THE VARIABILITY OF SPATIAL DISTRIBUTION AND DENSITY OF FISH IN THE KLIMKÓWKA DAM RESERVOIR

ANDRZEJ ŚWIERZOWSKI

Inland Fisheries Institute
ul. Oczapowskiego 10, 10-719 Olsztyn, Poland
a.swierzowski@infish.com.pl

The Klimkówka Dam Reservoir is situated on the Ropa River in southern Poland. The surface area of the reservoir is about 306 ha and its capacity is 43.5 hm^3. Acoustic surveys were conducted both in the daytime and at night using a SIMRAD EY-500 split beam 120 kHz echo sounder. Maps of the spatial distribution and density of fish were drawn up, and the fish species structure, size, number and biomass were estimated based on acoustic surveys and supervised net catches. The highest fish density at night occurred in the river tributary zones (836 fish/ha). In this area at night fish density was twice as high as in the central region of the reservoir. The density figure for the whole reservoir was 638 fish/ha and was 1.4 times higher than that in the Solina Reservoir and from ten- to twenty-fold lower than in several other studied lakes. Fish catches performed with pelagic trawls and net sets revealed the presence of nine fish species. Lake and river trout species which had been introduced to the reservoir were not noted. The fish biomass was estimated to be 11.5 tons, or 44.4 kg/ha, and was from three to 14 times lower in comparison to the estimated figure in several other lakes.

INTRODUCTION

Accelerated water eutrophication threatens the natural environment, angling and commercial fisheries. Changes in fish assemblages indicate permanent and directed changes in the environment. Eutrophication and the destruction of water ecosystems can be slowed down through controlling the composition and structure of ichthyofauna (biomanipulation). This type of manipulation must be preceded by detailed studies of fish resources and dependencies on the lower trophic levels [2, 3, 9, 13, 14, 22]. Fast and effective evaluations of ichthyofauna structure and resources can be achieved by combining hydroacoustic methods and control fishing using gear with low selectivity [15, 18]. The ichthyofauna species composition and age structure in dam reservoirs begin to change when hydrotechnical work begins in the river bed. The rate of these changes is the fastest in the first three-year period.

The character and speed of them depend on the degree of reservoir eutrophication and the type of angling and fisheries activities conducted [10, 12].

When the Klimkówka Dam Reservoir was built in 1994, the state of its ichthyofauna was unknown. Lake trout were introduced in the first year. Stream trout were introduced the following year, followed by whitefish hatch and fry [1].

The aim of the present study was to determine the state, distribution, density, species composition, age structure, abundance and biomass of the fish in the Klimkówka Dam Reservoir using hydroacoustic methods supported by data from control net fishing. Another aim was to evaluate the results of stocking and species introduction programs. The study results can be applied to control ichthyofauna composition and structure in the studied reservoir in order to halt destructive processes.

1. DESCRIPTION OF THE STUDY AREA

The purpose of the Klimkówka Dam Reservoir, which was built on kilometer 54 of the Ropa River, was to eliminate water deficiency, reduce flood risks, dilute sewage, use the cascades for energy production, provide opportunities for the development of recreational activities and stimulate the economy. A 210 m earthen dam was built. The maximum water swell height is 36.1 m, at which the maximum reservoir area is 306 ha. The total volume of the reservoir is 43.5 hm^3. The reservoir is 6 km long and its width ranges from 200 to 800 m, and the average depth, at medium swell, is 13 m. The water power plant is equipped with a 1.1 MW Kaplan-type turbo system. The reservoir is a typical, "young", medium-sized mountain reservoir, but it is important both locally and outside of the region [1, 8].

The studies, conducted in 1999-2001, indicated that the water quality in the reservoir was good (class I purity) and that there were low levels of organic compounds and nutrients and low bacteriological contamination. This is the transition between the oligotrophic and mesotrophic stages.

2. MATERIALS AND METHODS

The studies of the environmental conditions were limited to measurements of water temperature and oxygen content at various depths in the central and tributary regions (Fig.1).

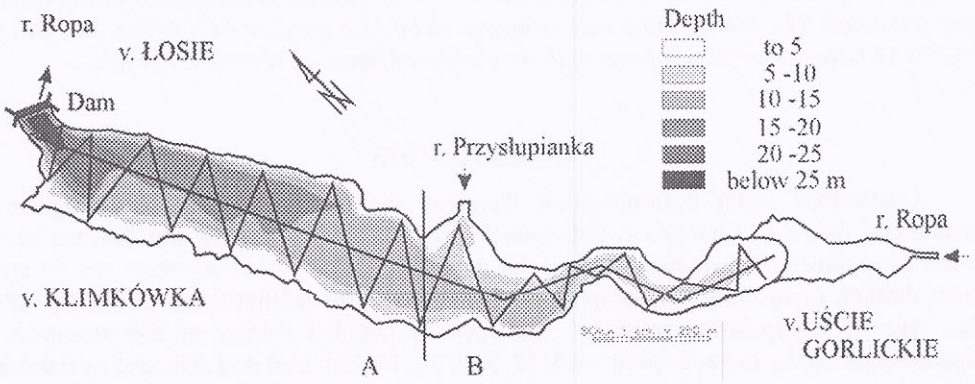

Fig 1 Klimkówka Dam Reservoir- bathymetry and transects.
A - central region , B - tributary region.

Since the spatial distribution of fish in aquatic ecosystems depends largely on thermal and oxygen stratification [6, 21], measurements of temperature and oxygen contents were made every 1 m from the surface of the water down to the bottom with an EO96 probe of an OXI 196 WTW microprocessor oxygen meter.

Acoustic measurements were taken during the day and at night in a zigzag pattern along previously determined routes (Fig. 1). A motor boat with an engine strong enough to haul the pelagic trawl was used during control fish catches. A system comprised of a SIMRAD EY-500 split beam research echosounder and a 120 kHz transducer with a sounding beam width of 7x7 deg was used. The acoustic data were registered in real-time on a laptop computer.

The fish densities were calculated at a methodologically justified number of water layers and segments along 30 acoustic routes with the aid of the EP-500 data analysis program. The analyses of echograms and acoustic data indicated that a much greater contribution of gas bubbles was released from the reservoir bottom than was detected by direct observation. Since the water was saturated with methane, it was necessary to apply a data separation method. In comparison with the lake monitoring procedures used to date, the analyzed segments in the current study were reduced three-fold while their number increased three-fold. The detailed analyses of the segments on the echograms allowed for the elimination of those "contaminated" with gas bubbles and those with very low trace resolution. A total of 1.5% of over 6,000 pieces of data regarding fish density in segments were eliminated.

By interpolating the data obtained using the Kriging method and the SURFER program (Gold. Soft. Inc. v. 4.04 1989), maps of the spatial distribution and density of fish were prepared and fish numbers were calculated at particular depths and areas in the Klimkówka Dam Reservoir. Detailed information regarding the applied methodology can be found in Mac Lennan and Simmonds [11] and Stepnowski [15]. The results of the acoustic studies were used to prepare an initial, approximate bathymetric map of the Klimkówka Dam Reservoir (Fig. 1), which is essential to the presentation and discussion of the study results.

Control fishing was conducted in order to determine the fish age structure and sizes and to verify acoustic fish density data. A pelagic trawl and two sets of gill-nets with low selectivity were used. The pelagic trawl netting had mesh bar lengths from 80 mm at the inlet to 5 mm in the codend. The area of the trawl inlet was S = 11 m^2, and water filtration was F = 849.2 $m^3 \cdot min^{-1}$ at a trawling speed of V = 77.2 $m \cdot min^{-1}$. The catches were made in the central area of the Klimkówka Dam Reservoir at different depths along the longitudinal axis. Two 16-panel gill-net sets with 10 to 65 mm mesh sizes were also deployed. The gill-nets were 6 m high. The fish caught were measured (*lt*) to the nearest 0.1 cm and weighed to the nearest 0.1 g. The acoustic determination of fish numbers, the percentages of species noted in the catches and the average specimen weight allowed the fish biomass for particular species and size classes to be estimated.

3. RESULTS AND DISCUSSION

The measurements of water temperature and oxygen content throughout the water column from the surface to the bottom were taken on 11 September 2001 at two stations - near the dam and in the tributary area (Fig. 2). The lack of thermal-oxygen stratification observed is typical of this lake type in this season. Good thermal and oxygen conditions ensured that all fish species would develop and grow appropriately. In both the horizontal and vertical transects, no significant variations in water temperature or oxygen content which could have influenced the spatial distribution of the fish were observed.

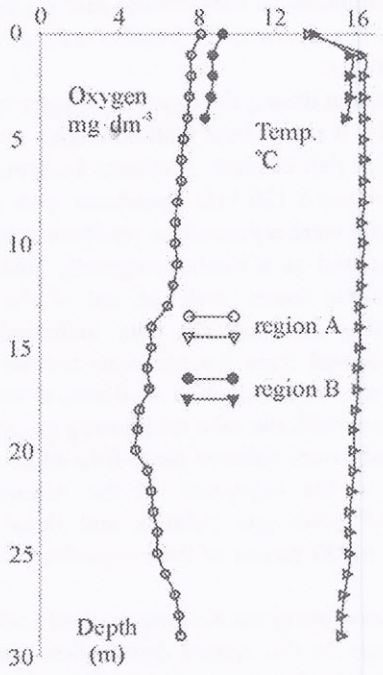

Fig.2 Klimkówka Dam Reservoir - oxygen contents and water temperature.

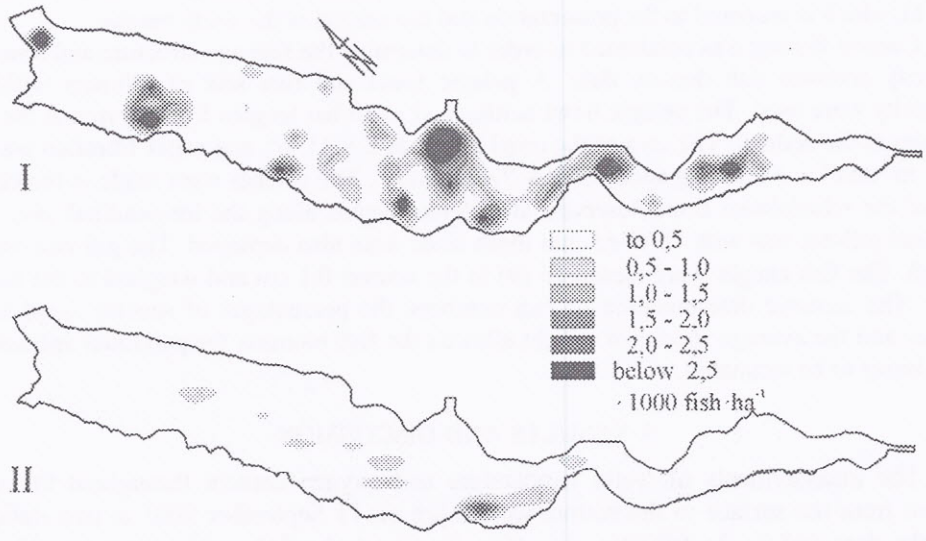

Fig. 3 Nocturnal distribution and density of fish from the 1-8 m (I) and 8-29 m (II) depth layers in the Klimkówka Dam Reservoir..

The results of the acoustic-fishing monitoring pertain to the pelagic zone of the Klimkówka Dam Reservoir; thus, they do not refer to shore areas at depths of up to 3 m, the near surface layer of up to 1 m deep or the near bottom layer.

Usually dam reservoirs are characterized by a significant diversity of abiotic and biotic conditions along the longitudinal axis. Such diversity influences the diurnal and seasonal diversity of fish distribution and density and may have an impact on the ways and speeds of matter circulation in reservoirs. Fish density which results from feeding behavior or the avoidance of predators can lead to a significant decrease in zooplankton density [3, 22]. Thus all data were analyzed separately for the central and tributary regions.

The comparison of the maps in Figure 3 indicates that the decisive role in fish location and density in the Klimkówka Dam Reservoir is played by the upper water layers of up to 8 m. The highest fish density in the central part of the reservoir was observed near the dam, the life-guard station and angling locations. The highest fish densities were observed in the tributary near the mouth of the Przysłupianka River and near angling locations and were probably related to the better trophic conditions associated with the input of communal sewage or fishing bait. Similar dependencies were confirmed in Lake Żarnowieckie, the heated Konin lakes and in the Solina Dam Reservoir [5, 6, 7, 16, 17].

The diurnal fish migrations which have been monitored with hydroacoustic methods in many lakes, including the Solina and Dobczycki dam reservoirs, are related either to feeding migrations or to the avoidance of predators. When there is a greater contribution of littoral and macrophytes in the reservoir, the differences between the hydroacoustic evaluations of fish resources during the day and at night are larger (even several-fold) [10, 16, 17, 18, 21]. Figure 5 illustrates the diurnal and nocturnal vertical distribution and density of fish in 2 m water layers in both parts of the reservoir. The results presented in Figure 4 indicate a rather typical situation – there is greater fish density in the upper water layers, especially at night.

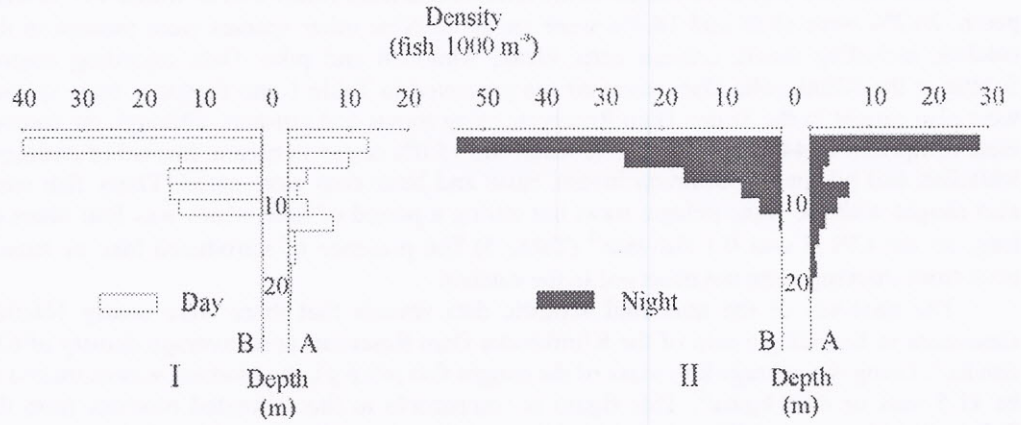

Fig.4 Diurnal (I) and nocturnal (II) vertical density of fish in the central (A) and tributary (B) regions of the Klimkówka Dam Reservoir.

Nocturnal fish migrations from littoral to pelagic areas and from deeper water layers to the surface are related to feeding when there is less pressure from internal (predatory fish) and external (water fowl) predators [4, 9, 10, 17, 20]. The average, diurnal fish density for the entire reservoir was 448 fish·ha^{-1} and at night it was 638 fish·ha^{-1} (fig. 5), which was slightly

higher than the figure for the Solina Reservoir [21] and much lower, frequently from ten- to twenty-fold lower, than in more than a dozen other lakes [16, 17, 18].

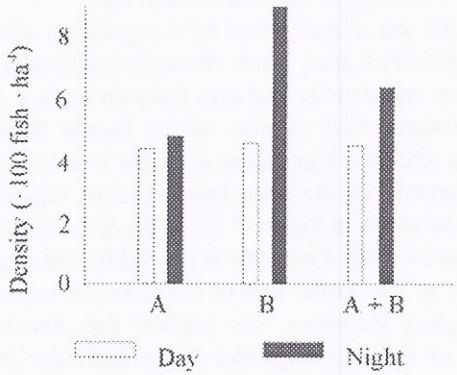

Fig. 5 Diurnal and nocturnal density of fish in the central (A) and tributary (B) regions of the Klimkówka Dam Reservoir

The pelagic trawl was used to perform catches along the reservoir axis in the 4-8 m and 12-16 m water layers, and in a total of 60 minutes 51,000 m^3 of water were "filtered". Thirty fish were caught, of which 53.3% were perch fry and 20% pikeperch fry. The catch effort was 0.6 fish·1000 m^{-3} and the CPUE was 0.5 fish·min^{-1}. Assuming that the trawl catch effort was 33%, fish density was approximately 1.8 fish·1000 m^{-3}, which correlates well with the results obtained from the acoustic estimations. A total of 48 fish were caught in the central area with the gill-net sets; 75.0% were gudgeon and 20.8% were perch. A total of 204 fish were caught in the tributary region; 50.5% were perch and 32.8% were chub.

A total of 282 fish were caught in the Klimkówka Dam Reservoir, of which 45.7% were perch, 26.2% were chub and 18.4% were gudgeon. Nine other species were present in the catches, including roach, crucian carp, bleak, whitefish and pike. Data regarding control fishing in the Klimkówka Dam reservoir are presented in Table 1 and Figure 6. Nine species were also caught in the Solina Dam Reservoir using trawls and gill-nets, although the catches were comprised of 44.5% bleak, 23.7% roach and 15.0% common bream. Instead of gudgeon, whitefish and pikeperch, common bream, ruffe and beak carp were noted. Thirty fish were also caught with the same pelagic trawl but during a period of time which was four times as long, so the CPUE was 0.1 fish·min^{-1} (Table 3).The presence of introduced lake or stream trout from stocking were not observed in the catches.

The analyses of the nocturnal acoustic data reveals that there were nearly 166,000 specimens in the pelagic area of the Klimkówka Dam Reservoir at an average density of 638 fish·ha^{-1}. Using the average unit mass of the caught fish (69.6 g), the biomass was estimated to be 11.5 tons or 44.4 kg·ha^{-1}. This figure is comparable to the estimated biomass from the Solina Dam Reservoir [19] and is from three to 14 times smaller than that of the majority of lakes studied in the last ten years (Table 3). The estimated characteristics of the fish resources in the Klimkówka Dam Reservoir from acoustic-fishing monitoring are presented in Table 2. The results show that, in terms of biomass, chub dominates with 19.1 kg·ha^{-1} (43.1%) followed by perch 13.2 kg·ha^{-1} (29.8%), gudgeon 4.7 kg·ha^{-1} (10.5%), roach 3.9 kg·ha^{-1} (8.7%) and other species 7.9 kg·ha^{-1} (3.5%).

In order to verify the fish density, abundance and biomass obtained acoustically, the CPUEs obtained in various lakes and dam reservoirs using the same calibrated pelagic trawl

Table 1
Characteristics of the control fishing in the Klimkówka Dam Reservoir

Species	Numbers		Biomass		Mean body length (SD) cm	Mean ind. weight (SD) g
	N	%	g	%		
Perch	129	45.7	5 779.2	17.4	15.1 (4.1)	44.8 (55.6)
Chub	74	26.2	8 370.8	25.2	21.7 (4.3)	13.1 (135.3)
Gudgeon	52	18.4	2 044.8	6.2	16.6 (1.3)	39.3 (8.9)
Roach	12	4.3	1 650.8	5.0	22.6 (3.2)	37.6 (61.1)
Pike perch	6	2.1	9.7	0.1	6.1 (0.4)	1.6 (0.3)
Crucian carp	3	1.1	1 409.4	4.3	30.2 (1.6)	469.8 (70.2)
Bleak	3	1.1	80.2	0.2	14.0 (3.5)	26.7 (18.2)
Whitefish	2	0.7	1 307.2	3.9	-	-
Pike	1	0.4	12 500.0	37.7	-	-
Total	**282**	**100.0**	**33 152.1**	**100.0**	**-**	**-**

Table 2
Estimated characteristics of the fish resources in the Klimkówka Dam Reservoir from acoustic-fishing monitoring.

Species	Numbers			Biomass			
	Ind.	%	Density fish·ha^{-1}	Mean ind. g	Total kg	%	kg·ha^{-1}
Perch	76 629	46.2	295	44.8	3 433.0	29.8	13.2
Chub	43 953	6.5	169	113.1	4 971.1	43.1	19.1
Gudgeon	30 850	18.6	119	39.3	1 212.4	10.5	4.7
Roach	7 298	4.4	28	137.6	1 004.2	8.7	3.9
Pike perch	3 483	2.1	13	1.6	5.6	0.1	0.02
Crucian carp	1 824	1.1	7	469.8	856.9	7.4	3.3
Bleak	1 824	1.1	7	26.7	48.7	0.4	0.2
Total	**165 861**	**100.0**	**638**	**69.5**	**11 531.9**	**100.0**	**44.4**

were compared. The data presented in Table 3 reveal that the CPUE in the Klimkówka Dam Reservoir was approximately four to 78 times smaller when expressed in numbers and from three to 50 times lower when expressed as biomass than in vendace-type lakes. The CPUE in the Klimkówka Dam Reservoir expressed as biomass (30.9 g·min^{-1}) was similar to the figure for the Solina Dam Reservoir (31.5 g·min^{-1}). Similar relationships were observed in other lakes and reservoirs [18, 19, 20] which confirms the reliability of evaluating fish resources when the appropriate acoustic systems and catch methods are applied.

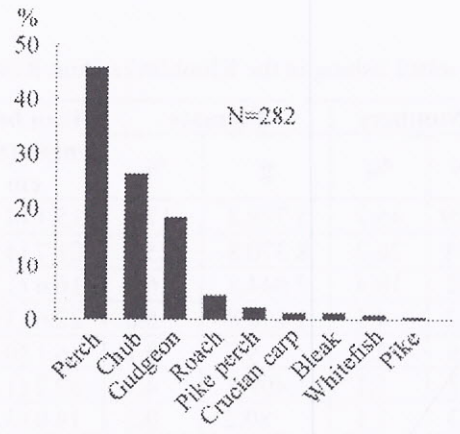

Fig.6 Percentage distribution of numbers in the control fishing.

Table 3
Pelagic trawl catches and CPUE data from acoustic-fishing monitoring of fish resources in lakes and dam reservoirs.

Lake or reservoir	Date mm-yy	Tow N	Fishing			CPUE	
			Time min	Numbers	Biomass g	fish·min^{-1}	g·min^{-1}
L. Wigry N	08.96	4	47	980	19 524.4	20.9	415.4
L. Wigry S	08.96	3	31	1 208	49 294.8	39.0	1 590.1
L. Pierty	08.96	3	41	1 596	19 414.4	38.9	473.5
L. Białe	08.96	4	52	1 162	31 886.4	22.3	613.2
L. Czerwonka	06.01	1	18	1 421	26 400.0	78.9	467.0
L. Pluszne	06.01	4	32	1 055	6 249.9	33.0	195.3
L. Łańsk	07.01	3	18	134	1 492.5	7.4	82.9
L. Pluszne	08.01	8	70	2 144	55 884.6	30.6	798.4
L. Pluszne	10.01	4	32	996	10 605.1	31.1	331.4
L. Łańsk	10.01	4	31	65	2 805.4	2.1	90.5
R. Soliński	09.99	12	254	30	7 990.0	0.1	31.5
R.. Klimkówka	09.01	2	60	30	1 853.1	0.5	30.9
R. Rożnowski	09.02	5	38	149	2 614.3	3.9	68.8

4. CONCLUSIONS

- The ichthyofauna of the Klimkówka Dam Reservoir was shaped by natural fish resources in the Ropa and Zdynia rivers, followed by both controlled and uncontrolled attempts to introduce fish species desired by fishermen.
- The greatest horizontal, nocturnal fish density is associated with the better trophic conditions near functional and recreational facilities and angling areas (due to baiting).

The nocturnal fish density in the central part of the reservoir was approximately two-fold lower than in the tributary area. The average fish density of this reservoir was 1.4 times higher than that in the Solina Dam Reservoir, but significantly lower, from ten- to twenty-fold, than in over a dozen other studied lakes.

- Greater fish concentrations in the upper water layers were not determined by thermal and oxygen stratification, but rather by trophic conditions.
- Control fishing indicated the presence of nine species, including perch (45.7%), chub (26.2%) and gudgeon (18.4%). Lake and stream trout and whitefish, which had been introduced in previous years, were not observed.
- The fish biomass in the pelagic area was estimated to be 44.4 $kg \cdot ha^{-1}$. This figure was similar to that estimated using the same method in the Solina Dam Reservoir. In comparison to the biomass of over a dozen lakes which were studied in the last ten years, it was from three to fifty-fold lower.
- Control fishing allowed the hydroacoustic data regarding fish density in the reservoir to be verified. In the Klimkówka Dam Reservoir, the pelagic trawl CPUE expressed as biomass (31 $g \cdot min^{-1}$) was the same as in the Solina Dam Reservoir and from three to over fifty-fold lower than in other lakes.
- As trophic conditions and eutrophication increase in the reservoir, so does the importance of predatory fish as regulators of the excessive development of cyprinids, especially juvenile forms. The proper proportions of predatory fish should be well established in advance.
- The ichthyofauna of the Klimkówka Dam Reservoir will depend on the prioritization of goals, managerial and economic strategies and especially controlled stocking and catches. The results of these studies should allow a program for the management of the natural resources of this ecosystem to be developed which will protect biodiversity and prevent ecological degradation.

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REFERENCES

1. R. Bartel, K. Bieniarz, R. Sych, L. Augustyn, Wstępne wyniki introdukcji troci jeziorowej (Salmo trutta m. lacustris L.), pstrąga potokowego (Salmo trutta m. fario L.) do zbiornika zaporowego Klimkówka na rzece Ropie. Zoologica Poloniae, Vol. 41, 105-112, 1996.
2. P.J. Colby, G.R. Spangler, D.A. Hurley, A.M. Mc Combie, Effect of eutrophication on salmonids communities in oligothrophic lakes. J. Fish. Board Can., Vol. 29, 975-983, 1972
3. P. Frankiewicz, Mechanizmy regulacyjne w obrębie zespołu ryb i ich wpływ, poprzez efekt kaskadowy, na jakość wody w nizinnym zbiorniku zaporowym. Folia limnologica, Uniwersytet Łódzki, 1998.
4. Z.M. Gliwicz, A. Jachner, Diel migration of juvenile fish: a ghost of predation past or present?. Arch. Hydrobiol.,Vol. 124, 385-410, 1992.
5. M. Godlewska, T. Półtorak, A. Świerzowski, Hydroacoustical estimation of fish abundance and distribution in the Solina Reservoir. Hydroacoustics,Vol. 3, 169-172, 2000.

6. M. Godlewska, T. Półtorak, A. Świerzowski, The relationship between fish spatial distribution measured acoustically and the environmental variability in the Solina Reservoir. ECUA 2000, Lyon, France, s. 1509-1514, 2000.
7. M. Godlewska, A. Świerzowski, Fish abudances and size structure distributions in reservoirs with different trophy level. Hydroacoustics, Vol. 4, 65-68, 2001.
8. J. Henning, Zbiornik Klimkówka na rzece Ropie - opis ogólny inwestycji. GospodarkaWodna Vol. 2, 26-29 i 41, 1994.
9. Jachner, "Biomanipulacja". 4. Zagęszczenie i aktywność pokarmowa ryb planktonożernych. Wiad. Ekol., Vol. 34, 143-163, 1988.
10. M. Jelonek, M. Godlewska, Ichtiofauna. W: Zbiornik Dobczycki. Ekologia - Eutrofizacja - Ochrona. Red. Starmach J. i Mazurkiewicz-Boroń G. Zakład Biologii Wód PAN, 137-147, Kraków 2000.
11. D.N. MacLennan, E.J. Simmonds, Fisheries Acoustic. Chapman & Hall, London, 323 p., 1992
12. J. Mastyński, Gospodarka rybacka i możliwości produkcyjne wybranych zbiorników zaporowych Polski. Roczniki Akademii Rolniczej w Poznaniu. Rozprawy naukowe, Vol. 146, 1985,
13. G. Mazurkiewicz-Boroń, Eutrofizacja - przyczyny i skutki. W: Zbiornik Dobczycki. Red. J.Starmach i G. Mazurkiewicz-Boroń, 225-231, Kraków 2000.
14. J. Starmach, M. Jelonek, Specjalistyczna gospodarka rybacka - jeden z czynników ochrony jakości wody. W: Zbiornik Dobczycki. Red. J.Starmach i G. Mazurkiewicz-Boroń, 234-240, Kraków 2000.
15. A. Stepnowski, Systemy akustycznego monitoringu środowiska morskiego. Gdańskie Towarzystwo Naukowe, Gdańsk 2001, 283 ss., 2001
16. A. Świerzowski, Hydroakustyczny monitoring zasobów ryb pelagicznych w jez. Żarnowieckim. Ed.: W. Majewski – Stan Jeziora Żarnowieckiego po 10 latach eksploatacji elektrowni szczytowo-pompowej: Monografie Komitetu Gospodarki Wodnej PAN. Vol. 11, 141-158, 1996.
17. A. Świerzowski, Lokalizacja i zagęszczenie ryb pelagicznych w systemie jezior konińskich monitoringowanych metodą akustyczno-połowową. Bibl. Monitoringu Środowiska – Konin, ss. 124, 1998.
18. A. Świerzowski, Characteristics and optimization of the exploitation of vendace resources on acoustic-fishing monitoring of lakes. Proceedings International Symposium on Responsible Fisheries and Fishing Techniques Ińsko – Poland, 16-19 June, 199-205, 1999.
19. A. Świerzowski, Distribution and assessment of fish resources in Solina Dam Reservoir monitored with an acoustic-cum-fishing method. Proceedings of the XLVII Open Seminar on Acoustics OSA'2000. Rzeszów-Jawor, Vol. 1, 163-168, 2000.
20. A. Świerzowski, Ecological and fishery implication of the distribution of vendace resources in lakes monitored with an acoustic – fishing method. ECUA 2000, Lyon, France, 1503-1508, 2000.
21. A. Świerzowski, M. Godlewska, T. Półtorak, The relationship between the spatial distribution of fish, zooplanton and other environmental parameters in the Solina reservoir, Poland. Aquat.Living Resources, Elsevier SAS, Vol. 13, 373-377, 2000.
22. M. Zalewski, B. Brewińska-Zaraś, P. Frankiewicz, S. Kalinowski, The potential for biomanipulation using fry communities in a lowland reservoir: corcordance between water quality and optimal recruitment. Hydrobiologia Vol. 200/201, 549-556, 1990.