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QUALITY OF WATERS DISCHARGED FROM FISHPONDS DURING THE FALL CARP (*CYPRINUS CARPIO* L.) HARVEST

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ABSTRACT. The work presented contributes to the quality assessment of fishpond waters discharged into a river during the fall carp, *Cyprinus carpio* L., harvest, of waters discharged before and after fishing, and of riverine waters that feed the ponds. The subject of the study was a complex of ponds with semi-intensive carp production situated in the upper catchment of the Vistula River (southern Poland). While the water reaction or pH, the concentration of dissolved oxygen, and the biochemical (BOD_5) and chemical oxygen demand (COD_{Mn}) in the pond effluents exceeded the respective concentrations in the river waters, they did not exceed permissible levels of contamination for surface river waters. The only exception was the concentration of total suspended matter, which also exceeded these limits in river waters. The value of BOD_5, COD_{Mn}, COD_{Cr}, and suspended matter in the pond water increased towards the end of the fish harvest when the bottom water layers, equal to about 10% of the entire pond volume, were discharged. During the fish harvest the average diurnal pond loads exceeded more than once the loads before and after the harvest and more than twice the loads in riverine waters. The pond loads decreased decidedly after cold, cloudy weather in July and August. The share of the net pond load (pond load minus river load) in that of the river ranged from several to a few dozen percent. In very warm, dry seasons the share of the pond load increased exceptionally to over 100% due to low water flow in rivers. However, in very wet, cold seasons the share of this decreased to just a few percent due to high water levels. An exception to this was the extreme cold of November 1998 when the share of pond BOD_5 increased considerably. After the fish harvest the concentration and loads of the investigated parameters of pond and riverine waters declined distinctly and were approximate to each other; an additional decrease was observed after cold weather in October.

Key words: POND WATER QUALITY, CHEMICAL COMPONENT CONCENTRATION, LOAD

INTRODUCTION

One of the important unproductive functions of fishponds in a catchment basin is the equalization of river flow through the intake of river waters during the period of rising waters in spring and their discharge into rivers during the fall pond fish harvest (Drabiński et al. 1994). This is particularly important in sub-mountainous regions where water flow in rivers is determined by rainfall and where the annual precipitation

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minimum occurs in the fall (Augustyn 2002, Szumiec and Augustyn 2002). Due to the important role of pond waters in the flow of rivers during the fall fish harvest, their quality is of great significance for rivers. On the other hand, the quality of river waters feeding the ponds is highly significant to fish farming, and the load of the waters discharged from the ponds also depends on their quality.

The composition of river waters is an individual feature of a catchment area which depends on, among others parameters, its geological and soil structures, the vegetation cover, and the efficiency of river output, which also increases after intense precipitation (Starmach et al. 1976, Augustyn et al. 1994, Chełmicki 1997). However, the quality of river waters is chiefly affected by the degree and quality of river catchment management. While the intensification of fish farming contributes significantly to the load of pond waters, the aeration of water, polyculture, and feeding fish with high quality fodder can balance significantly the results of intensified rearing (Guziur 1991, Milstein 1993, Szumiec 2002). Investigations in German carp, *Cyprinus carpio* L., ponds have shown that ponds have a high phosphorus retention capacity of 5.71 kg P ha^{-1} $year^{-1}$ (Knősche et al. 2001). The waters discharged from ponds during fall fish harvests contain chiefly organic suspended matter since biogenic salts are utilized by water plants (Starmach et al. 1976, Kosturkiewicz et al. 1992, 1993, Lewkowicz 1996). The load of effluents from ponds increases with the discharge of deeper water layers (Jezierska-Madziar 1995, Kwei Lin et al. 2001, Kolasa-Jaminska 2002a, 2002b).

The current work is an attempt to demonstrate the relationships between the loads of pond waters and the river waters feeding the ponds based on the example of a pond complex in the Upper Vistula drainage basin. It was also attempted to assess their dependence on changes in weather during the rearing season from May to September and in the fall.

MATERIAL AND METHODS

STUDY AREA

The subject of the study was a complex of fishponds at the Experimental Pond Fish Station and the Institute of Ichthyobiology and Aquaculture of the Polish Academy of Sciences in Golysz (PAS). This facility is situated on the right side of the upper catchment of the Vistula River above the Goczałkowice Reservoir (southern Poland; Fig. 1).

The area of the pond complex is 370 ha, and the water volume is 4574000 m^3. The areas of the individual ponds range from a few to several hectares, and most ponds are stocked with two-year carp caught in fall. Ponds comprising about 25% of the area are stocked with hatch that are caught after two years. Semi-intensive carp culture is conducted in commercial ponds. The complex also includes 24 experimental ponds of 1500 m^2 each, which, in most cases, are used for intensive fish culture experiments. The bottoms of the ponds are usually composed of heavy and medium density clays that are impervious to water (Pasternak 1962). The ponds are fed with waters of the Vistula and Bajerka rivers from the water intake below the treatment plant. Pond water

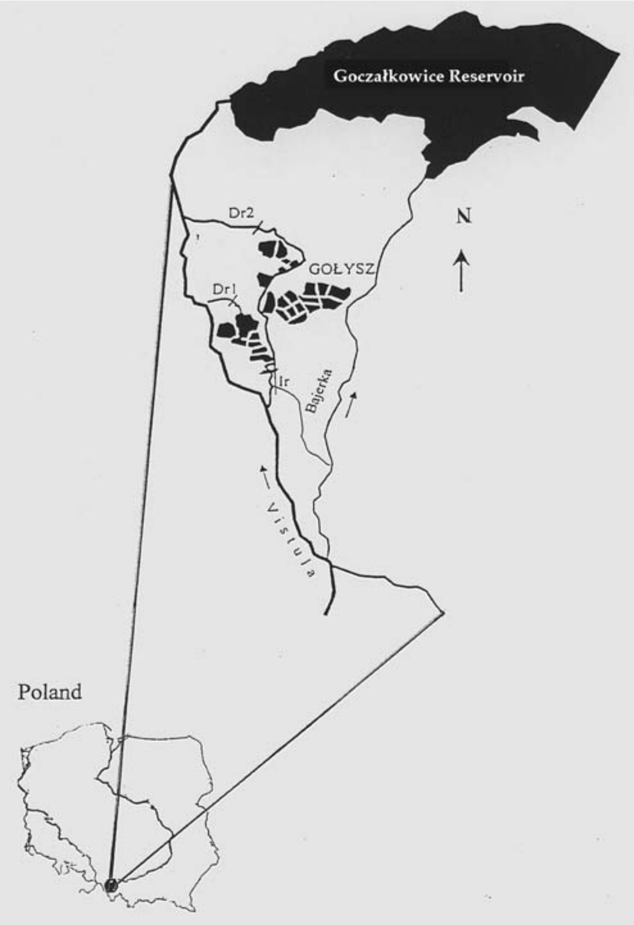

Fig. 1. Map illustrating the ponds of the Institute of Ichthyobiology and Aquaculture of the Polish Academy of Sciences (for details see Material and methods).

is discharged mainly into the Vistula River above the Goczałkowice Reservoir through a surface system of two outlets – Dr_1 and Dr_2, (the latter outlet drains waters from a greater number of ponds; Fig. 1).

METHODS

The chemical parameters of the waters that feed the ponds and are drained into the river were assessed based on determining the concentrations of hydrogen ions (pH), dissolved oxygen (mg O_2 dm^{-3}), the biochemical oxygen demand (BOD_5; mg O_2 dm^{-3}), the chemical oxygen demand using the permanganate (COD_{Mn}; mg O_2 dm^{-3}) and dichromate (COD_{Cr}; mg O_2 dm^{-3}) methods, and total suspended matter (mg dm^{-3}). Standard methods (Hermanowicz et al. 1976) were used in the assessment; a WTW oxygen meter (Wisseschaftlich-Technische Werkstätten GmbH, Weilheim, Germany) was used for oxygen determinations. Water for analyses was sampled at the beginning and towards the end of the fishing season; in 1996 measurements were conducted only towards the end of the fish harvest. For the comparison of pond water quality during the catches with that after the fishing season, water samples were collected in November and in 1995 only before the catches in September.

The loads of BOD_5, COD_{Mn}, COD_{Cr}, and suspended matter were calculated as the product of the concentration and volume of the investigated waters. The volume of the waters was calculated on the basis of results of water level monitoring in the Ir inflow canal, using a float gauge and a staff gauge, fixed at the point of water inflow from both rivers. Volume in the Dr drainage canals was calculated using staff gauges deployed several dozen meters behind the water discharge from the last pond (Fig. 1). The rate of water flow was measured repeatedly throughout the year with a hydrometric current meter. The volume of waters fed to the ponds and discharged to the catchment basin during fish catches was calculated using standard methods developed by the Institute of Meteorology and Water Management (Warsaw, Poland), and the degree of vegetation cover in canal beds was also taken into consideration (Dębski 1970). The net loads were computed as the difference between the loads of waters drained and fed the ponds. The investigation was conducted from October 1995 to November 1999. Data concerning the volume of waters and temperatures in the Vistula River in the Skoczów cross-section were obtained from the Katowice Branch of the Institute of Meteorology and Water Management (Poland). The evaluation of the impact of the weather on the ponds and river was conducted based on data obtained from the meteorological station of the Institute of Ichthyobiology and Aquaculture of the PAS. Water temperature (± 0.1°C) was measured in a pond of 4 ha in area and 1.5 m in depth.

RESULTS AND DISCUSSION

Changes in pH, O_2, BOD_5, COD_{Mn}, COD_{Cr}, and suspended matter concentration in waters drained from the ponds to the river during the fish harvest were within the range of permissible pollution limits for inland surface waters (Chełmicki 1997) or within ranges that are favorable for fish (Starmach et al. 1976). However, the chemical oxygen demand in waters discharged from the ponds during the fish harvest (Fig. 2) exceeded by nearly two-fold that of the waters feeding the ponds (Fig. 3). The concentration of suspended matter exceeded considerably the range of permissible pollution; however in waters feeding the ponds it was also higher than this level (Fig. 2). The highest concentrations of the investigated components were usually noted in the last phase of the fish harvest (Fig. 2, second column), when the 10-15 cm bottom water layer, which represented about 10% of the whole water volume, was discharged from the ponds (Kolasa-Jamińska 2002b). The discharge of waters from various depths of particular ponds contributed to considerable differences in the temporary loading of waters in the Dr_1 and Dr_2 outlet canals; in most cases a greater load was recorded in canal Dr_2 which carried waters from a greater pond area (Fig. 1).

In 1995, following the warmest, sunniest July and August of the study period, high concentrations of BOD_5, COD_{Mn}, COD_{Cr}, and suspended matter were noted in waters discharged from the ponds. However, after the cool, cloudy months of the 1996-1998 period, the concentrations of oxygen, COD_{Cr}, and partly of BOD_5 and COD_{Mn} were low in both the ponds and the river (Fig. 2).

The range of changes in BOD_5 of waters discharged from the Gołysz ponds during the fish harvest were approximate to the range of annual changes of BOD_5 in ponds in Wielkopolska (western Poland); however, the latter are characterized by much more abundant water flow as shown by short retention periods ranging from 20 to 65 days (Kosturkiewicz et al. 1989, 1992). In the Gołysz ponds this period is 110 days (Szumiec and Augustyn 2000, unpublished data).

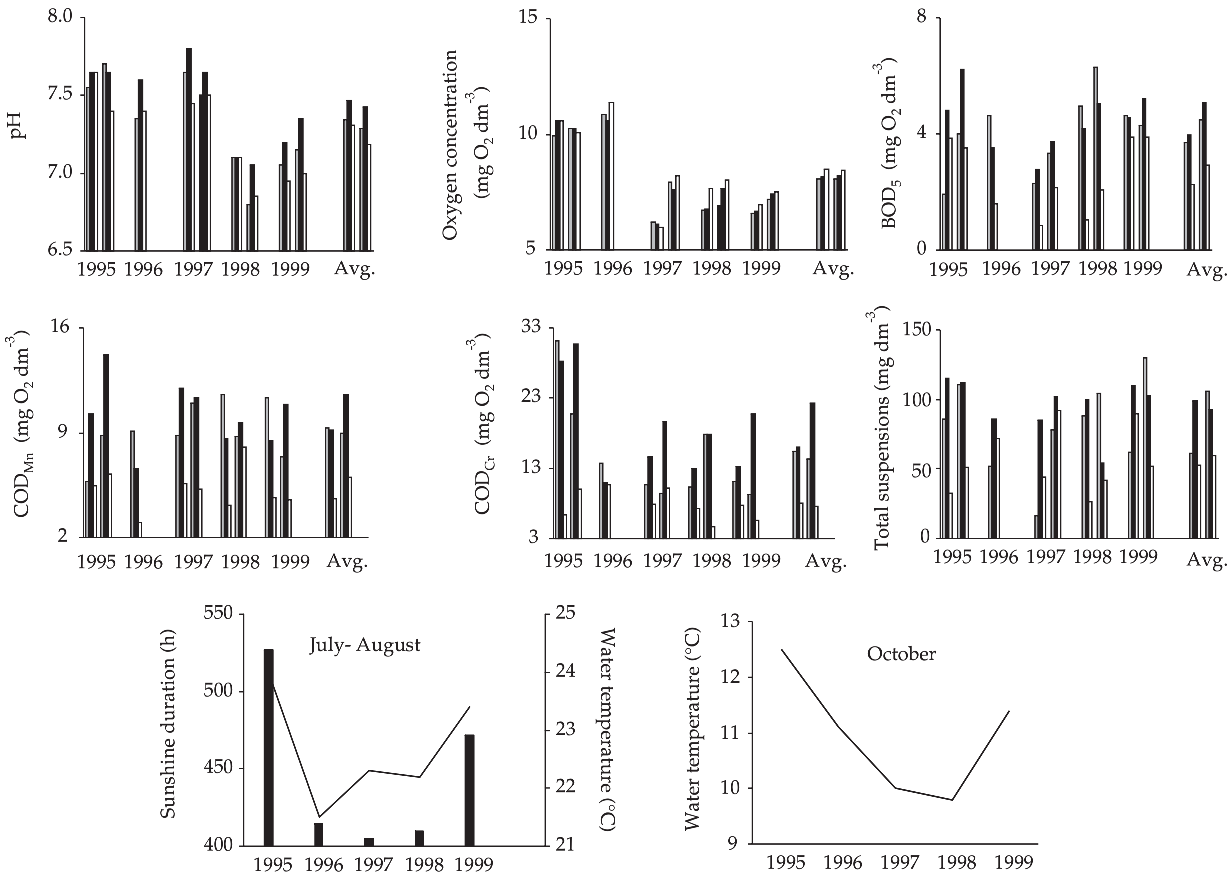

Fig. 2. Chemical composition of waters discharged from the ponds to the river through the Dr_1 and Dr_2 outlets (grey and black bars) at the beginning and end of pond fishing (first and second group of bars), and the composition of riverine waters feeding the ponds (white bars), Avg. – average values for the years from 1995 to 1999. Bottom figures; bars – total sunshine duration (hours) in July and August, curves – average monthly water temperature in the ponds in October in the years from 1995 to 1999.

In both drainage canals the loads of BOD_5, COD_{Mn}, COD_{Cr}, and suspended matter increased towards the end of the fish harvest. In this period the average loads were more than double those noted in the waters flowing into the ponds (Fig. 3) while the share of net pond loads in river water loads reached several to several dozen percent. Due to very low water levels in the Vistula (in October the total monthly precipitation was just 25% of the norm) in 1995, the share of COD_{Mn}, COD_{Cr}, and suspended matter was exceptional and exceeded 100% of the river load mainly in the second phase of the study. In the remaining years the share of pond loads in the river waters varied from several dozen to a few percent depending on the level of river waters (Fig. 4).

After the fish harvest the concentration and loads of BOD_5, COD_{Cr}, and suspended matter in the waters discharged from the ponds stocked with carp fingerlings decreased considerably, although the degree varied in different years. Low concentrations and loads of BOD_5, COD_{Cr}, and suspended matter in the 1997-1998 period could have

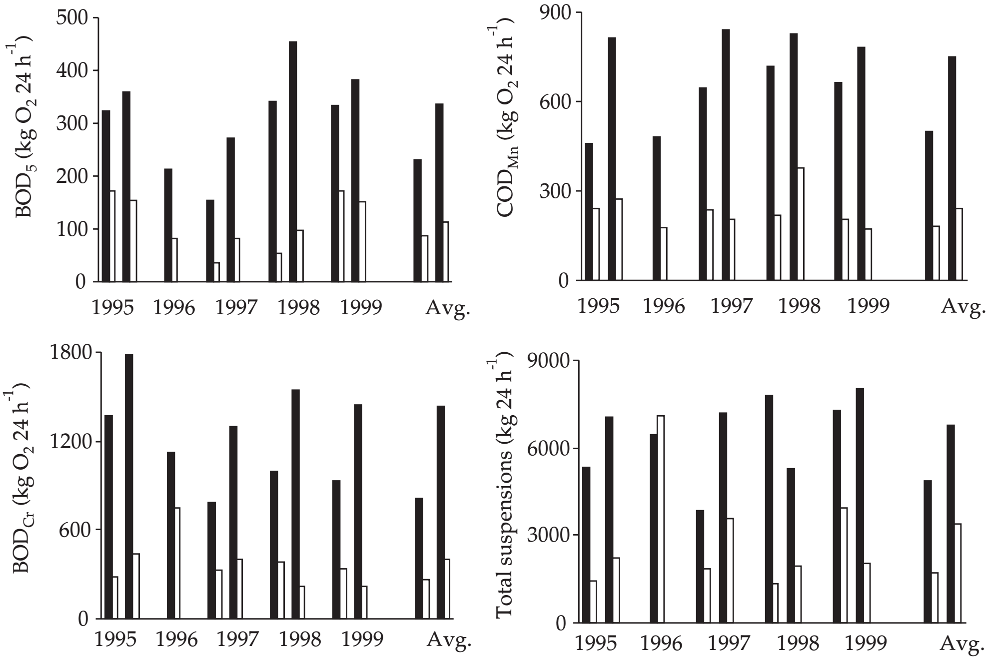

Fig. 3. Loads discharged from ponds through the Dr_1 and Dr_2 outlets (black bars) and loads in waters feeding ponds (white bars) during pond fishing (1995-1999).

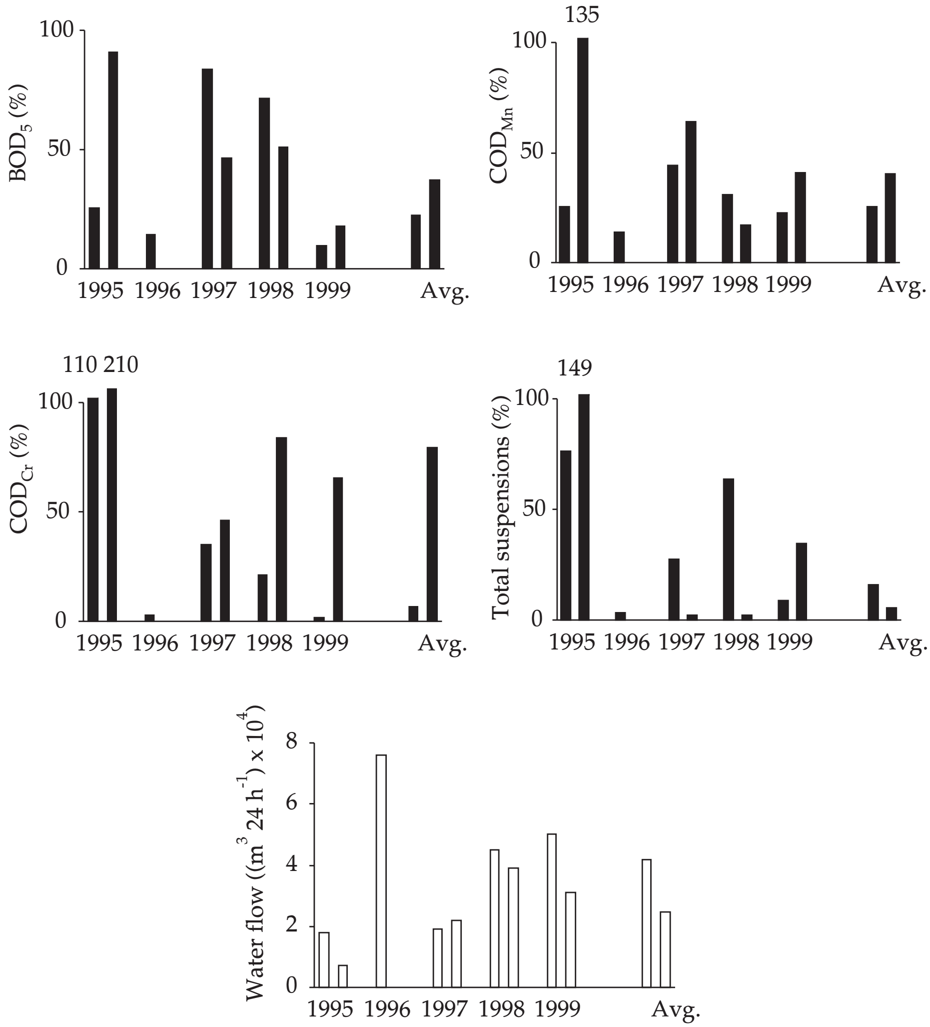

Fig. 4. Percentage of pond loads in river loads and water flow in the Vistula River during pond fishing (1995-1999).

been affected by the cool weather in October. However, the five-year average loads were approximate to those noted in waters fed into the ponds, and the load of suspended matter was equal to that in river waters (Figs. 5 and 6). After the harvest the share of pond loads in the river loads varied from a few to several percent, and, in general, they were inversely proportional to the level of water flow in the river (Fig. 7). Attention should be drawn to the exceptionally high (216%) share of the pond BOD_5 loads in the

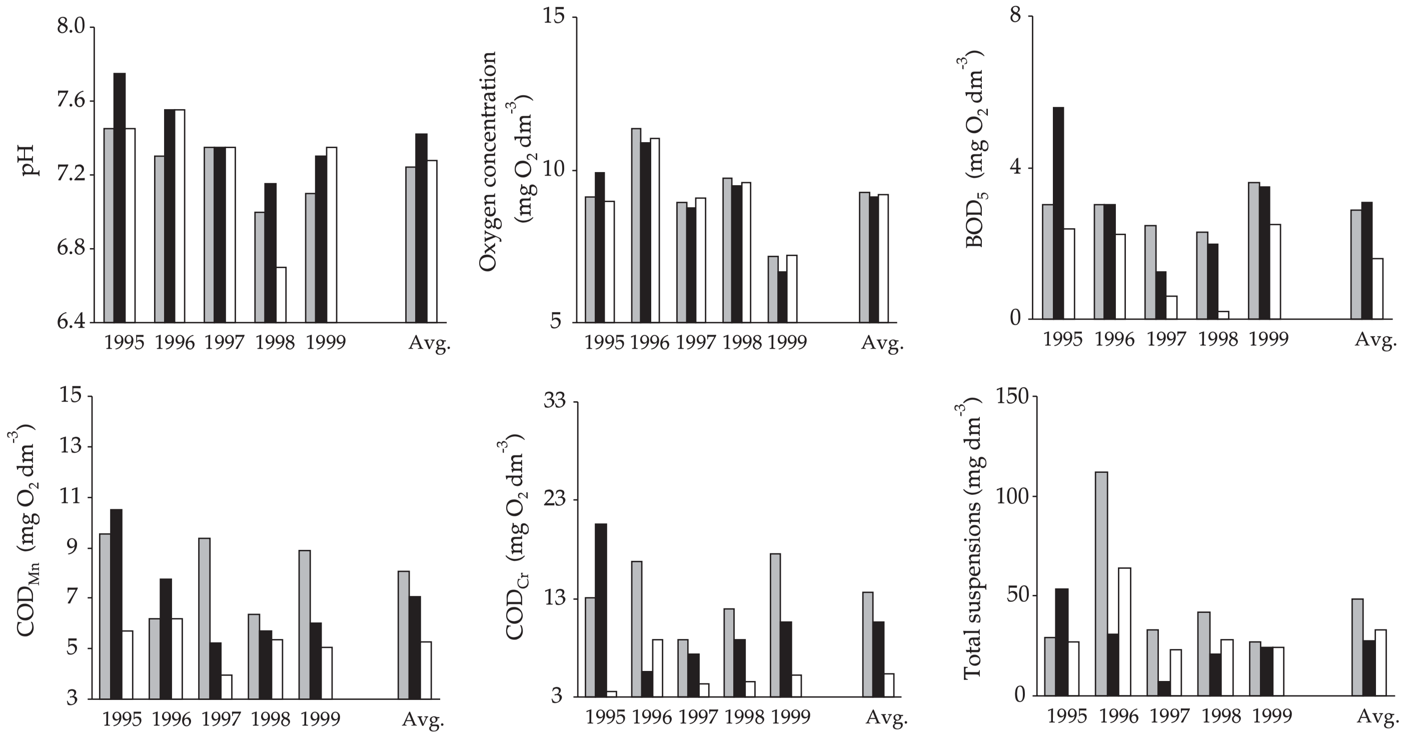

Fig. 5. Chemical composition of waters discharged from ponds by the Dr_1 and Dr_2 outlets (grey and black bars) and the composition of riverine waters feeding ponds (white bars) before and after pond fishing (1995-1999).

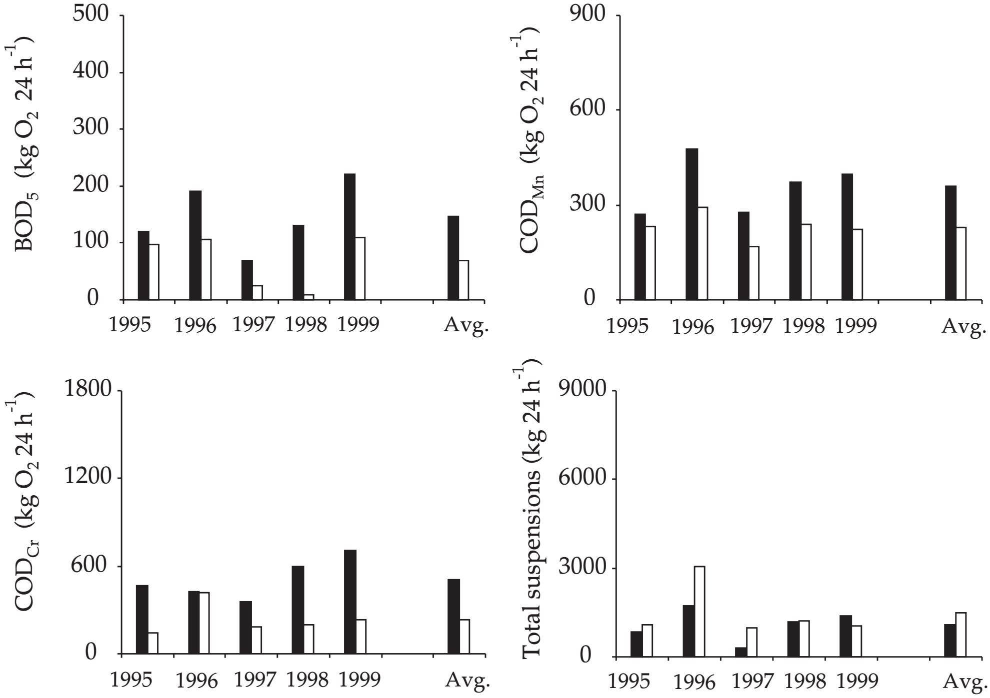

Fig. 6. Loads discharged from the ponds by the Dr1 and Dr2 outlets (black bars) and loads in waters feeding ponds (white bars) before and after pond fishing (1995-1999).

river waters in November 1998. This was probably the result of a rapid cooling which caused a decrease in water temperature in the river to 0.5°C and in the ponds to just 2.8°C which resulted in the slower reduction of organic matter in the ponds.

The higher load of suspended matter in river waters than in pond waters in 1996 and 1997 was caused by the abundant precipitation in the catchment area.

SUMMARY

The reaction, concentration of dissolved oxygen, and the biochemical and chemical oxygen demand in waters discharged from the ponds during the fall harvest of commercial carp varied within the limits of permissible pollution norms for surface waters. Only in the case of suspended matter was this range exceeded; it was also exceeded in

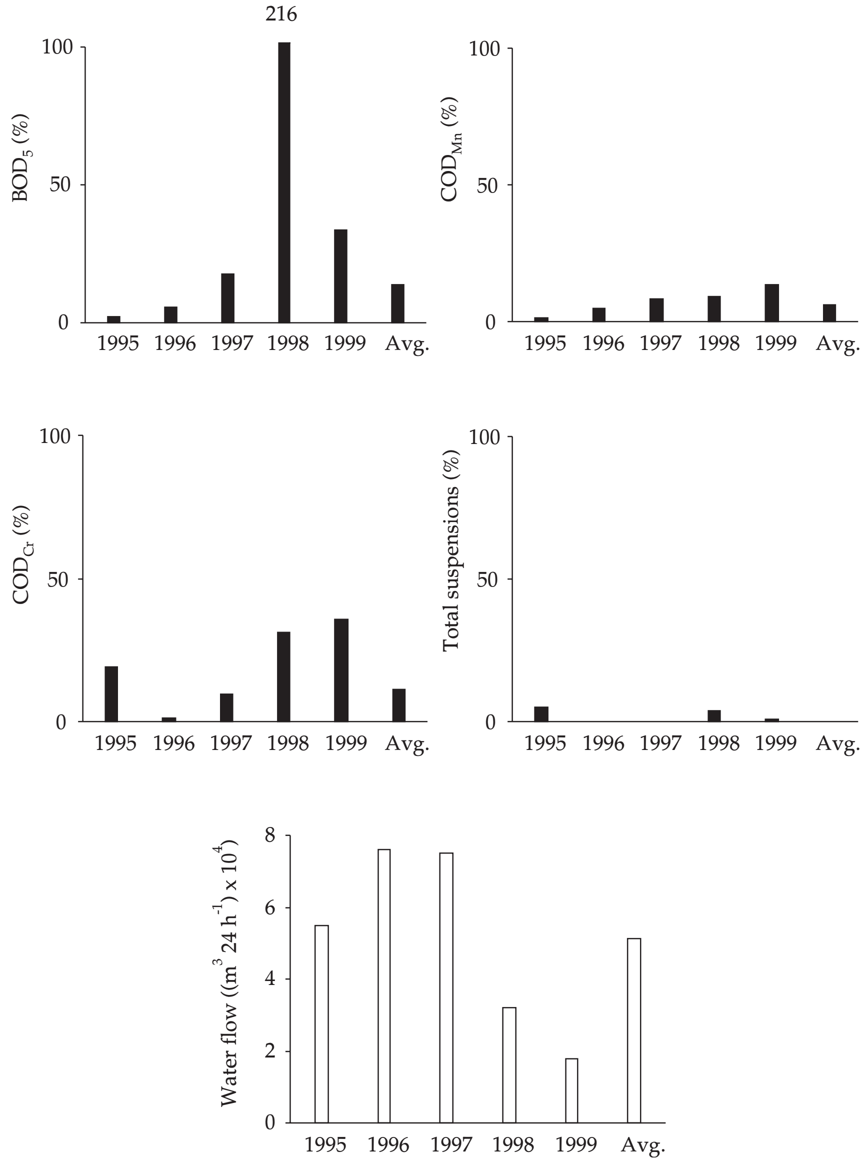

Fig. 7. Percentage of pond loads in river loads and water flow in the Vistula River before and after pond fishing.

the waters that fed the ponds. Moreover, a higher concentration of suspended matter in the river than in the ponds was also recorded. During the fish harvest, the average concentration of biochemical and chemical oxygen demand and of the total suspension in pond waters exceeded by more than 100% oxygen demands in the waters feeding the ponds. This was particularly evident towards the end of the fish harvest when the 10-15 cm bottom water layer was discharged. The loads in the pond waters were almost double of those in the riverine waters. Sunny weather and high water temperature in July and August induced an increase in the loads of pond waters during the fish harvest, while the cool weather in October after the harvest promoted a decrease in the biochemical and chemical oxygen demand and in the concentration of suspended matter both in the pond and river waters. After the fish harvest the average load of BOD_5, COD_{Mn}, and COD_{Cr} were approximate to those in waters feeding the ponds, while the load of suspended matter was equal to that in the river waters. The participation of net pond loads in the loads of river waters during the fall fish harvest was from several to several dozen percent and increased to over 100% when the level of river waters was low, decreasing to a few percentages when the river level was high. The share of the pond loads was negligible before and after the harvest; an exception was the high 216% participation of BOD_5, probably due to the rapid cooling that resulted in a drop in the temperature of river water to 0.5°C and in the ponds to just 2.8°C.

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STRESZCZENIE

JAKOŚĆ WÓD ODPROWADZANYCH ZE STAWÓW W CZASIE JESIENNYCH ODŁOWÓW KARPIA (*CYPRINUS CARPIO* L.)

Praca jest próbą ukazania relacji między obciążeniem wód odprowadzanych ze stawów karpiowych w czasie jesiennych odłowów ryb do rzeki i wód rzecznych zasilających stawy oraz ich zależności od przebiegu pogody w sezonie hodowlanym (maj-wrzesień) poprzedzającym odłów. Badania prowadzono od października 1995 do listopada 1999. Obiektem badań był kompleks stawów Zakładu Ichtiobiologii

i Gospodarki Rybackiej PAN Gołysz usytuowany w zlewni prawobrzeżnej Wisły (rys. 1). Powierzchnia kompleksu wynosi 370 ha, a objętość wody w stawach 4574000 m^3. Stawy są zasilane wodami rzeki Wisły i Bajerki. Dopływ wody do stawów monitorowano w jednym doprowadzalniku, odpływ w dwóch odprowadzalnikach, prędkość przepływu mierzono kilkakrotnie w każdym roku. Objętość wód zrzucanych i zasilających stawy obliczano standardowymi metodami przyjętymi w Instytucie Meteorologii i Gospodarki Wodnej. Odczyn wody, tlen rozpuszczony w wodzie (O_2 mg dm^{-3}), biochemiczne (BZT_5 mg O_2 dm^{-3}) i chemiczne zapotrzebowanie tlenu oznaczone metodą nadmanganiową ($ChZT_{Mn}$ mg O_2 dm^{-3}) i dwuchromianową $ChZT_{Cr}$ (mg O_2 dm^{-3}) oraz zawiesinę ogólną (mg dm^{-3}) badano metodami standardowymi.

W czasie odłowów ryb pH, O_2, $ChZT_{Mn}$ i $ChZT_{Cr}$ wód odprowadzanych ze stawów do rzeki mieściły się w zakresach dopuszczalnych zanieczyszczeń śródlądowych wód powierzchniowych, jedynie stężenie zawiesiny przekraczało znacznie zakres dopuszczalny, lecz przewyższało go również w wodach zasilających stawy (rys. 2). Wyższe obciążenie wód na ogół stwierdzono w końcowej fazie odłowów ryb, kiedy odprowadzano przydenną warstwę, odpowiadającą około 10% objętości wód stawowych. Słoneczny i ciepły lipiec i sierpień sprzyjały wysokiej koncentracji BZT_5, $ChZT_{Mn}$, $ChZT_{Cr}$ i zawiesiny w wodach odprowadzanych ze stawów (rys. 2), natomiast chłodna pogoda w październiku wpływała na obniżenie koncentracji zarówno w wodach stawowych, jak i rzecznych. Ładunki BZT_5, $ChZT_{Mn}$, $ChZT_{Cr}$ i zawiesiny w obu odprowadzalnikach wzrastały pod koniec odłowów, średnie ładunki ponad dwukrotnie przewyższały ładunki wód zasilających stawy (rys. 3). Średni udział stawowych ładunków netto w ładunkach wód rzecznych wynosił od kilkunastu do kilkudziesięciu procent, wzrastał do ponad 100% jedynie przy niskim stanie wód rzecznych (1995 rok) oraz spadał do kilku procent przy wysokim stanie (1996 rok, rys. 4). Po odłowach ryb koncentracja i ładunki BZT_5, $ChZT_{Mn}$, $ChZT_{Cr}$ i zawiesiny w wodach odprowadzanych ze stawów znacznie się obniżyły i zbliżyły do ładunków w wodach zasilających stawy, a ładunek zawiesiny zrównał się z ładunkiem w wodach rzecznych (rys. 5, 6). Udział stawowych ładunków netto w ładunkach rzecznych wahał się od kilku do kilkunastu procent i na ogół zmieniał się odwrotnie proporcjonalnie do wysokości przepływu w rzece (rys. 7). Wyjątkowo wysoki 216% udział ładunku BZT_5 w wodach stawowych w 1998 był prawdopodobnie wynikiem gwałtownego oziębienia i spadku temperatury w rzece do 0,5°C, podczas gdy w stawach temperatura obniżyła się tylko do 2,8°C.