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# Effect of bighead carp (*Aristichthys nobilis* Rich.) stocking on zooplankton and some parameters of organic carbon cycling in carp ponds

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Abstract — Stocking ponds with bighead carp brought about a decrease in zooplankton biomass and production as compared with ponds of carp monoculture. Primary production of phytoplankton and total respiration of plankton did not differ to any greater degree in ponds with fish mono- and polyculture. The strong elimination of zooplankton by bighead carp increased the share of bacteria in the total respiration of plankton. The share of filtrator fish in the accumulation of organic matter was slight and did not significantly affect the balance of organic matter and oxygen in the ponds.

Key words: ponds, carp, bighead carp, phytoplankton production, zooplankton, respiration, organic carbon.

## 1. Introduction

In pond fishery a problem not so far elucidated is that of stocking ponds with such fish species as would most effectively utilize the natural food resources there. Stocking with mixed carp of different agees rather than of one age, applied in the fifties, was more efficient in eliminating zooplankton of various size from the water. Nevertheless, this method was discarded for sanitary reasons, above all the possible transmission of disease from older to younger fish (Gościński, Rudnicki 1956). In the past ten years intensive methods of carp rearing in monoculture have been developed, based on increasing the density and biomass of coeval carp stocking, mineral and organic fertilization, and feeding with pellets of high protein content. In the zooplankton of such ponds there occurs a mass development of small species of rotifers, cladocerans, and copepods, which are not consumed by carp, while large species, e.g. *Daphnia*, are most totally eliminated by the fish (Grygierek 1979, Lewkowicz M., S. Lewkowicz 1981).

Different species of Cyprinidae have various ways of feeding, hence mixed stocking makes it possible to utilize the natural resources of ponds more efficiently than monoculture. The carp is an omniphagous species; it consumes organic detritus, zooplankton, benthos, and according to Buck et al. (1978), the faeces of other fish. Bighead carp feed on phyto- and zooplankton and organic and mineral suspension (Moskul 1977).

In recent years manipulation of the structure of fish species, the highest level in the trophic chain in water bodies, has been become one of the measures in reducing algal biomass in eutrophic waters. In dam reservoirs, where blooms or blue-green algae occurred, the introduction of silver and bighead carp contributed to the elimination of this phenomenon Vovk, Stechenko 1985).

In investigating carp ponds, Opuszyński (1979) found that silver carp in those with intensive rearing efficiently eliminated small zooplankton, i.e. rotifers and *Bosmina*. According to this author, the intensification of carp rearing in ponds produces good feeding conditions for silver carp, stimulating the mass development of phytoplankton and small zooplankton. Grygierek (1978a, b) found that a great density of bighead carp in ponds stocked with carp brought about a decrease in the absolute numbers of zooplankton, negatively affecting the feeding conditions of fish. Komarova (1969) recorded drastic decreases in the abundance of zooplankton owing to overstocking of silver and bighead carp. Kharitonova and Abu-el-Vafa (1977) recommended the limitation of 2-yaer bighead carp stocking to 500 indiv. $ha^{-1}$ in ponds with carp culture.

In ponds with intensive fish culture the role of allochtonous organic carbon increases. According to Avnimelech and Lacher (1979), the accumulation in the biomass of fish of organic carbon supplied in pellets is less than 36%. In the season of intensive feeding of fish the diel loading of organic matter contained in the pellets may several times exceed the primary production of phytoplankton (Lewkowicz M., S. Lewkowicz 1981).

The cycling of organic carbon in pond ecosystems to the affects the oxygen conditions to the highest degree. Its metabolism chiefly depends on the structure and functioning of the ecosystem. A great part of the organic matter not utilized by the fish is included in the cycling by all levels of the trophic chain.

The aim of the present work was to investigate the impact of bighead carp stocking on the structure of species, numbers, and biomass of zooplankton, and to analyse the effect of changes in the numbers of zooplankton on the total respiration of plankton in these ponds. A further aim was to compare selected elements of the organic carbon balance in ponds with carp monoculture in relation to ponds with mixed stocking of carp and bighead carp.

## 2. Study area, material, and methods

The investigation was carried out in the years 1977—1978 in six ponds, each of 0.15 ha and 1.5 m in depth, in the Fish Culture Experimental Station Gołysz of the Polish Academy of Sciences. The ponds were stocked in May and catches were made in October. In

Table I. Characteristics of ponds, stocking, and yield of fish in the years 1977—1978. C — carp; B — bighead carp

| Year | Pond | Stocking: indiv. $ha^{-1}$ | | Stocking: weight g $indiv.^{-1}$ | | Fertilization kg $ha^{-1}$ | | Pellets t $ha^{-1}$ | Yield: kg $ha^{-1}$ | | Yield: weight g $indiv.^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | B | C | B | P | N | | C | B | C | B |
| 1977 | M | 24000 | 0 | 62.5 | 0 | 29 | 186 | 10.1 | 3423 | 0 | 302.0 | 0 |
| | P1 | 24000 | 3700 | 62.5 | 17.5 | 29 | 186 | 9.9 | 2240 | 907 | 262.0 | 259.0 |
| | P2 | 20000 | 3700 | 62.5 | 17.5 | 29 | 186 | 8.9 | 2337 | 827 | 253.0 | 250.0 |
| 1978 | M | 24000 | 0 | 78.0 | 0 | 33 | 210 | 16.4 | 5840 | 0 | 338.0 | 0 |
| | P1 | 24000 | 3000 | 78.0 | 219 | 33 | 210 | 16.4 | 4920 | 393 | 313.0 | 399.0 |
| | P2 | 16000 | 3000 | 78.0 | 219 | 36 | 233 | 11.0 | 3067 | 413 | 323.0 | 393.0 |

both years of the study ponds M were stocked with carp (*Cyprinus carpio* L.) (1+) monoculture. Ponds P were stocked with carp (1+) and bighead carp (*Aristichthys nobilis* Rich.) (1+) in the first and (2+) in the second year of the experiment (Table I).

Each year the primary production of phytoplankton and respiration of plankton were measured in two ponds: pond M with monoculture and P1 with polyculture. In the period May—October the measurements were carried out at weekly intervals, using the method of light and dark bottles (Vinberg 1960). The content of chlorophyll was determined in acetone extract (Golterman 1970).

Calculation of the organic carbon balance was based on the work by Zur (1981). The magnitude of fish respiration was accepted from

Kopylova and Lyakhnowich (1986). The loading of a pond with allochtonous organic carbon originating from pellets supplied as supplementary food not taken up by the fish, was calculated from the difference between the content of organic carbon in the pellets and the amount utilized for growth and metabolism of the fish (Lewkowicz M., S. Lewkowicz 1981).

Quantitative samples of zooplankton were taken with a 5 $dm^3$ plankton sampler at weekly intervals from April to September at 5 stations in each pond. Samples of 50 $dm^3$ water from each pond were filtered through nets with a mess of about 60 μm. Qualitative samples were collected with a plankton net drawn by a boat. The measurements involved 100 individuals each of different species of cladocerans, nauplii, copepodides, and adult copepods. The biomass of zooplankton was calculated as dry weight according to equations given by Doohan and Rainbow (1971), Schindler and Noven (1971), Doohan (1973), Dumont et al. (1975), and Botrell et al. (1976). Data concerning the length of development of crustaceans as depending on temperature were taken from works by Filimov and Sokolova (1973), Bottrell et al. (1976), Spindler (1976), Lair (1977), and Lim and Fernando (1978).

The production of rotifers was calculated according to the Galkovskaya method (1965) and of crustaceans according to equations of depenedence between production and biomass (Ivanova 1985). The respiration of rotifers was calculated according to Krylov (1971) and Doohan (1973), and of crustaceans according to equations given by Shushchyenya (1972).

Factor analysis of similarity, using the method of principal component analysis (Góralski 1979) which was applied for fish ponds by Vallod (1984) and Milstein et al. (1985), was used in describing the impact of fish on the density of different zooplankton species.

It was assumed that phytoplankton respiration reached 20% of gross primary production (Hillbricht-Ilkowska 1977). The respiration of bacterioplankton and Protozoa was taken as the difference between the total respiration of plankton and the respiration of phyto- and zooplankton. The remaining physico-chemical analyses of the water were carried out according to Golterman (1970).

## 3. Results

In both years in all the investigated ponds the following species dominated among rotifers: *Polyarthra trigla vulgaris* Sudzuki, *Filinia longiseta* Ehrenberg, *Brachionus calyciflorus* Pallas, *B. angularis* Gosse, *B. diversicornis* Daday, *B. rubens* Ehrenberg,

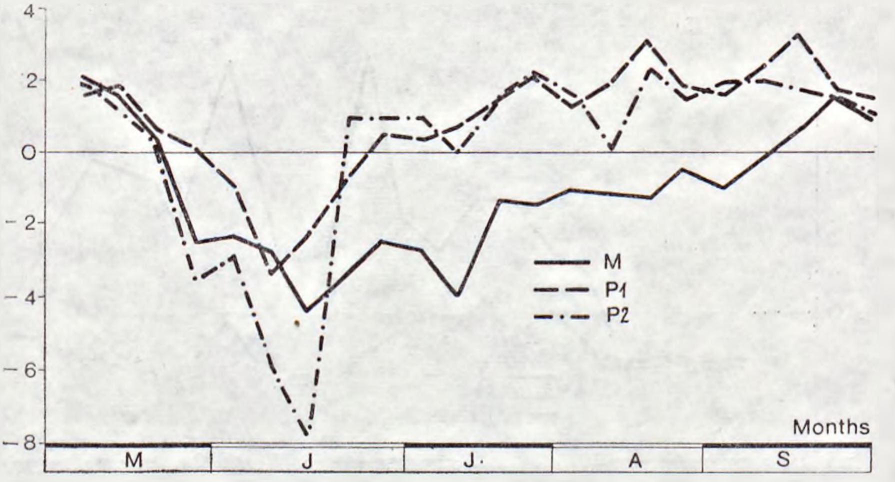


Fig. 1. $PC_1$ analysis covering 14.4% of the total quantitative variation of zooplankton in 1977. $PC_1$ included the following species: *Cyclops vicinus*, *Eudiaptomus gracilis*, *Bosmina longirostris*, *Daphnia galeata*, and nauplii (all unipolar negative components). Explanation of M, P1, and P2 in Table I

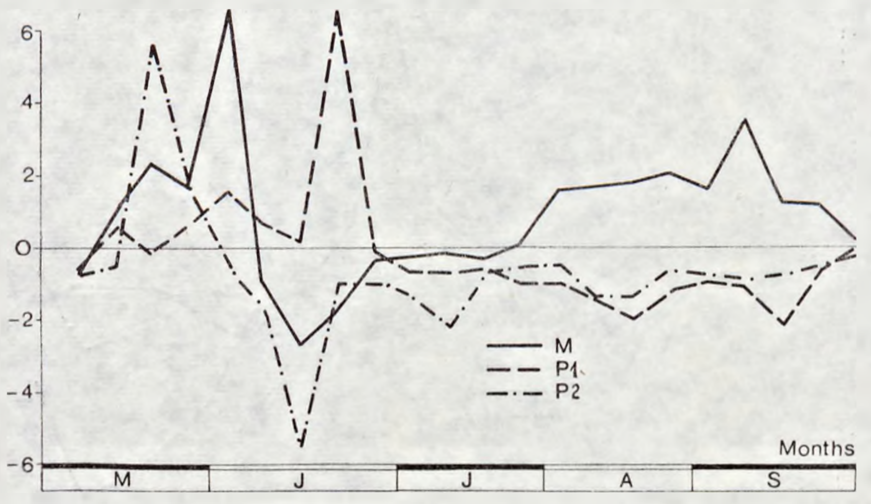


Fig. 2. $PC_2$ analysis covering 10.6% of the total quantitative variation of zooplankton in 1977. $PC_2$ included the following species: *Filina longiseta*, *Polyarthra* sp. div., *Keratella quadrata*, *K. cochlearis*, and *Brachionus angularis* (all unipolar positive components). Explanation of M, P1, and P2 in Table I

*Keratella cochlearis* Gosse, *Asplanchna* sp. Gosse, *K*, *quadrata* Müller, *Pompholyx sulcata* Hudson, and *Anuraeopsis fissa* Gosse. The dominant cladoceran was *Bosmina longirostris* Müller with *Daphnia galeata* Sars as an accompanying species in May and June,

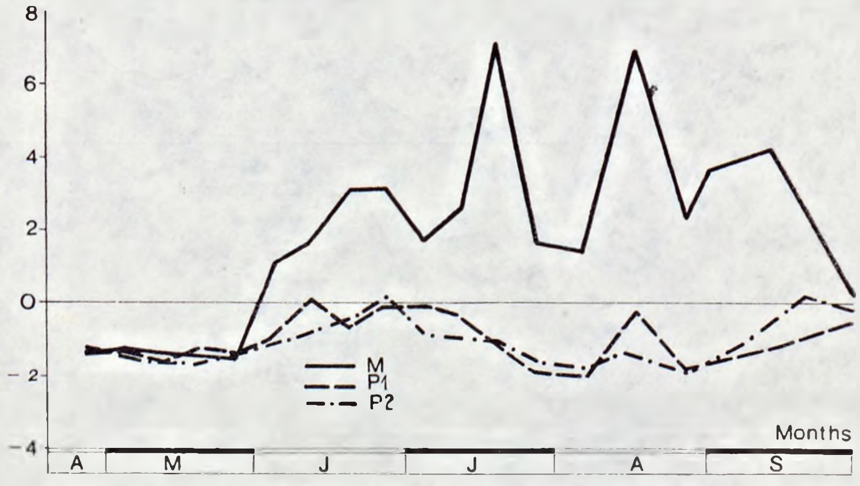


Fig. 3. $PC_1$ analysis covering 15.1% of the total quantitative variation of zooplankton in 1978. $PC_1$ included *Cyclops vicinus, Bosmina longirostris, Daphnia galeata*, nauplii, and *Pompholyx sulcata* (all unipolar positive components). Explanation of M, P1, and P2 in Table I

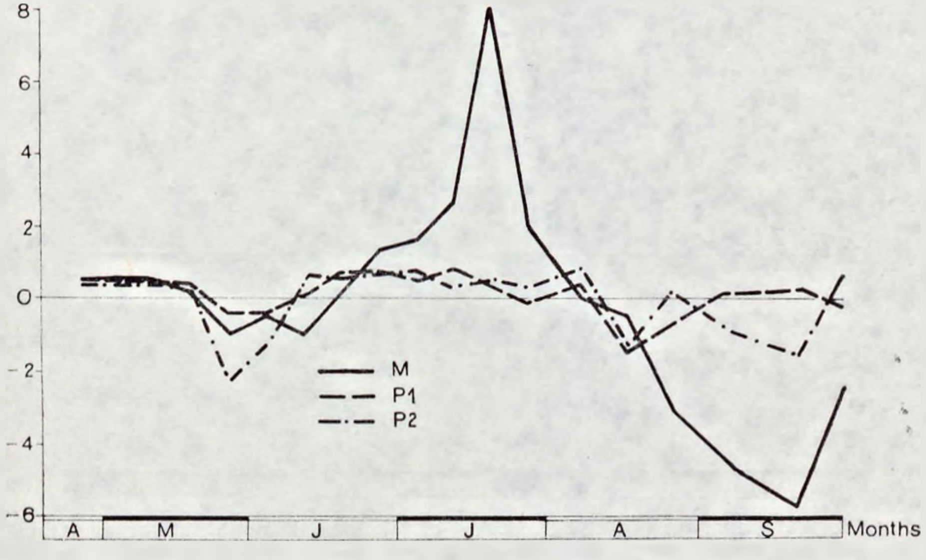


Fig. 4. $PC_2$ analysis covering 10.6% of the total quantitative variation of zooplankton in 1978. $PC_2$ included *Polyarthra vulgaris, Brachionus angularis, B. diversicornis, Keratella cochlearis*, and *Pompholyx sulcata* (all unipolar negative components). Explanation of M, P1, and P2 in Table I

and *Moina micrura* Kurtz in August. Among copepods *Cyclops vicinus* Uljanine was decisively dominant.

Factor analysis of similarity showed a strong effect of bighead carp stocking on the numbers of zooplankton. The bighead 1+ stocking brought about a great differentiation in the density of populations of species associated with $PC_1$ (axis 1), between ponds M and P1 and P2 within 6 weeks of stocking (fig. 1). On the other hand, in species associated with $PC_2$ (axis 2) a more distinct differentiation between the ponds occurred in the later part of the season (fig. 2).

Already within a month of stocking the ponds with bighead carp 2+ great differences appeared between them in the numbers of species connected with $PC_1$ (fig. 3). Also the numbers of populations of species connected with $PC_2$ varied (fig. 4), with the reservation that in pond M a decrease in the numbers of Rotatoria may have been caused by the predaciousness of *Cyclops vicinus*, whose biomass was large in this pond in July (fig. 5), being reduced to 1/10 in ponds P1 and P2. Not until towards the end of the season were the numbers of populations of species connected with $PC_2$ distinctly greater in pond M than in ponds P1 and P2.

Bighead carp stocking considerably decreased the biomass and production of zooplankton. With the stocking of bighead 1+ the smallest differences between monoculture pond M and polyculture ponds P1 and P2 were found in May and June (figs 6, 7). With the growth of bighead carp and their filtration capacity in the course of the season, zooplankton biomass and production became smaller in ponds P1 and P2 than in pond M. Already from the beginning of the season the biomass of crustaceans and of total zooplankton was smaller in ponds with bighead carp 2+ than in pond M (Table II).

In stocking ponds with bighead carp it was expected that the reduction of zooplankton would intensify the development of phytoplankton and, hence, improve the oxygen conditions. This tendency appeared but its effects were too weak, since the growth of phytoplankton was chiefly limited by the physical conditions (great turbidity and poor transmission of radiation). The impact of trophic conditions was less important, since excessive amounts of nutrients were found in the water during the entire season. In summer the content of mineral nitrogen was about 1 mg N $dm^{-3}$ and of phosphates 0.5 mg $dm^{-3}$.

The impact of bighead 1+ stocking on the zooplankton was low early in the season while in July and August, with increasing biomass and filtration capacity of the fish, the content of chlorophyll was higher in ponds P1 and P2 than in pond M (fig. 8). With bighead 2+ stocking, the content of chlorophyll in pond P2 was greater than in pond M in the period May — late July; in May and July the same situation occurred in pond P1 compared with pond M. A decrease in chlorophyll content observed towards the end of the season was brought about by increased water turbidity, to which large amounts of mineral

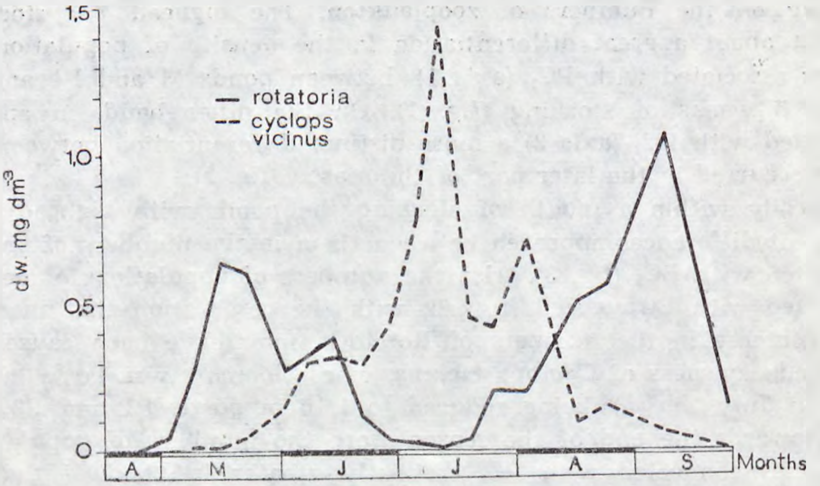


Fig. 5. Rotatoria and *Cyclops vicinus* biomass in pond M in 1978

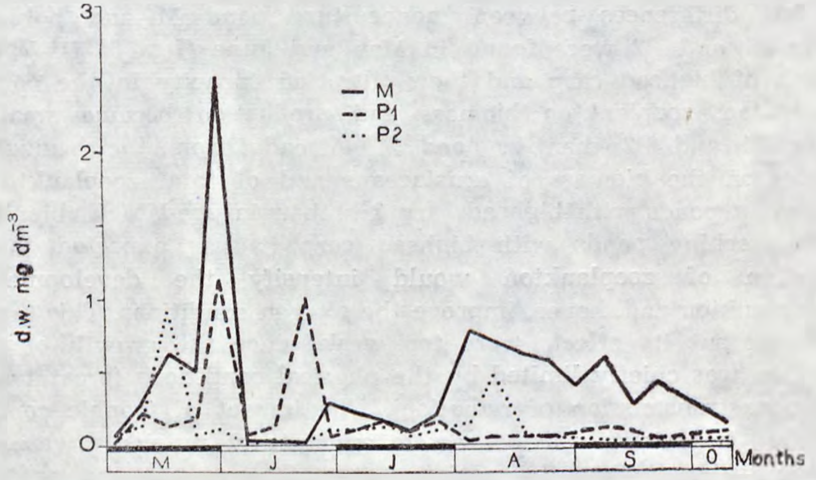


Fig. 6. Rotatoria biomass in ponds in 1977. Explanation of M, P1, and P2 in Table I

suspension, as an effect of resuspension of sediments by the fish, contributed. In both years of the investigation the turbidity of the water exceeded 300 mg $SiO_2$ $dm^{-3}$ towards the end of the season.

In both years the highest content of oxygen dissolved in the pond water was found in May and in the first half of June, and the lowest (1—2 mg $O_2$ $dm^{-3}$) in July and August. In the first year of the study the average monthly content of dissolved oxygen was lower in ponds M than in ponds P1 and P2. In ponds P2, with smaller numbers of carp,

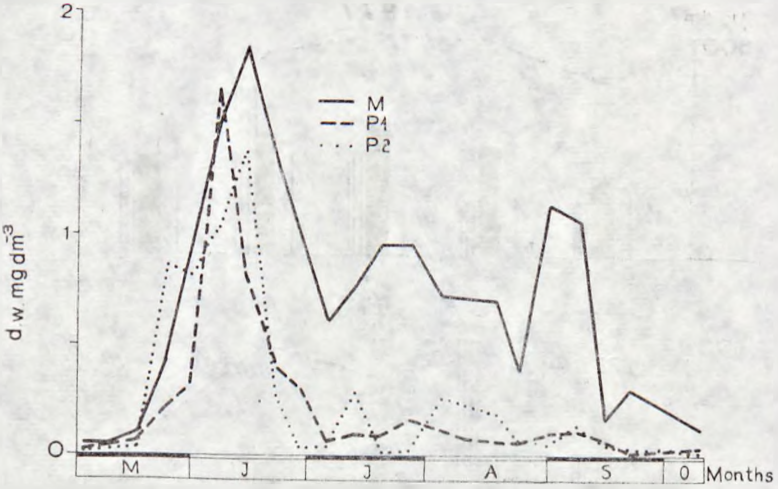


Fig. 7. Crustacea biomass in ponds in 1977. Explanation of M, P1, and P2 in Table I

the average monthly content of dissolved oxygen was higher in both years of the investigation (fig. 9).

The addition of bighead carp to ponds with carp did not to any greater degree affect the primary production of phytoplankton or plankton respiration. The primary production of phytoplankton in the ponds did not significantly differ in the two years of the study. A slightly greater production (mean for the season) appeared in pond M (Table III). Nor did the respiration of plankton significantly differ in the investigated ponds, being only slightly greater in ponds P1 and P2.

The primary production did not constitute the only source of organic carbon entering the ponds. A significant factor was their loading with

Table II. Mean monthly zooplankton biomass (B, g $m^{-2}$) and production (P, g $m^{-2}d^{-1}$) (d.w.)

| Year | Pond | May | | June | | July | | August | | September | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | P | B | P | B | P | B | P | B | P |
| 1977 | M | 0.77 | 0.25 | 2.83 | 0.99 | 1.42 | 0.51 | 1.98 | 0.47 | 1.38 | 0.29 |
| | P1 | 0.35 | 0.10 | 1.77 | 0.46 | 0.34 | 0.12 | 0.19 | 0.06 | 0.18 | 0.06 |
| | P2 | 0.80 | 0.20 | 1.18 | 0.30 | 0.27 | 0.10 | 0.45 | 0.14 | 0.10 | 0.02 |
| 1978 | M | 0.65 | 0.13 | 0.93 | 0.28 | 1.94 | 0.34 | 1.90 | 0.30 | 1.03 | 0.21 |
| | P1 | 0.41 | 0.09 | 0.34 | 0.08 | 0.32 | 0.07 | 1.07 | 0.36 | 0.31 | 0.05 |
| | P2 | 0.38 | 0.06 | 0.19 | 0.04 | 0.21 | 0.07 | 0.44 | 0.11 | 0.35 | 0.09 |

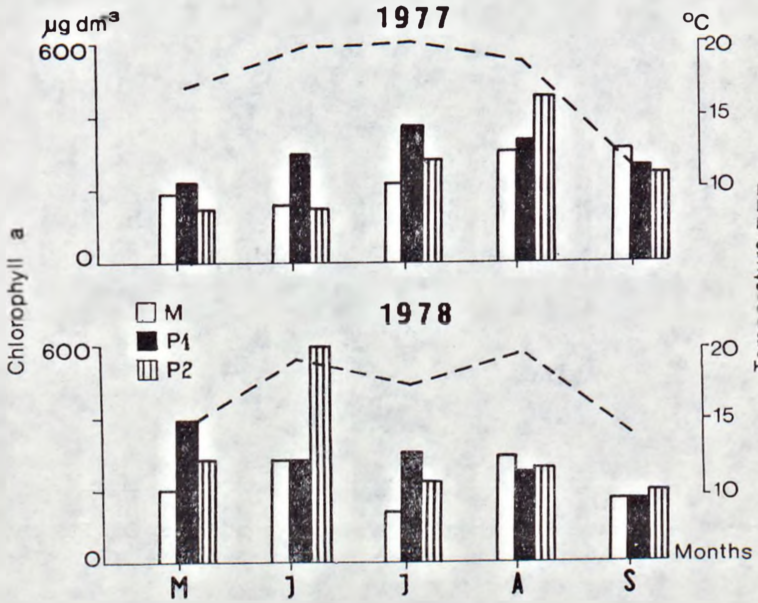


Fig. 8. Monthly averages of chlorophyll a content and of water temperature in ponds in the years 1977 and 1978. Explanation of M, P1, and P2 in Table I

organic matter contained in the supplied pellets but not assimilated by the fish. Table III shows the average monthly inflow of organic carbon, determined as allochtonous organic carbon. In the second year of the study, when the amounts of supplied pellets were increased, the loading of ponds with allochtonous organic carbon was greater than the amount of organic carbon from the primary production of phytoplankton.

The balance of organic matter showed no basic differences between the ponds (Table IV). The additional stocking of carp ponds with bighead carp decreased the carp production and in spite of the reduction of zooplankton, respiration of the total plankton was slightly greater in ponds with carp monoculture. In ponds with highly intensive fish culture supplementary feed constitute the main source of organic C. In the second year of the study the inflow of organic carobn from the feed twice exceeded the primary production of phytoplankton in these ponds. The accumulation of organic carbon in the fish in relation to the total inflow of organic compounds to the ponds was of no great importance, amounting to less than 10% of the total inflow of carbon. The respiration of the fish was of more consequence since in ponds with a large fish stock it may exceed 50% of the total plankton respiration.

With increasing amounts of feed supplied to the ponds, an even

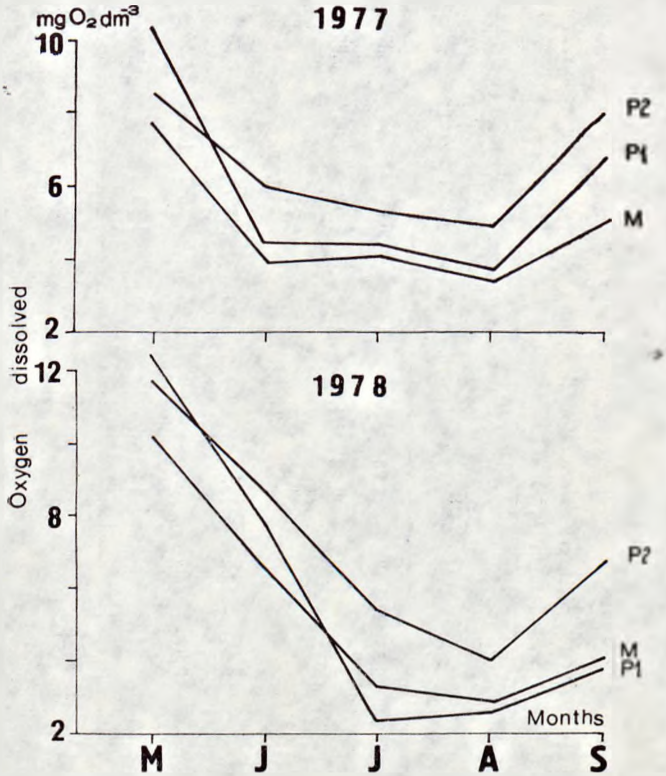


Fig. 9. Monthly averages of dissolved oxygen content in pond water in 1977 and 1978, Explanation of M, P1, and P2 in Table I

greater part of the organic carbon is accumulated in the bottom sediments. In 1978, with a much greater loading of the ponds with pellets, the sums of plankton and fish respiration were similar, while the accumulation of organic carbon in the sediments differed to a considerable degree. The above results suggest that increased intensification above all causes a greater and greater loading of bottom sediments with organic compounds, while polyculture stocking does not restrain this process. As the last trophic level, fish can only to a small degree affect the total balance of organic carbon in such ponds.

It was found that filtrator fish affect the flow of carbon through different trophic levels. The most significant changes appeared in the share of groups which took part in the total plankton respiration, which, together with the production of phytoplankton, did not greatly differ in M and P ponds (Table III). There occurred, however, a change in the share of bacteria and protozoa and of zooplankton in the total plankton respiration (Table V). As the biomass of zooplankton was reduced by

Table III. Mean monthly loading of allochtonous organic matter (AOC), primary production (Pp), and total plankton respiration (R) of the ponds (g C $m^{-2}d^{-1}$)

| Year | Pond | May | | | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AOC | Pp | R | AOC | Pp | R | AOC | Pp | R | AOC | Pp | R | AOC | Pp | R |
| 1977 | M | 0.78 | 1.61 | 0.82 | 0.94 | 1.79 | 1.00 | 2.32 | 2.35 | 1.43 | 2.20 | 2.32 | 1.29 | 0.91 | 1.04 | 0.87 |
| | P1 | 0.81 | 1.84 | 1.00 | 0.94 | 1.92 | 1.76 | 2.42 | 2.20 | 1.48 | 2.28 | 1.66 | 1.03 | 0.94 | 1.03 | 0.66 |
| | P2 | 0.75 | | | 0.86 | | | 1.98 | | | 1.81 | | | 0.74 | | |
| 988 | M | 0.44 | 1.38 | 1.15 | 1.62 | 2.10 | 2.37 | 3.37 | 2.24 | 1.52 | 3.62 | 2.89 | 1.82 | 2.23 | 1.62 | 0.95 |
| | P1 | 0.47 | 1.62 | 1.32 | 1.72 | 2.01 | 1.42 | 3.58 | 2.87 | 2.20 | 3.85 | 1.90 | 1.94 | 2.36 | 1.46 | 1.54 |
| | P2 | 0.24 | | | 0.80 | | | 1.63 | | | 1.82 | | | 1.10 | | |

Table IV. Organic carbon balance in ponds (kg C ha$^{-1}$)

| Year | Pond | Input: in pellets | Input: from primary production | Accumulation: in carp | Accumulation: in bighead | Plankton respiration | Fish respiration | Accumulation and respiration in bottom deposits |
|---|---|---|---|---|---|---|---|---|
| 1977 | M | 4090 | 2800 | 430 | 0 | 2755 | 985 | 2720 |
| | Pl | 4010 | 2680 | 280 | 113 | 3005 | 904 | 2390 |
| 1978 | M | 6640 | 3155 | 730 | 0 | 2510 | 1670 | 4885 |
| | Pl | 6640 | 3020 | 615 | 50 | 2600 | 1527 | 4872 |

Table V. Mean monthly share of phyto- (P), zoo- (Z) and bacterio- (B) plankton in total plankton respiration (%)

| Year | Pond | May | | | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P | Z | B | P | Z | B | P | Z | B | P | Z | B | P | Z | B |
| 1978 | M | 26 | 22 | 52 | 20 | 32 | 48 | 19 | 25 | 56 | 19 | 23 | 58 | 15 | 24 | 61 |
| | Pl | 24 | 8 | 68 | 14 | 20 | 66 | 16 | 5 | 79 | 16 | 3 | 81 | 21 | 7 | 72 |
| 1977 | M | 25 | 14 | 61 | 21 | 16 | 63 | 26 | 22 | 52 | 25 | 15 | 60 | 30 | 22 | 48 |
| | Pl | 23 | 7 | 70 | 24 | 5 | 71 | 24 | 4 | 72 | 19 | 21 | 60 | 28 | 6 | 66 |

the bighead carp, the share of this group in the total respiration of plankton also decreased. In ponds with polyculture the share of bacteria in the total plankton respiration distinctly increased.

## 4. Discussion

High productivity of ponds with intensive carp monoculture is based on the supply of organic matter in the form of pellets and fertilization, this frequently changing the ponds into hypertrophic ecosystems (Barica 1980). The rearing of carp in a dense stock results in the accumulation of large amounts of organic matter in the ponds. A considerable part of the accumulated matter consists of fish faeces and unconsumed food, contributing to a decrease in oxygen content and increasing bacterial destruction. A typical feature of ponds with intensive monoculture of carp is an excessive concentration of nutrients. Only part of them are accumulated in the fish, the rest being accumulated or metabolized in the pond environment. Lewkowicz (1980) reported that in the period of the most intensive feeding in ponds with dense fish stocks the amount of organic compounds contained in the feed several times exceeded that produced in the process of phytoplankton photosynthesis. In such ponds there occurs an increase in the biomass and production of small zooplankton, chiefly rotifers and *Bosmina* (Lewkowicz M., S. Lewkowicz 1981), which are not efficiently eliminated by carp. The intense respiration of plankton, in which the share of zooplankton reaches nearly 60%, unfavourably affects the oxygen conditions in water. In such ponds an improvement in the living conditions for fish may only be accomplished by removing the excess organic matter not subjected to accumulation in the fish bodies.

Phyto- and zooplanktophagous fish such as silver and bighead carp may contribute to the limitation of numbers of large and small plankton in ponds (Merla, Müller 1985, Grygierek 1987b). In lakes and dam reservoirs filtrator fish are introduced in order to prevent eutrophication by removing small particles of live and dead organic matter (Vovk, Stechenko 1985).

In lakes and reservoirs the zooplankton constitute an important factor limiting phytoplankton blooms, which may deteriorate the quality of the water. Spataru and Gophen (1985) found that the introduction of silver carp fry to Lake Kinneret in the years 1969—1981 brought about a decrease in zooplankton biomass by 22% in 1975—1981 as compared with the years 1969—1974. According to the above authors' recommendation, the stocking of this lake with silver carp should have been stopped on account of the worsening water quality caused by increasing abundance of nannoplankton, not limited by large zooplankton filtrators.

The zooplankton, as a natural biofilter, takes up enormous amounts of suspended organic matter (phyto- and bakterioplankton) from the water and in conditions of a pronounced reduction of cladocerans a bloom of phytoplankton may occur. The magnitude of zooplankton species depends on the predaciousness of the fish. With its increase the zooplankton decrease and in water bodies with large populations of planktophagous fish there occurs a decrease in the numbers of large filtering herbiphagous animals. Therefore, some authors (Koksvik, Lageland 1987) postulate that the numbers of planktophagous fish introduced to lakes and reservoirs should be maintained at a level permitting a suitable rate of propagation of large zooplankton species. Grygierek (1979) stressed the necessity of maintaining the development of large cladocerans in carp ponds throughout the season in order to assure optimum growth of carp.

According to the results reported by Vovka and Stechenko (1985), the share of zooplankton in the food of bighead carp varied from 1—69%. Bitterlich and Gnaiger (1984) showed that as the main food of bighead carp zooplankton are very rapidly digested in the alimentary tract, e.g., nauplii and rotifers are digested within 20 min. of consumption, hence the matter produced in the alimentary contents is very difficult to identify.

According to Błędzki and Szarowski (1988), the food of bighead carp chiefly consisted of organic suspension with an admixture of mineral particles, phyto- and zooplankton, and pellets. The above authors estimated the share of zooplankton as amounting to 9—48% of weight of the alimentary contents during the season.

As compared with carp monocultures, in ponds with bighead carp the numbers and biomass of all zooplankton groups were reduced. Factor analysis of the principal component showed that *Cyclops vicinus* and *Bosmina longirostris*, i.e. species of a longer life cycle or preferred body size, are eliminated by bighead carp most effectively, this already occurring in the earliest part of the season. The next group to be eliminated were Rotifers. According to Antipchuk et al. (1977), in ponds stocked with bighead carp the elimination of zooplankton and the shortened cycling of nutrients produced better conditions for the development of phytoplankton. Hence, the above authors postulate that in ponds with polyculture of filtrator fish hydrochemical conditions should be better than in those with carp monoculture. Opuszyński (1980) and Kharitonova (1984) found improved oxygen conditions in ponds with polyculture of carp and silver carp as compared with ponds with carp monoculture. Moreover, Opuszyński (1980) found a larger content of chlorophyll and a more intense primary production in ponds with silver carp.

In the investigated pond with carp mono- and polyculture no greater differences were found in the primary production of phytoplankton or the total plankton respiration. The strong elimination of zooplankton by bighead carp brought about an increase in the share of bacteria in the total respiration of plankton. Above all, the factor limiting phytoplankton photosynthesis in these ponds was the increased turbidity of the water owing to the large content of mineral-organic suspension, released from the sediments by the activity of the carp.

The accumulation of organic carbon in the biomass of bighead carp constituted 0.5—17% during the season in relation to the total loading of the pond with organic carbon from pellets and primary production. The low level of utilization of organic substance by bighead carp could not significantly contribute to the improvement of oxygen conditions. Admittedly, the average monthly oxygen content in the water of polyculture ponds was greater than in ponds with carp monoculture, but the minimum values, decisive for fish survival, were the same in all ponds.

The increased loading of ponds with supplementary feed in the second year of the investigation did not intensify the plankton respiration but increased the accumulation of organic matter in the bottom sediments. Filtratory fishes in polyculture with carp had no significant effect on the organic matter balance.

## 5. Polish summary


### Wpływ obsad tołpygą pstrą (*Aristichthys nobilis* R.) na zooplankton i niektóre parametry obiegu węgla organicznego w stawach karpiowych

W latach 1977—1978 badano wpływ obsad tołpygą pstrą na liczebność i biomasę zooplanktonu oraz bilans węgla organicznego. Badania przeprowadzono w sześciu stawach Zakładu Doświadczalnego Ichtiobiologii i Gospodarki Stawowej PAN w Gołyszu (tabela I).

Przy obsadzie tołpygą 1+ redukcję liczebności zooplanktonu stwierdzono po dwóch miesiącach od obsady. W pierwszej kolejności redukcji uległy gatunki o długim okresie rozwoju (ryc. 1), a w drugiej wrotki (ryc. 2). Przy obsadzie stawów 2+ redukcję zooplanktonu skorupiakowego stwierdzono już po kilku tygodniach od obsady (ryc. 3), natomiast wahania liczebności Rotatoria w stawie M były prawdopodobnie pod silnym wpływem drapieżnictwa *Cyclops vicinus* (ryc. wyższe niż w stawach z polikulturą (tabela II, ryc. 6, 7). W stawach z polikulturą stwierdzono nieznacznie wyższą zawartość chlorofilu i rozpuszczonego tlenu w wodzie (ryc. 8, 9).

Dodanie tołpygi pstrej do stawów z karpiem nie miało większego wpływu na produkcję pierwotną i destrukcję materii organicznej w wodzie (tabela III). Produkcja pierwotna fitoplanktonu nie stanowiła jedynego źródła dopływu węgla organicznego do stawów. Istotnym źródłem była materia organiczna zawarta w dodawanej paszy (tabela III). Dopływ węgla organicznego z paszy nie wykorzystywanej przez ryby znacznie przewyższał ilość węgla zawartego w substancji organicznej wytworzonej w trakcie fotosyntezy glonów.

Akumulacja węgla organicznego w rybach w stosunku do całkowitego jego dopływu do stawów miała niewielkie znaczenie, stanowiła poniżej 10% (tabela IV). Wzrost intensyfikacji powoduje coraz większe obciążenie osadów dennych materią organiczną, a obsady rybami filtrującymi nie wpływały na obniżenie tego procesu (tabela IV).

W miarę redukcji przez tołpygę ilości i biomasy zooplanktonu zmniejszał się udział zooplanktonu w ogólnej respiracji planktonu, zwiększał się natomiast udział bakterii (tabela V).


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