Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 9	Fasc. 2	209-218	2001

THE EFFECT OF TEMPERATURE DECREASE ON CARP *CYPRINUS CARPIO* L. CULTURE IN A TEMPERATE CLIMATE. PART II. ZOO- AND PHYTOPLANKTON DYNAMICS AND THE CHEMICAL COMPOSITION OF POND WATER

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ABSTRACT. Considerable decreases in temperature during the juvenile period of carp development directly affected the pond environment, its biotope and fish survival rates. High survival rates were observed when the temperature fell not earlier than ten days after stocking, while there was about a 25% decrease in dominating survival when it occurred earlier. The cumulative, unfavorable impact of temperature decrease on the pond biotope and fish appetite manifested itself in increased numbers of small Cladocera forms, decreased Copepoda and Rotatoria densities and an increase in the average number of phytoplankton species. When early cooling occurred, the increase of fish stock density in ponds caused an increase in small Cladocera forms due to the low fish pressure and an increase in the number of Cyanophyta and Chlorophyta in all seasons, which, in turn, was caused by the increasing productivity of the ponds. The chemical composition of the pond water was not deficient in nutritive salts. With only one exception, the fry survival rate was not threatened by the high concentration of non-ionized ammonia nitrogen.

Key word: *CYPRINUS CARPIO*, FRY SURVIVAL, WEATHER COOLING, TROPHIC CHAIN, POND ENVIRONMENT

INTRODUCTION

Environmental conditions can reduce or intensify the effect of temperature on fish survival by limiting or stimulating food resources and changing the chemical composition of water (Hrbaćek 1969). Temperature fluctuations also affect food resources directly as do fish survival and the pond environment. The rate of reproduction and growth of zooplankton organisms increase with water temperatures of up to 20°C (Hillbricht-Ilkowska and Patalas 1967, Bottrell et al. 1976). When temperatures fall below 20°C, the development of zooplankton is limited and this impacts fish survival. Chemical processes which threaten fish survival, such as concentrations of non-ionized ammonia (Vamos 1967, EIFAC 1970, Russo et al.1981, Dąbrowska and Sikora 1986, Svobodova 1992), also depend on temperature. However, in this case, lower temperatures play a positive role by lowering the ammonia concentration.

The goal of the study was to evaluate the cumulative impact of considerable temperature decreases from above 20°C and fish survival in the first five to six weeks after pond stocking on the density of zooplankton, phytoplankton and chemical changes in pond water.

METHODS

The site and methods of water temperature monitoring and the method used to determine the time of fish mortality are presented in part I of this paper (Szumiec and Pilarczyk 2001). All the ponds dried up in winter.

The zooplankton studies were conducted in the 1986-1990 seasons and those of phytoplankton in 1981-1985. The samples of zoo- and phytoplankton were collected weekly and classified using previously developed methods (Starmach 1955, Jakubas 1996, Urbaniec-Brózda 1996). The dependence of the plankton on thermal conditions was calculated based on the average number of organisms and on values obtained from individual samples. The number of Cladocera, Copepoda, Rotatoria, and naupli were determined in 24 ponds which had been fertilized with mineral nitrogen-phosphorus fertilizer and fresh cow manure. The number of Bacillariophyceae, Cryptophyceae, Cyanophyta, and Chlorophyta were determined only in ponds which had been fertilized with mineral nitrogen-phosphorus fertilizer.

Standard methods were applied to analyze the chemical composition of the water on a weekly basis from 1981 to 1990. The concentration of non-ionized ammonia nitrogen NH_3-N (Vamos 1967, EIFAC 1970, Russo et al.1981, Dąbrowska and Sikora 1986, Svobodova 1992) was calculated as the portion of total ammonia (TAN = NH_4^+-N + NH_3-N) in pond water based on temperature and hydrogen ion concentration (Krüger and Niewiadomska-Krüger 1990, Svobodova 1992).

RESULTS

TEMPERATURE AND FISH SURVIVAL

Favorable seasons occurred in 1982, 1983, 1986 and 1988, while 1981, 1984, 1985, 1987 and 1990 were unfavorable. The results from the nine-year study period showed the quasi-symmetrical smoothed distribution of the density in the survival rate of hybrid progeny (W × 3) under average and favorable thermal conditions. Thus, the

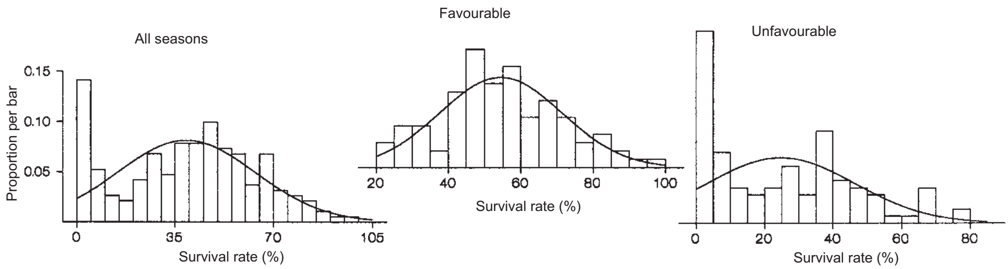

Fig. 1. Density histograms of larval survival rate and the smoothed survival distributions under differentiated thermal conditions.

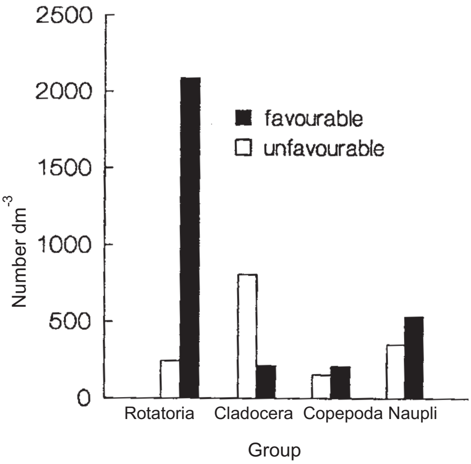

Fig. 2. Average density of Rotatoria, Cladocera, Copepoda and naupli during the first weeks of favorable and unfavorable thermal conditions.

highest and the average survival rate frequency had similar values of about 40% under average conditions and approximately 55% under favorable ones. Under unfavorable conditions, the dominating frequency was reduced to about 30%, but the average survival rate was slightly higher because of the positive asymmetry of the density distribution (Fig. 1).

PLANKTON

During long warm periods, the average number of Rotatoria greatly exceeded that during periods when there was early cooling; Copepoda and naupli were only slightly more numerous. When conditions were unfavorable only Cladocera, represented chiefly by *Bosmina longirostis*, occurred more abundantly (Fig. 2). The number

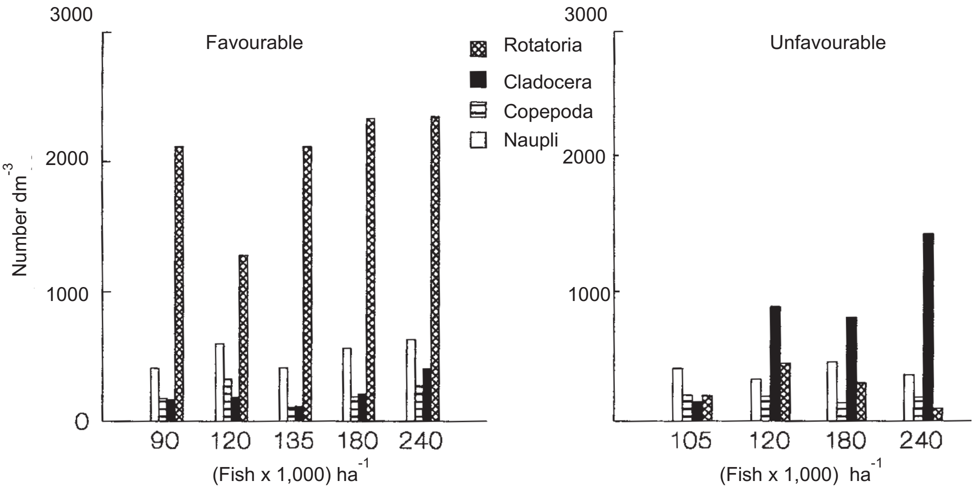

Fig. 3. Average density of the studied zooplankton species vs. fish stock density.

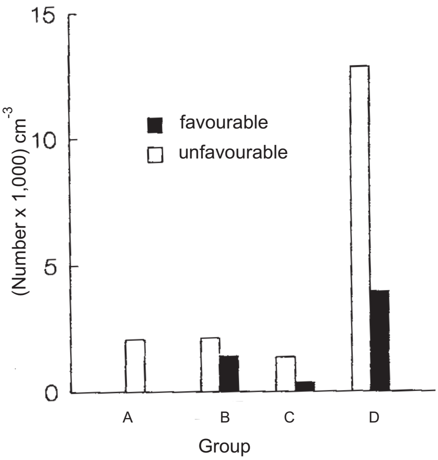

Fig. 4. Average density of Cyanophyta (A), Cryptophyceae (B), Bacillariophyceae (C) and Chlorophyta (D) during the first weeks of favorable and unfavorable seasons.

of Cladocera increased with greater fish stock densities (Fig. 3); however, as the fish survival rate rose, a decrease was observed in the average number of Cladocera, Copepoda and Rotatoria ($r = 0.421$, $P = 0.082$).

The average number of the phytoplankton was smaller in the favorable period than in the unfavorable one (Fig. 4). The increasing number of Cyanophyta, Cryptophyceae, and Bacillariophyceae, especially Chlorophyta, accompanied

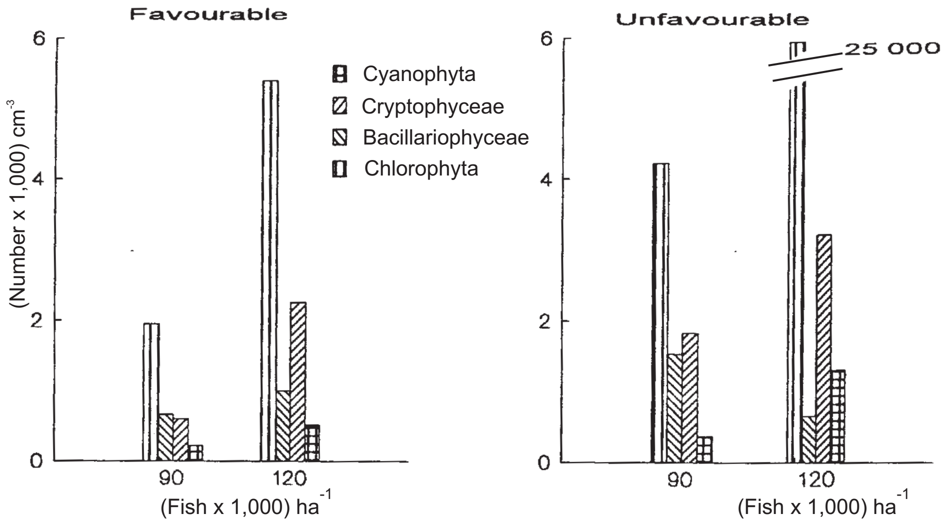

Fig. 5. Average density of Cyanophyta, Cryptophyceae, Bacillariophyceae and Chlorophyta in ponds fertilized with NP vs. fish stock density.

TABLE 1

Concentration of ammonia nitrogen corresponding to un-ionized ammonia NH_3-N, lethal for carp (LC_{50}), according to Dąbrowska (1986)* and Svobodova (1992)** calculated against pH and temperature

NH_3-N (mg dm^{-3})	TAN (mg dm^{-3})	pH	Temperature (°C)
0.89-1.96*	4.35 - 9.58	9	15
	1.23 - 2.72	10	
	3.25 - 7.17	9	20
	1.12 - 2.48	10	
1.0-1.50**	4.88 - 7.33	9	15
	1.38 - 2.08	10	
	3.66 - 5.49	9	20
	1.26 - 1.89	10	

increased fish stock density in the ponds. Only the number of Bacillariophyceae decreased with fish density under unfavorable thermal conditions (Fig. 5).

CHEMICAL FACTORS

The dissolved oxygen content in the water did not fall below the level which limits fingerling survival, and nutritive salts did not limit the development of plankton.

As a result of a high pH level and the greater concentration of total ammonia nitrogen, non-ionized ammonia reached very high concentrations early in 1987, and lethal values of NH_3-N induced 50% fish mortality in some ponds (LC_{50}, Table 1). However, the fall in temperature at this time had a positive effect as it limited photosynthetic processes and decreased the pH. Due to this, only in the 1987 season was NH_3-N at lethal levels (Fig. 6). No dependence between NH_3-N, pH and TAN concentration and the number of warm days after pond stocking was found.

DISCUSSION

Carp farmers in temperate climates are well-acquainted with the disadvantageous effect deep cooling has on the survival of juvenile carp. It is difficult to quantify its influence due to the complex factors which affect fish in ponds. The results presented in this paper indicate that a considerable decrease in water temperature from above 20°C in the first ten days after stocking lowered the dominating survival rate of

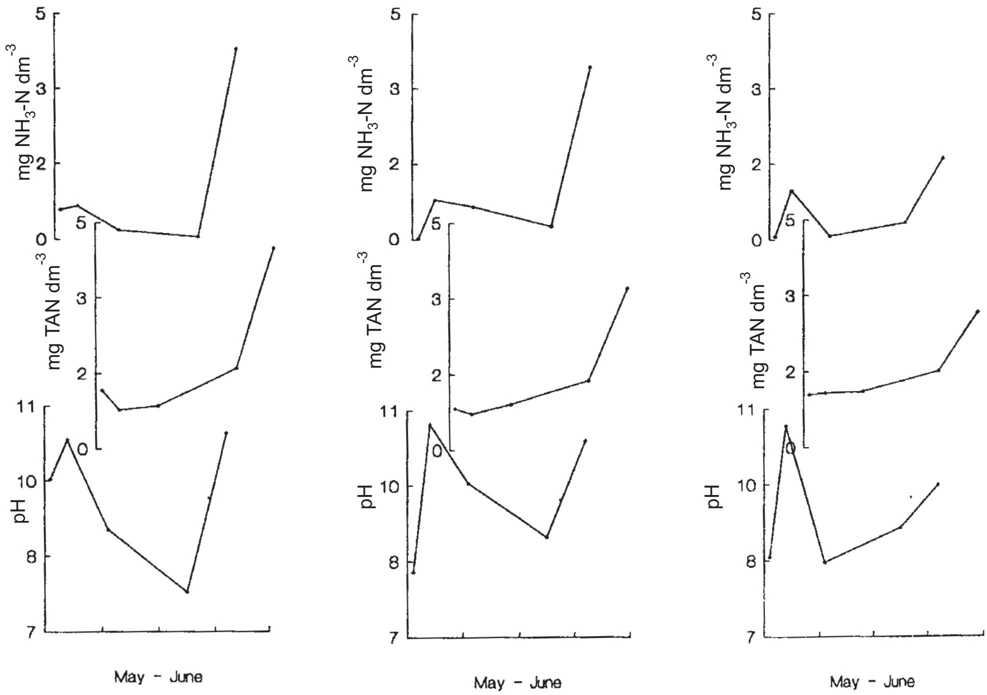

Fig. 6. Lethal concentrations of non-ionized NH_3-N found in the water of three ponds at the beginning of the 1987 season.

W × 3 hybrid progeny by approximately 25%. If the fall in temperature does not occur for a period of weeks following pond stocking, then survival rates rise to 55%.

During the first three weeks of life, zooplankton, first rotifers and then crustaceans, is the main food of carp. In later weeks, Chironomidae larvae dominate the food spectrum of carp (Grygierek 1962, Ciborowska 1970). The reproduction rate and growth of zooplankton organisms increase with water temperature up to about 20°C (Hillbricht-Ilkowska and Patalas 1967, Bottrell et al. 1976). Thus, it may be conjectured that with favorable thermal conditions food did not limit fish survival. The low numbers of Cladocera which occurred under favorable conditions resulted from the intensive feeding of the developing fish; their high number under unfavorable conditions resulted from the weak appetites and decreasing numbers of fish. Since the fish consumed rotifers only during the first days after stocking, their number was high during five to six weeks of favorable conditions. The absence of Rotatoria in most ponds during the unfavorable thermal conditions in 1987 might have been an additional reason for the high larval mortality.

Increasing fish density did not have an effect on the decrease of the zooplankton numbers under favorable conditions; this might have resulted from the preference of the fish for protein pellets, the dose of which was raised 10 to 40% as stock density increased. The greater number of Cladocera which occurred under unfavorable thermal patterns were the result of less feeding pressure from the generally smaller fish population and their decreased appetite. The increased number of Cladocera at greater fish densities was brought about by both the increasing productivity of the ponds and the more pronounced dominance of smaller forms, chiefly *Bosmina longirostis* (Hrbaćek et al. 1961, Grygierek 1962, Szumiec 1966, Schlott-Idl 1990).

Phytoplankton reproduction supplied a sufficient food base for the zooplankton under both favorable and unfavorable thermal patterns. However, when conditions were favorable, their numerous occurrence met the intensive feeding of zooplankton which had faster metabolic and growth rates (Kawecka and Eloranta 1994). If unfavorable conditions had lasted for a longer period, phytoplankton development might have been affected since most species studied preferred temperatures above 20°C (Patrick 1969, Wilde and Tilly 1981), although, in this case an abundant number of phytoplankton developed before the temperature fell (Urbaniec-Brózda 1994, 1996). The lower zooplankton filtration during cooling caused the phytoplankton density to exceed that found under favorable conditions. A number of authors (Straškraba 1966, Straškraba and Javornicky 1973, Żurek et al. 1991) have also shown that the number and/or biomass of the phytoplankton are inversely proportional to the number of zooplankton. They also indicated that the number of the phytoplankton, particularly Cyanophyta and Chlorophyta, increased with the productivity of the reservoirs.

The concentration of oxygen in water did not fall below the values that would limit the survival rate of juveniles (approximately 3.5 mg dm^{-3}). In 1987, however, a decrease in the resistance to diseases and parasite invasion might have occurred because of the reduced oxygen saturation caused by the fall in water temperature (Reinbach-Klinke 1980).

The pronounced consumption of carbon dioxide by intensive phytoplankton photosynthesis in spring was accompanied by an increase in water pH and high concentrations of total ammonia nitrogen. The resulting increase in the concentration of the non-ionized form of ammonia was probably the supplementary cause of very low larval survival in 1987. However, the low temperature in the first days following stocking improved conditions since the occurrence of toxic NH_3-N concentrations at lower temperatures requires a higher TAN content in the water. The results of laboratory experiments by Krüger and Niewiadomska-Krüger (1990) show that NH_3-N can be lethal for fish at concentrations as low as 0.5-1.0 mg dm^{-3}. The lethal values, however, depend on a number of environmental factors such as dissolved oxygen (Vamos 1967, Epler 1971, Svobodova 1992) and pH. The occurrence of univalent Cl^-, HCO_3^- and NO_3^- ions also increases the lethal effects of NH_3-N (Russo et al. 1981).

CONCLUSIONS

Sudden falls in temperature were manifested by an approximate 25% decrease in the dominating survival of carp juveniles. Unfavorable thermal conditions caused an increase in the number of small Cladocera forms, a decrease in Rotatoria and Copepoda, and an increase of the average number of phytoplankton, especially of Chlorophyta. The results suggest that an abundant number of rotifers at the beginning of pond stocking appeared under favorable thermal conditions.

The increase of small Cladocera forms along with increasing fish stock density in the ponds under unfavorable thermal conditions was the result of lower fish pressure. The increase in the number of Cyanophyta and Chlorophyta along with increasing fish density in both favorable and unfavorable seasons were caused by the increasing productivity of the ponds.

REFERENCES

Bottrell H. H., Duncan Z., Gliwicz Z. M., Grygierek E., Herzig A., Hillbricht-Ilkowska A., Kurasawa H., Larsson P., Węgleńska T. 1976 – A review of some problems in zooplankton production studies - Norw. J. Zool. 24: 419-456.

Ciborowska J. 1970 - The effect of nursery pond depth on the food composition of common carp hatch - Rocz. Nauk Rol. 92, H 4: 7-16 (in Polish).

Dąbrowska H., Sikora H. 1986 - Acute toxicity of ammonia to common carp – Pol. Arch. Hydrobiol. 33: 121-128.

EIFAC 1970 - Water quality criteria for European freshwater fish. Report on ammonia and inland fisheries - EIFAC Tech. Pap.: 11 -12 .

Epler P. 1971 – The impact of polluted water on its ichthyofauna. II. Toxicity of ammonia, phenols and cyanides - Post. Nauk Rol. 4: 67-90 (in Polish).

Grygierek E. 1962 - Influence of a growing carp fry population on crustacean plankton - Rocz. Nauk Rol. 81 B-2: 189-210 (in Polish).

Hillbricht-Ilkowska A., Patalas K. 1967 - Methods of production and biomass estimation and some problems of quantitative calculation methods of zooplankton - Ekol. Pol. B, 13 (2): 139-172.

Hrbaćek J. 1969 - Relations between some environmental parameters and the fish yield as a basis for a predictive model - Verh. Internat. Verein. Limnol. 17: 1069-1081.

Hrbaćek J. Dvořakova M., Kořinek V., Prochazkova L. 1961 - Demonstration of the effect of the fish stock on the species composition of zooplankton and the intensity of metabolism of the whole plankton association - Verh. Internat. Verein. Limnol. 14: 192-195.

Jakubas M. 1996 - Effects of diversified pond carp culture. V. Comparison of development of zooplankton and bottom fauna in ponds with different carp production - Acta Hydrobiol. 37 (1): 157-163.

Kawecka B., Eloranta P.V. 1994 - Outline of the ecology of freshwater algae and land ecosystems - PWN, Warszawa, 251 pp. (in Polish).

Krüger A., Niewiadomska-Krüger D. 1990 - Permissible concentrations of mineral nitrogen compounds in waters for Cyprinidae culture - Instytut Rybactwa Śródlądowego Olsztyn No. 149, 16 pp. (in Polish).

Patrick R. 1969 - Some effects of temperature on freshwater algae. In: Biological aspects of thermal pollution (Eds.) B.A. Krenkel and F.L. Parker, Vanderbildt Univ. Press, Nashville. Tenn.: 161-185.

Reinbach-Klinke H.H. 1980 - Temperatur und Fischkrankheit. In: Neue Erkenntnisse auf dem Gebiet der Aquakultur. Arbeiten d. Deutscher Fisch. Verb. E. V. 16: 180-187.

Russo R.C., Thurston R.V., Vinogradov G.A. 1981 - Acute toxicity of nitrite to rainbow trout: effects of pH, nitrite species and anion species - Can. J. Fish. Aquat. Sci. 38: 387-393.

Schlott-Idl K. 1990 - Qantitative Aspekte der Zooplanktonentwicklung in Waldviertler Fischteichen - Wiss. Mitt. Niederösterr. Landesmuseum 7: 407-414.

Starmach K. 1955 - Methods of plankton investigations - Kraków, PWN, 136 pp. (in Polish).

Straškraba M. 1966 - Interrelations between zooplankton and phytoplankton in the reservoirs Slapy and Klicava - Verh. Internat. Verein. Limnol. 16: 719-726.

Straškraba M., Javornicky P. 1973 - Limnology of two re-regulation reservoirs in Czechoslovakia - Hydrobiol. Studies 2: 249-316.

Svobodova Z. 1992 - Etiologie otrav ryb. In: Havarijni a dlouhodobe znečisteni povrchovych vod. VURH, Vodnany: 88-112.

Szumiec J. 1966 - Participation of food in carp feeding - Acta Hydrobiol. 8 (1): 199-253.

Szumiec M. A., Pilarczyk A. 2001– Effect of the temperature decrease on carp, *Cyprinus carpio* L. culture in the temperate climate. Part I. Survival of carp juvenile in ponds and inflammation of swim bladder frequency – Arch. Pol. Fish. 9: 87-96.

Urbaniec-Brózda W. 1994 - Improvement of carp fingerling culture. Phytoplankton in ponds with differentiated stock - Acta Hydrobiol. 36 (2): 179-189.

Urbaniec-Brózda W. 1996 - Effect of diversified pond carp culture. 4. Number and composition of phytoplankton in ponds with different carp production - Acta Hydrobiol. 37 (1): 151-156.

Vamos R. 1967 - Ammonia poisoning in carp. The oxygen content as a factor influencing the toxic limit of ammonia - Acta Biol. 13: 99-105.

Wilde E.W., Tilly L.I. 1981 - Structural characteristics of algal communities in thermally altered artificial streams - Hydrobiologia 76: 57-63.

Żurek R., Lewkowicz S., Ronchetti R., Augustyn D. 1991 - The relationships between zooplankton and biotic/abiotic factors - Acta Hydrobiol. 33 (3/4): 209-228.

STRESZCZENIE

WPŁYW SPADKÓW TEMPERATURY WODY NA EFEKTYWNOŚĆ CHOWU KARPIA *CYPRINUS CARPIO* L. W KLIMACIE UMIARKOWANYM. II. DYNAMIKA ZOO- I FITOPLANKTONU ORAZ SKŁAD CHEMICZNY WODY

Celem badań była ocena łącznego wpływu znacznego spadku temperatury wody i spadku przeżywalności wylęgu krzyżówki W × 3 (część I) na liczebność zoo- i fitoplanktonu i na skład chemiczny wody. Badania zooplanktonu prowadzono w latach 1986-1990, fitoplanktonu w 1981-1985, składu chemicznego wody w 1981-1990. Materiał nie obejmuje sezonu hodowlanego 1989. Próby pobierano co tydzień.

W niekorzystnych warunkach cieplnych, kiedy spadek temperatury następował przed 10 dniem po obsadzie wylęgu, przeżywalność wylęgu wynosiła jedynie około 30%, podczas gdy w korzystnych warunkach, kiedy spadek temperatury następował co najmniej kilkanaście dni po obsadzie wynosiła około 55% (rys. 1). W wyniku mniejszego apetytu ryb w niekorzystnych warunkach wyraźnie większa była jedynie liczebność Cladocera (rys. 2), natomiast wskutek mniejszej liczebności pozostałych grup zooplanktonu wzrastała liczebność fitoplanktonu (rys. 4). Wzrost zagęszczenia obsad ryb wpływał na wzrost liczebności małych form Cladocera tylko w niekorzystnych warunkach cieplnych (rys. 3), natomiast powodował wzrost liczebności większości badanych grup fitoplanktonu, głównie Chlorophyta, zarówno w korzystnych, jak i niekorzystnych warunkach (rys. 5). Był to oczywisty wpływ większej żyzności stawów z zagęszczonymi obsadami ryb.

Ilość tlenu rozpuszczonego w wodzie nie limitowała przeżywalności wylęgu, natomiast wysoka koncentracja niezjonizowanego amoniaku stwierdzona w 3 stawach (rys. 6) mogła przyczynić się do wysokiej śmiertelności ryb w sezonie 1987.

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