within 24 hours of the first parathion treatment, in the presence of fish it responded differently; In one of the limnocorrals (No. 8) the cladoceran population continued to decline and finally disappeared after 3 days. In the other limnocorral (No. 7) its population recovered in spite of the repetitive treatments with parathion and became dominant till the end of the experiment. The Rotifers populations in the parathion-treated limnocorrals (Nos. 3; 4; 7; 8) responded to the decline in the cladocera population by a sharp increase which lasted for 2-3 days, thereafter

their populations declined. The Brachionus population completely disappeared in either the presence or absence of fish. The extent of decline of the population of the other rotifer (Asplanchna) was negatively correlated with the change in the population of either the copepod or the cladocera species. In the limnocorrals devoid of fish where the copepod population gradually increased, the population of Asplanchna gradually decline. In one of the limnocorral containing fish where the cladocera population declined and disappeared (No. 8), Asplanchna maintained a relatively stable population till the end of the experiment. In the other limnocorral where the cladocera population recovered and increased (No. 7), the Asplanchna population continued to decline to the end of the experiment.

Dynamics of algal biomass

The dynamics of algal biomass as reflected in changes in chlorophyll a content is shown in Fig. 5. The algal biomass in the untreated limnocorrals devoid of fish (Nos. 1; 2) rapidly declined for the first 2 days; thereafter, it stabilized at a level approximately 40% lower than the initial level: In the parathion-treated fish-free limnocorrals (Nos. 3; 4) the algal biomass greatly fluctuated. During the first 2 days it declined to an average level 40% lower than the initial algal biomass. Thereafter, it sharply increased for at least 2 days reaching the initial biomass level and again sharply declined to 25% of the initial biomass level at the end of the experiment

In the presence of fish the algal biomass slightly increased in 3 out of the 4 limnocorrals (Nos. 5; 6; 8) with overall higher fluctuations in the parathion-treated limnocorral (No. 8). In the other parathion-treated limnocorral (No. 7) algal biomass also fluctuated, but on the whole it declined to a level 40% lower than the initial algal biomass.

Plankton metabolism

Photosynthesis of planktonic algae

The changes in the net photosynthesis of the planktonic algae over the experimental period, in the various limnocorrals is shown in Fig. 6. Over the experimental period the rate of the net photosynthesis rapidly declined in all the limnocorrals. The results suggest that the photosynthetic activity declined in two steps. The first step lasted 2-3 days during which the rate of photosynthesis generally declined more rapidly in the limnocorrals devoid of fish

(Nos. 1-4). In the second step that followed, the rate of decline of the photosynthetic activity was similar in all the limnocorrals. Least squares regression analysis of the results supported a two step exponential decline as described above (Table 3).

Respiration of the plankton community

Changes in the respiration rate of the plankton community in the various limnocorrals over the experimental period is shown in Fig. 7. The rate of oxygen consumption considerably increased within the first 24 hours in all the limnocorrals. Whereas in the parathion-treated limnocorrals (Nos. 3; 4; 7; 8) the respiration rate more than doubled, in the parathion-free limnocorrals (Nos. 1; 2; 5; 6) it increased by approximately 35% only. Within 24 hours later the rate of respiration sharply decreased to a level about 45% lower than the initial respiration rate. Thereafter, the respiration rate in the limnocorrals containing fish (Nos. 5-8) remained relatively stable. In the absence of fish (limnocorrals Nos. 1-4) it continued to decline attaining a minimum level about 75% lower than the initial respiration rate.

Community metabolism

The consequence of the overall photosynthetic and respiratory activity in the system (community metabolism) was evaluated by following the changes in the midday in situ oxygen regime. The midday oxygen profile in the fish pond and the limnocorrals was typical of highly eutrophic systems. Maximum saturation level of 150% or more was always obtained at the surface or 10-20 cm below the surface. For comparative purposes a representative depth of 30 cm was chosen. As shown in Fig. 9 the midday oxygen saturation level at 30 cm depth generally declined over the experimental period in the fish pond as well as in the limnocorrals. However, changes in oxygen saturation were more gradual in the fish pond and in control limnocorrals while in the parathion-treated limnocorrals and in the presence of fish the oxygen fluctuations were more pronounced. In the fish-free, parathion-treated limnocorrals (Nos. 3; 4) the oxygen concentration sharply increased within the first 24 hours after the introduction of parathion, exceeding 270% saturation level. Thereafter, the oxygen concentration gradually declined but remained at a higher saturation level than that of the other limnocorrals, during most of

the experimental period. Except for the first 24 hours, the oxygen concentration in the limnocorrals containing fish (Nos. 5-8) was the lowest among all limnocorrals including the fish pond. In the presence of fish no significant difference was found between the oxygen regime in the parathion-treated or parathion-free limnocorrals.

Discussion

Dynamics of parathion in the water

As found in our previous studies (Gasith and Perry, 1980; Perry, Gasith and Halevy, 1979) the dynamics of parathion residue in the eutrophic water of fish ponds was characterized by a rapid exponential disappearance of the toxicant. In the present investigation the rate of decline of parathion residue in the water after the 2nd and 3rd introductions was somewhat higher than after the first introduction. This phenomenon may be associated with sorption of the chemical on the massive periphyton community which developed on the walls of the limnocorrals. The maximum measured concentration of parathion in the water was sublethal to the fish (carp, Tilapia) but was lethal to the cladoceran component of the zooplankton. A similar effect was observed in the fish pond experiments mentioned above.

The effect of parathion on the suspended particulate matter and the light conditions

Theoretical analyses and empirical observations have shown that the reduction in light transmission in relation to Secchi disc transparency (SDT) measurements is associated to a greater extent with increased light scattering by suspended particulate matter (Szczepanski 1968). The significant increase in SDT in the limnocorrals as compared with the stable situation in the fish pond indicates that the containment of the water in the flexible limnocorrals increased sedimentation of the suspended particulate matter (seston) probably by reducing the effect of wind action on water turbulence. The seston of fish ponds is composed mainly of live and dead algal cells, zooplankton, detrital matter of animal origin and soil particles suspended from the bottom. The increase in SDT, in spite of an unchanged, relatively high algal biomass in the limnocorrals containing fish (Nos. 5; 6; 8, fig. 5), suggests that the light conditions in these limnocorrals are primarily affected by the non algal components of the seston. The fact that in the presence of fish the SDT was the lowest among the limnocorrals most of the time, supports the assumption that fish may have an important function influencing the seston

content in the limnocorrals system by increasing water turbulence and thus increasing resuspension of bottom sediments. The additional effect of fish excretion and fecal pellets deposition cannot be excluded. Comparison of the changes in SDT between parathion-treated and untreated limnocorrals, in the presence or absence of fish, revealed no apparent effect of the toxicant.

The effect of parathion on the dynamics of zooplankton under containment conditions

Comparison of the zooplankton community in the parathion-free limnocorrals and the fish pond revealed a pronounced containment effect, exhibited by a drastic change in the composition and dynamics of the zooplankton. Under the fish pond conditions the zooplankton community gradually changed from 4 genera to a 2 genera community with consistent dominance of the cladoceran component (*Moina*). Upon containment, the cladoceran population dramatically increased and within 24 hours became the only population present. The coincidental disappearance of the rotifers and the copepod species appeared as a typical competitive exclusion response (Hardin 1960). This conclusion was supported by the fact that throughout the experimental period the presence and relative abundance of the rotifers and the cladocera populations in the different limnocorrals was negatively correlated. Strong competitive relations between the two groups are reported by other studies (Daborn *et al.* 1978, Dumont 1972).

In spite of the drawback of the experimental system mentioned earlier, there was a distinct effect of the toxicant on the composition and dynamics of zooplankton. Within 24 hours of the parathion introduction the population of the cladoceran species was severely reduced or completely eliminated. The elimination of the potentially dominant species, under the containment conditions, prevented the immediate exclusion of the other zooplankton species, which responded in a massive build-up of their populations. A similar response to parathion exposure was observed in previous fish pond experiments (Gasith and Perry, 1980). However, unlike the situation in the latter experiments the zooplankton community in the control (untreated) limnocorrals rapidly changed and finally collapsed, thus preventing any long-term observations.

In spite of the assumption that the fish in the limnocorrals were probably not feeding primarily on the zooplankton, their presence had an

impact on the dynamics of the zooplankton. In the untreated limnocorrals the existence of the single cladoceran species population was prolonged by about 40% in the presence of fish as compared to its existence in the limnocorrals devoid of fish. When treated with parathion, the effect of the toxicant on the zooplankton community in the limnocorrals containing fish was not uniform. The fact that in the limnocorrals containing fish, the cladoceran population was not immediately eliminated, and in one instance the population recovered in spite of the repetitive parathion treatments, suggests that the presence of fish may influence a yet undetermined factor, which in turn may affect the substrate-biological species interaction and thus the apparent toxic effect of the chemical in the environment.

The effect of parathion on the dynamics of algal biomass in the presence and absence of fish

The dynamics of the algal biomass was greatly influenced by the presence or absence of fish. However, the overall effect of parathion of increasing the fluctuations in algal biomass was similar in either the presence or absence of fish.

In the absence of fish the exponential decline in algal biomass in the control limnocorrals during the first 3 days may be associated with increased sedimentation and increased grazing pressure by the cladoceran population. This conclusion is supported by the increase in secchi disc transparency and in the population size of cladocera during this period. The disappearance of the cladoceran population after 5 days may explain the stabilization of the level of algal biomass thereafter.

The fluctuations in algal biomass observed in the fish-free, parathion-treated limnocorrals may be associated with the respective fluctuations in the zooplankton populations.

In the presence of fish, algal biomass remained high in spite of the presence of the cladoceran population. It should be noted, however, that the period of relative increase in algal biomass in the parathion-free limnocorrals corresponded to the period in which the cladocera population declined. As observed in the absence of fish, the presence of the toxicant

had an indirect effect on the algae as evidenced by the higher fluctuation in algal biomass. These fluctuations corresponded to those of the zooplankton population as shown in our previous fish pond experiments (Gasith and Perry, 1980; Perry, Gasith and Halevy, 1979).

The significantly higher algal biomass in the presence of fish suggests that fish may increase algal biomass by reducing their rate of sedimentation and by enhancing their growth. The latter effect may be a consequence of the impact of fish on redistribution of particulate matter and dissolved nutrient from the bottom sediments to the water column or by enriching the water with essential nutrients via excretion.

Effect of parathion on plankton metabolism

Changes in the net photosynthetic activity may be the consequence of one or all of the following factors: changes in algal biomass, changes in the photosynthetic activity per cell (or chlorophyll) and changes in respiratory activity.

In the case of the fish-free limnocorrals the reduction in photosynthetic activity may partly be explained by the decline in algal biomass. This explanation may not hold true for the changes in the photosynthetic activity observed in the limnocorrals containing fish in which the algal biomass was high throughout the experimental period.

As shown in fig. 7 the respiration rate sharply decreased 48 hours after the initiation of the experiment and remained relatively unchanged or continued to decline. Thus, changes in respiration rate may not explain the continuous decline in the photosynthetic activity.

Analysis of the net photosynthetic activity per mg chlorophyll-a revealed a general decline with time. The reduction in algal activity was most pronounced in 3 out of 4 limnocorrals containing fish (Nos. 5; 6; 8). Considering the dynamics of algal biomass it appears that in the absence of fish the decline in the net photosynthesis is also due to reduction in the activity per cell. In the presence of fish the decline in the net photosynthetic activity may be totally explained by the reduction in the activity per cell which may be a consequence of a limiting factor.

It should be noted that under the experimental conditions the comparative aspects of the changes in photosynthetic activity had a certain bias since, unlike the situation in the fish pond, the light conditions in the limnocorrals were continuously changing while the incubation bioassay was performed at a fixed depth.

No effect on the net photosynthetic activity could be detected by the parathion treatment.

Effect of parathion on plankton respiration

Respiration in water is primarily bacterial. The rate of bacterial respiration is influenced by temperature, substrate and bacterial density.

During the experimental period the water temperature varied within 4 degrees (28°-32°C). Changes observed in the respiration rate could not be explained by this variation. In the parathion-free limnocorrals the moderate initial increase in the respiration rate may be explained by an increase in the bacterial population under containment conditions. The exposure to parathion had a most pronounced effect of doubling the respiration rate 24 hours after the first introduction of the toxicant. This phenomenon was probably associated with an increase in the organic substrate following the death of zooplankton. Thereafter, the decline in respiratory activity in the water column, in all the limnocorrals, was probably associated with the loss of particulate matter by sedimentation. Loss of particulate matter may result in reduction of both organic substrate and bacterial cells which are adsorbed to the particles.

The effect of the presence of fish on respiration was apparent only at a later stage of the experiment where the respiration rate in the fish-containing limnocorral was higher than in the limnocorrals devoid of fish.

Effect of parathion on community metabolism

The oxygen concentration in water is a function of the overall air-water diffusion process, biogenic processes of oxygen production and consumption, and chemical oxygen consumption. In eutrophic waters the biogenic processes are the most important.

Although the overall decline in the oxygen concentration in the water corresponded to the decline in the net photosynthesis of the phytoplankton,

there was no agreement between the in situ oxygen fluctuations and the individual change in photosynthesis and respiration in each of the limnocorrals. This suggests the presence of other biogenic oxygen sources than those of the phytoplankton community. The most probable source is that of the periphyton community which includes algae, bacteria and protozoa, attached to submerged objects in the water. This assumption is supported by the massive periphyton growth encountered on the walls of the limnocorrals at the end of the experiment.

The treatment with parathion had a most pronounced effect on community metabolism in the limnocorrals devoid of fish in which the in situ oxygen saturation level almost doubled within 24 hours of the parathion introduction. This effect may be associated with reduced grazing pressure as a consequence of elimination of the cladocera population and the more favorable light conditions due to the loss of seston by sedimentation. These two processes will enhance phytoplankton and periphyton activity and as a consequence augment the in situ oxygen content.

CONCLUSIONS

The enclosure of a small portion of a eutrophic aquatic system significantly changed its abiotic conditions and biotic structure and dynamics. As shown in other studies as the size of the enclosure increases the effect of containment diminishes (Lund 1972; 1978). In spite of the limitations of the small limnocorral the dynamics of a short-lived toxicant, parathion, and its impact on the ecosystem in the early phase of containment were similar to those observed under fish pond conditions.

As has been observed in open system situation the exposure to relatively low levels of a toxicant primarily affect ecosystem stability by selectively eliminating certain biotic components. Such an effect under containment condition was apparent by the change in zooplankton community composition and the resulting fluctuations in algal biomass and community metabolism.

The existence of relatively large size organisms such as fish under limited space conditions may significantly affect the abiotic conditions and the structure and dynamics of the biotic components. consequently, influencing the substrate-biological species interaction and, hence, the apparent toxic effect of the chemical in the environment.

Considering the above limitations, the use of relatively small enclosures for evaluation of toxic effect of chemicals in eutrophic ecosystems should be limited to short term experiments only. This consideration prohibits the use of small limnocorrals for evaluation of chronic effects of toxicants in the aquatic environment but may be useful in investigating the effects of short-lived chemicals.

Table 1. Vertical light attenuation coefficient k (\pm SD), percent light transmission per meter T ($T=100 e^{-k}$) and secchi disc transparency (SDT) values in the fish pond and limnocorrals at the end of the experiments (5/8/1981).

<u>LIMNOCORRAL</u>	<u>TREATMENT</u>	<u>K</u>	<u>T</u>	<u>SDT</u>
1;2	Control	2.9 \pm 0.45	6	42.5
3;4	+ Parathion	2.0 \pm 0.04	14	72.5
5;6	+ Fish	3.6 \pm 0.2	3	32.5
7	+ Parathion + Fish	2.0	13	72
8	"	3.2	4	37
FISH POND	"	8.0	0.03	11

Table 3. Least squares exponential regression of the net photosynthetic activity against time in the various limnocorrals ($y = ae^{bx}$; r = regression coefficient, n = number of values).

<u>PERIODS</u> <u>(days)</u>	<u>LIMNOCORRALS</u>	<u>REGRESSION PARAMETERS</u>			
		<u>a</u>	<u>b</u>	<u>r</u>	<u>n</u>
0 - 2	1 - 4	4.53	-0.31	0.86	12
0 - 3	7 ; 8	4.82	-0.10	0.90	10
3 - 10	1 - 4	2.44	-0.18	0.86	16
3 - 10	5 - 8	3.43	-0.13	0.92	16

Table 2. Parathion residue (PPB) in water (mean \pm SD).

<u>Date</u>	<u>Limnocorral^a</u>	<u>Before Introduction</u>	<u>After Introduction</u>
26.7	3	0	26.2 \pm 2.9
	3	0	32.9 \pm 1.8
	7	0	26.4 \pm 8.3
	8	0	29.2 \pm 6.0
27.9	3	25.9 \pm 1.4	-
	4	25.1 \pm 1.6	-
	7	20.7	-
	8	24.4	-
29.7	3	11.6 \pm 2.6	26.1 \pm 5.7
	4	-	23.5 \pm 6.7
	7	-	19.7 \pm 0.7
	8	-	30.2 \pm 12.4
30.7	3	14.1 \pm 1.8	
	4	15.8	
	7	10.6 \pm 1.4	
	8	11.4 \pm 1.3	
2.8	3	7.50 \pm 2.0	35.7
	4	3.0 \pm 0.6	20.2
	7	2.06 \pm 0.5	24.5
	8	2.9 \pm 0.5	17.6
5.8	3	6.2 \pm 2.0	
	4	6.4 \pm 1.4	
	7	4.3	
	8	5.1 \pm 0.6	

^a Without fish - Nos. 3;4, With fish - Nos. 7;8

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- Fig. 7. Changes in the respiration rate of the plankton community in parathion-free and parathion-treated limnocorrals, in the absence and presence of fish. Arrows indicate dates of parathion introduction.
- Fig. 8. Changes in the photosynthesis per mg chlorophyll-a in the parathion-free and parathion-treated limnocorrals in the absence and presence of fish. Arrows indicate dates of parathion introduction.
- Fig. 9. Changes in the dissolved oxygen content at 30 cm depth in the parathion-free and parathion-treated limnocorrals, in the absence and presence of fish. Arrows indicate dates of parathion introduction.

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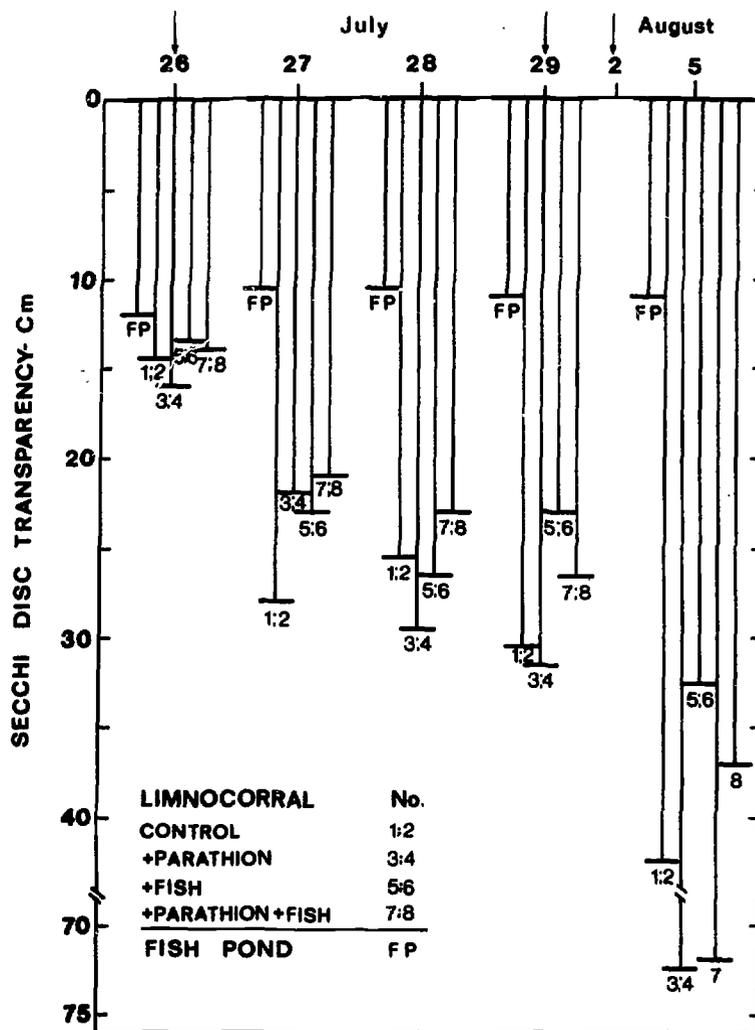


FIGURE 1

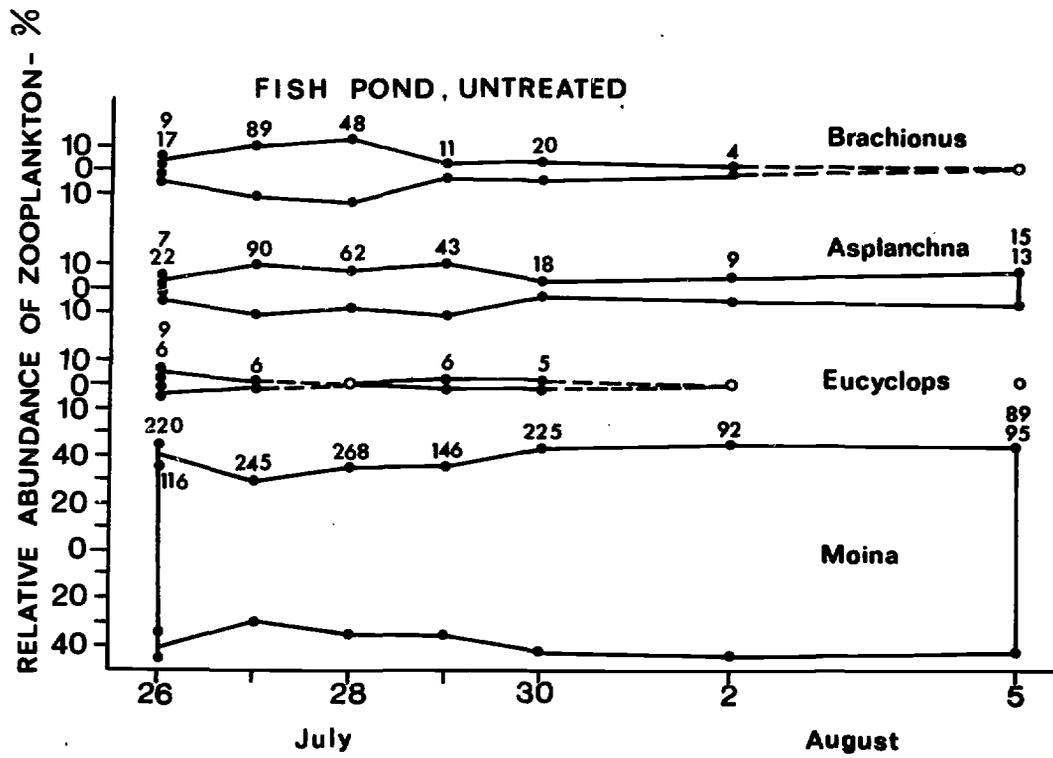


FIGURE 2

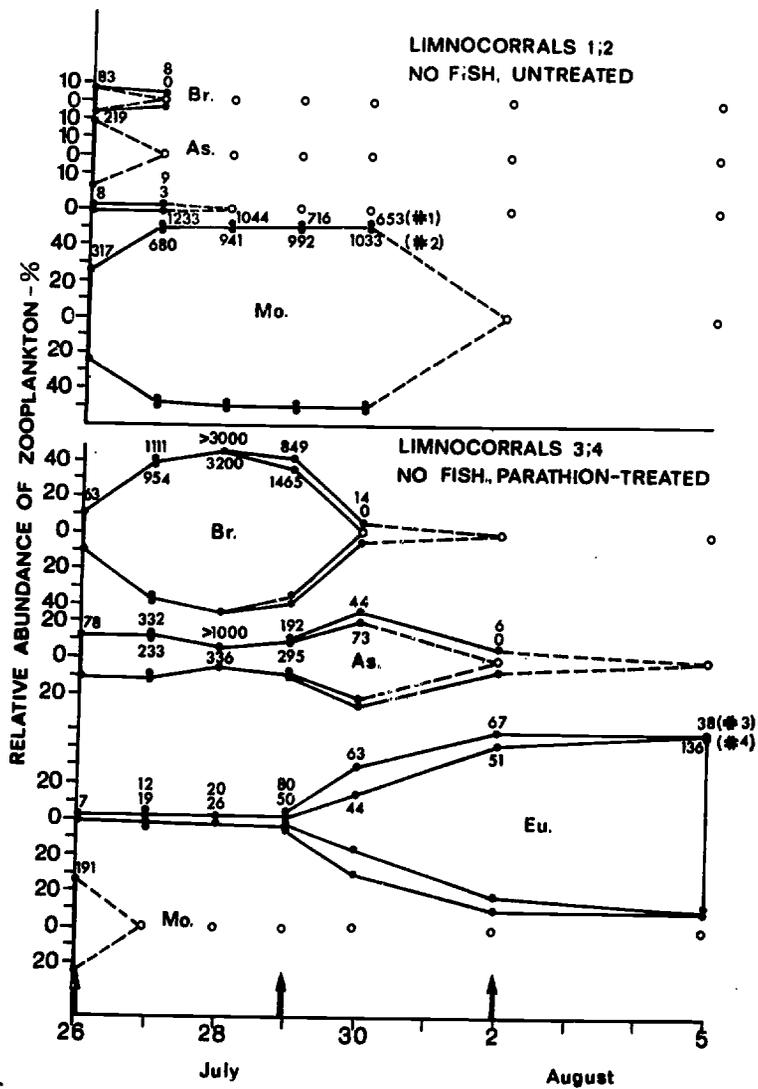


FIGURE 3

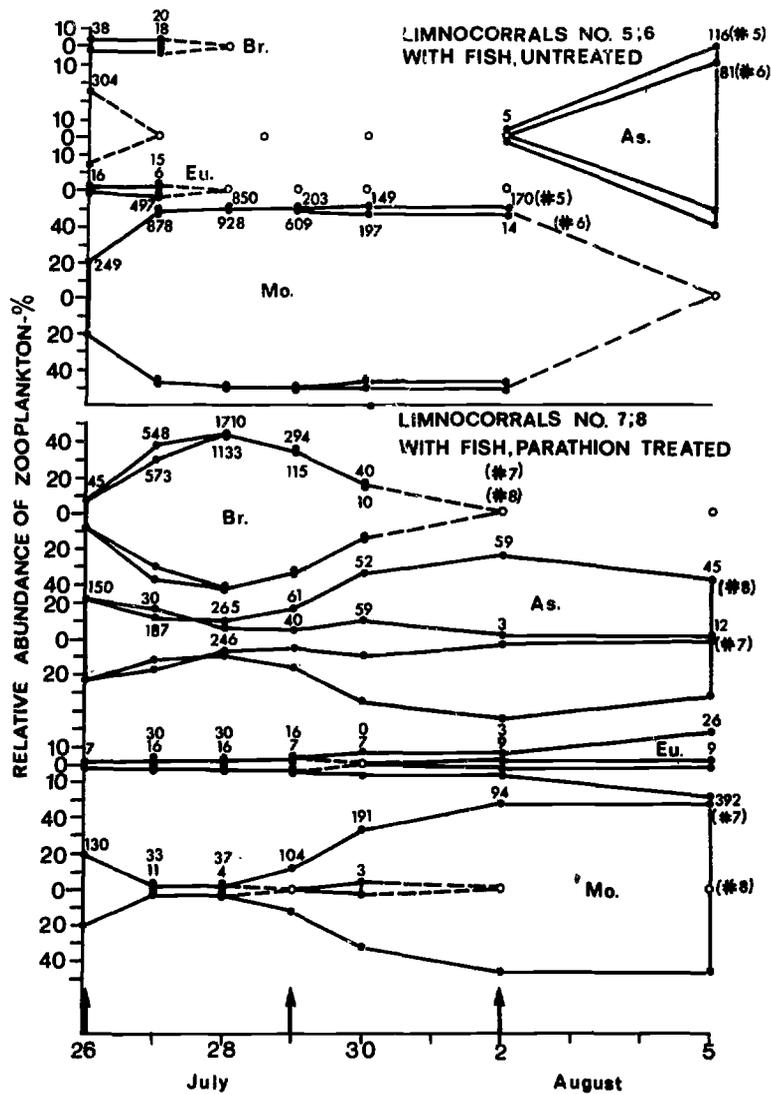


FIGURE 4

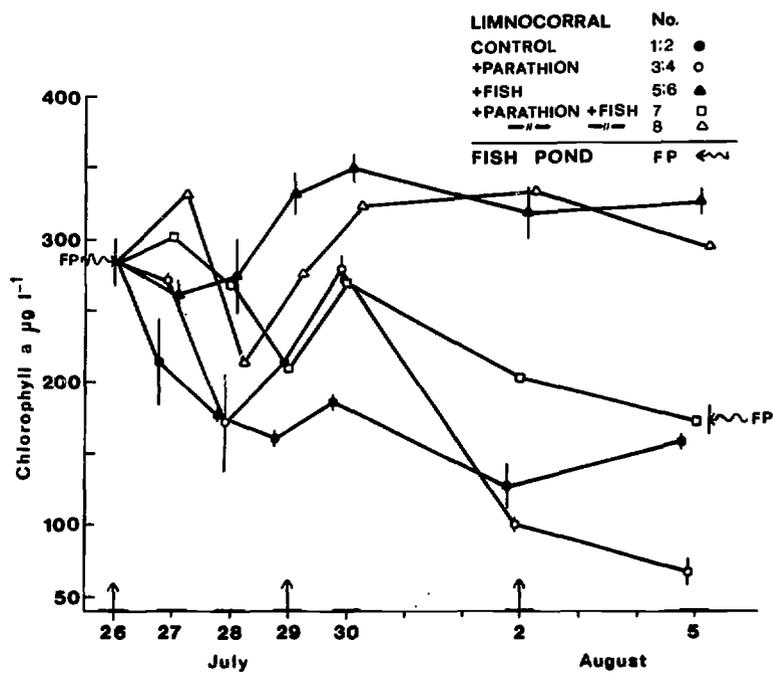


FIGURE 5

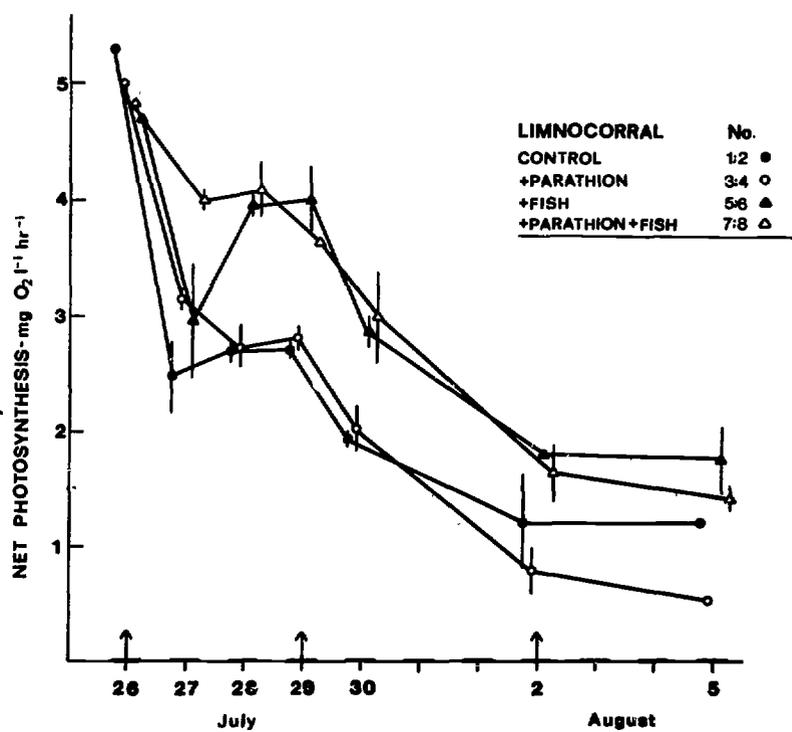


FIGURE 6

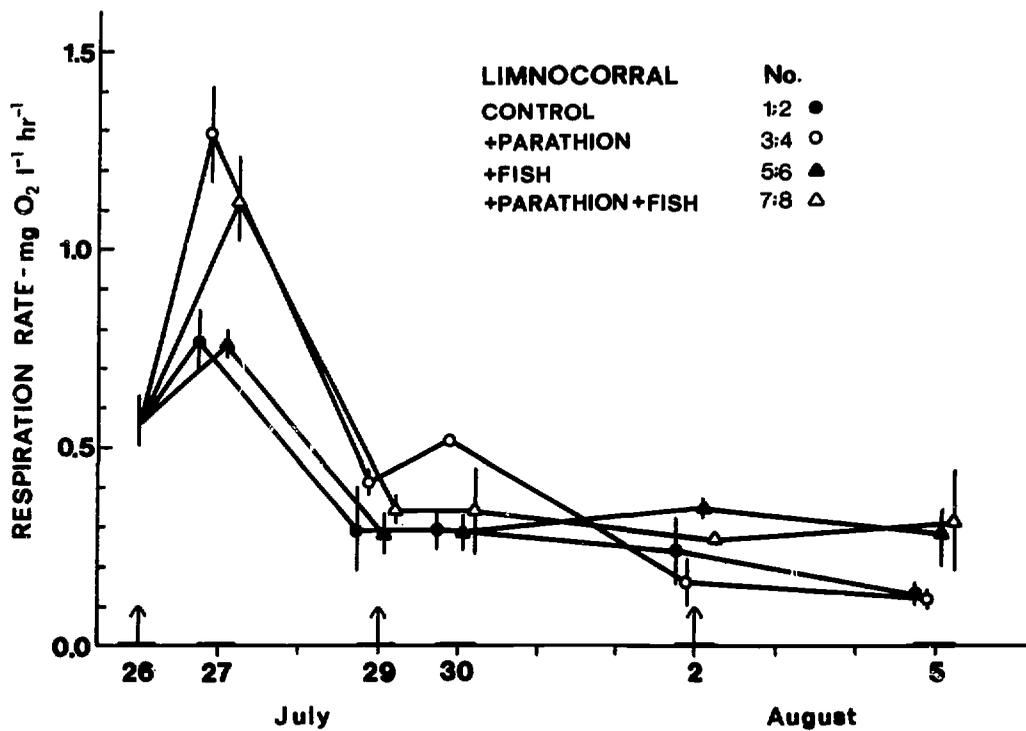


FIGURE 7

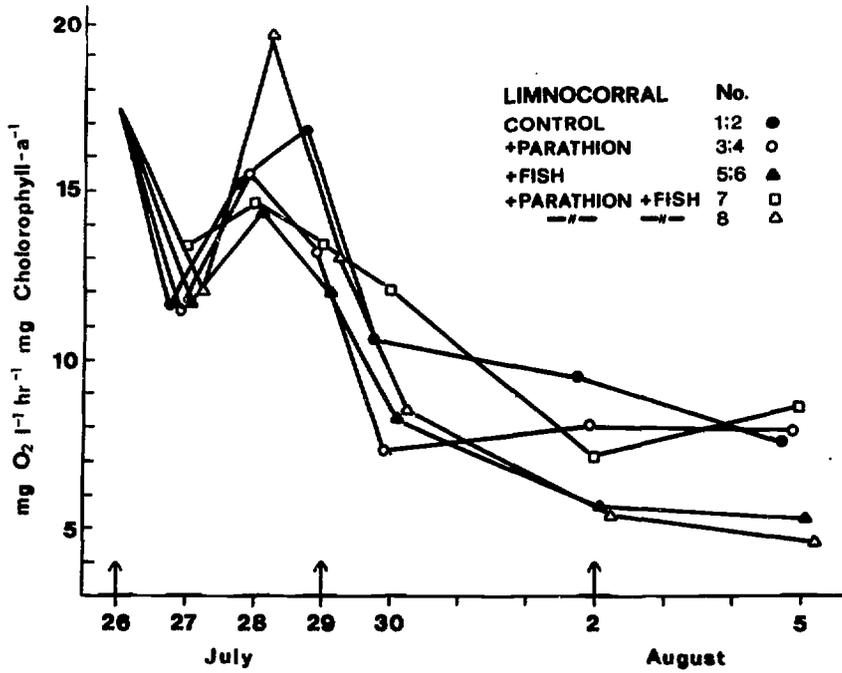


FIGURE 8

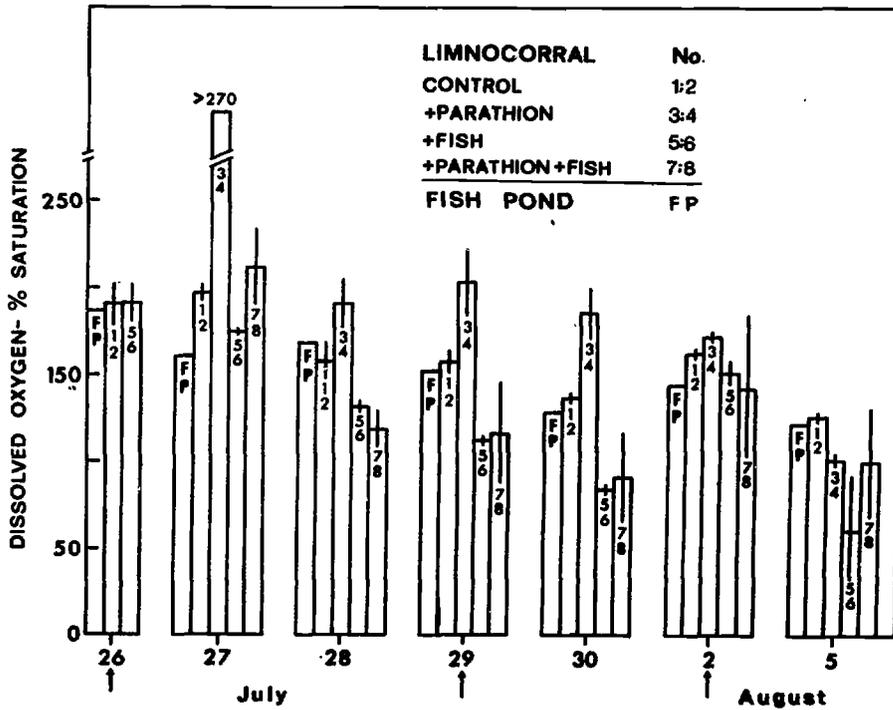


FIGURE 9