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ENVIRONMENTAL AND TROPHIC CONDITIONS IN LAKE POGUBIE WIELKIE AFTER DISAPPEARANCE OF SUBMERGED VEGETATION

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A b s t r a c t. Physico-chemical and biological investigations of the polymictic lake Pogubie Wielkie revealed its outstanding eutrophy. This was demonstrated by a high accumulation of nutrients and organic matter in water and in sediments, low transparency, very intensive phytoplankton blooms, great number and biomass of small, non-predatory crustaceans and scarce bottom fauna and low abundance of phytophilous fish. Shifts in the trophic status are to be related to the gradual subsidence of water level since nineteen seventies and to the nearly total disappearance of submerged plants.

Key words: LAKE, EUTROPHICATION, WATER LEVEL, WATER AND SEDIMENT CHEMISTRY, PHYTOPLANKTON, ZOOPLANKTON, BOTTOM FAUNA

INTRODUCTION

Lake Pogubie Wielkie is located in the north-eastern corner of the Kurpiowska Plain, close to the southern border of the Great Mazurian Lakes region where four catchment areas adjoin. Watershed boundaries are very obscure and water discharge depends on water levels in the adjacent streams.

Lake area is 670.8 ha, maximum length 3900 m, maximum breadth 2500 m. Pogubie Wielkie is fed by Rybnica River which has its sources at Snopki and flows through lake Brzozolasek (Fig. 1). Pogubie Wielkie and the lake situated south of the former- Pogubie Małe- are connected by a 500 m long stretch of Rybnica River. This results in the same water level in these two water bodies. A water gate at the outlet of Rybnica River from Pogubie Małe impounded waters in both lakes to the mean level of 117.07 m above sea level and kept an average depth in Pogubie Wiekie Lake equal to 81 cm (according to the Water Project and Melioration Bureau w Olsztynie).

There was a distinct annual cycle of water level fluctuation in the period of 1958-1985, with a maximum in early spring just after thaw, then a gradual decrease with a minimum level in autumn. The mean annual amplitude was 35 cm (according to WPMB as above).

The only published information on Pogubie Wielkie Lake before the catastrophic eutrophication is a paper by Olszewski and Paschalski (1959) who wrote that „water

Fig. 1. Outline of Lake Pogubie Wielkie showing sites of sampling in May 1981 (A-E) and in the year 1982 (I - III)

surface (of the lake) is mostly covered by water-soldier, water-thyme, pond-weed ect., occasionally there are „windows" free of plants. Water level rises by 0.5 m during winter but even so winter kills occur. "...On 27 Aug. 1953 water temperature at the surface on 18 hr was 20.7°C, oxygen (content) 10.9 mg/l, pH 8.6, MC 1.0, visibility down to bottom. Water colour was somewhat yellowish with a lot of suspended

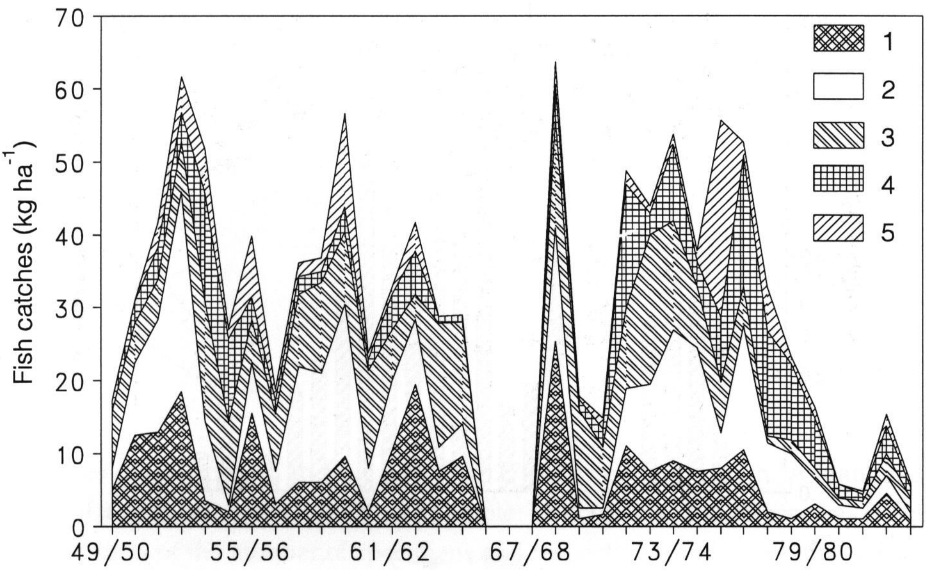

Fig. 2. Total catches of fish from the Pogubie Wielkie in years 1950 through 1983; catches of pike (1), tench (2), crucian carp (3), roach (4), and other fishes (5) are shown as components of the totals.

matter. The water body is of peculiar character, large and extremely shallow , overgrown by submerged plants".

Unpublished data in fisheries records depict the composition of the fish yield over 34 years. From the fishery point of view the lake represented a winter-kill-susceptible, tench-pike type in which abundant water plants created good spawning and growing conditions for tench, pike and crucian carp (Fig. 2). Average annual catch of these species' amounted to 29 kg/ha and the total catch - to about 40 kg/ha.

Water level was falling down due to gradual devastation of the impounding works during the nineteen seventies. Minimum level occurred on the turn of 1976 when it reached 116.75 m asl. The depth was 49 cm at that time being 31 cm lower than the long-term average (according to the WPMB Olsztyn). This decrease was associated with the persistent decrease of fish catches recorded in the fisheries books implying distinct diminishing of the abundance of fish in this lake (Fig. 3).

The status of vegetation in the lake was investigated over the years 1981-1983 (Polakowski et.al. 1989). Almost total disappearance of elodeids and drastic impoverishing of pleustonic plants was then found. Typically developed shoreward belt of bulrush consisted of fully vital individuals.

The aim of this paper was to determine the trophic status and to show changes in the structure and functioning of this water body.

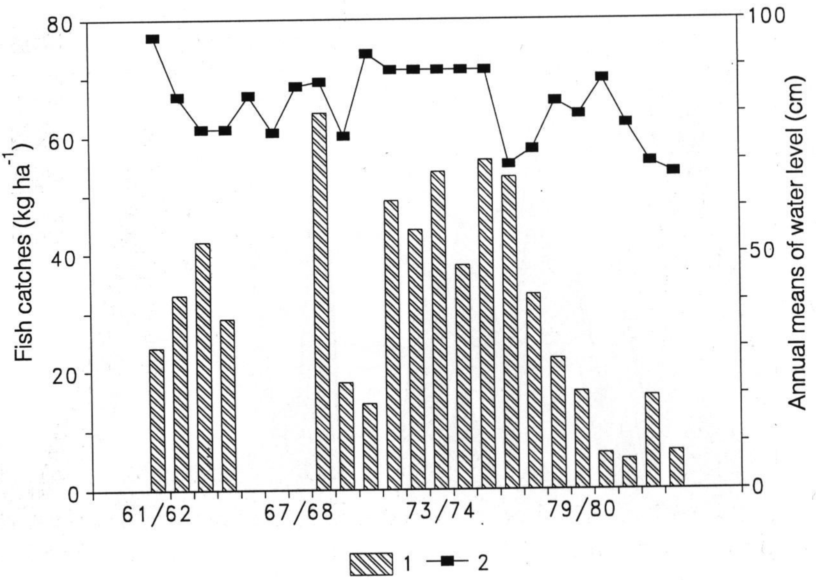

Fig 3. Comparison of total catches with the annual means of water level.

METHODS

Extensive investigations were conducted in 1981, 1983 and 1984. They dealt with physico-chemical parameters of water and sediments. Horizontal differentiation of these parameters as well as of zooplankton and benthos was determined in May 1981. Samples were collected at five sites along the longer axis of the lake (sites A- E, Fig. 3). Monthly sampling was carried out during the 1982. Then, physical and chemical properties of water and of sediments, chlorophyll-a, biomass and composition of phytoplankton and of zooplankton (on site D) as well as specific composition and biomass of bottom fauna (on sites I-III, Fig. 3) were determined.

Samples were taken with the Ruttner sampler, volume 3 dm^3, provided with a thermometer with the accuracy of 0.1°C. Secchi's disk, 30 cm in diameter, was used to determine water transparency. Chemical analyses were made using standard methods (Hermanowicz et al. 1976, Faber et al. 1955).

Quantitative samples of phytoplankton (ca. 150 ml of water) were fixed in Lugol fluid with potassium acetate. Counting of the organisms was carried out by means of a reverted microscope. After a preliminary check, subsamples of 0.5 and 1 cm^3 of water were analyzed. The whole chamber was examined under low magnification in order to count species of large individual size. Dominant species were counted under ten times magnification of the objective glass, examining two diagonals from two chambers. Abundance of nannoplankters was estimated under the objective glass of

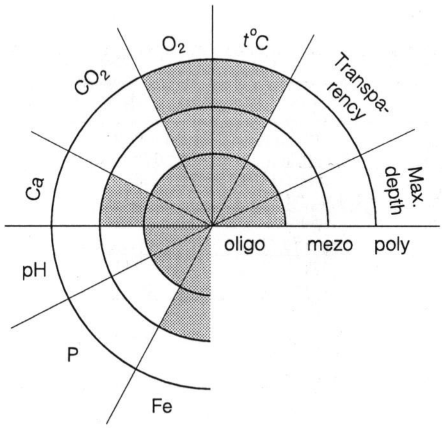

Fig. 4. Hydrochemical spectrum of water of the Pogubie Wielkie according to Stangenberg's (1936) typology.

forty times magnification, in four bands of 27 fields of vision each. A standard of volume of taxons was estimated in each sample. The biomass was assessed as the sum of the products of the number of specimens and respective standard volumes assuming specific wet weight of 1.05 mg $\cdot$ mm^{-3}. Samples of 0.25 or 0.5 dm^3 for chlorophyll-a determinations were filtered off by means of Whatman GF/C filter paper. Extraction and estimation followed the method of Lorenzen (1967).

Zooplankton samples were taken by Bernatowicz sampler. Each sample was obtained from filtering off 20 dm^3 of water through plankton net of nr 27 mesh. Biomass of zooplankters was determined using standard weights (Kosowa 1961, Morduchaj-Boltowvskoj 1954, Starmach 1955).

Bottom fauna was taken by means of a sampler described by Kajak et al. (1965) which has the capture area of 55.42 cm^2. The samples were then sieved out on 0.5-0.6 mm mesh, organisms were selected while living and fixed with 4% formalin. Torsion balance with the accuracy of 0.1 mg was used and length measurements were made to the nearest 0.5 mm.

RESULTS

CHEMICAL COMPOSITION OF WATER AND BOTTOM SEDIMENTS

Most of chemical measurements fall into types oligo or meso of the hydrochemical spectrum (Fig. 4). This concerns particularly the concentrations of magnesium, sodium, potassium, silicates, nitrates and phosphates as well as the electrolytic conductivity (Table 1). Concentrations of oxygen, calcium, ammonia nitrogen, total iron, total nitrogen and total phosphorus belonged to the types eu and poly. High concentration of organic matter, expressed as oxidability, correlated with very high concentrations of organic phosphorus and nitrogen (Table 1).

TABLE 1

Chemical composition of water in Lake Pogubie Wielkie in 1981–1984 during spring (a) and summer (b)

Parameters	a	b
Secchi's disk visibility (m)	0.65 0.60–0.70	0.25 0.15–0.30
T (°C)	19.9 6.7–22.8	22.0 17.6–25.0
O ($mg \cdot dm^{-3}$)	10.9 10.0–13.7	11.8 9.1–16.4
O_2 saturation, %	122 116–132	140 95–186
pH	8.7 8.4–9.3	9.2 8.4–9.9
CO_2	0 0–0	0 0–0
NH_4-N	0.32 0.10–0.43	0.12 0–0.60
NO_2-N	0.003 0–0.016	traces
NO_3-N	0.14 0.09–0.30	0.19 0.08–0.38
N org.–N	2.5 2.0–2.8	3.8 1.6–3.5
PO_4-P	0.010 0.004–0.016	0.012 0.010–0.014
P total	0.125 0.095–0.164	0.345 0.210–0.615
Fe	0.24 0.09–0.38	0.47 0.18–0.78
Mn	traces	traces
SiO_2	1.2 0.8–2.1	5.8 1.4–16.7
Oxidability ($mg \cdot O_2 dm^{-3}$)	29.5 22.7–31.7	30.2 21.2–37.8
Ca	38.0 37.0–41.0	23.0 16.8–29.0
K	1.0 0.1–2.0	0.4 0–0.64
Na	2.5 1.8–2.7	3.1 2.9–3.8
Mg	6.5 5.6–7.2	5.4 4.2–6.3
CO_3	0.75 0–1.5	-
HCO_3	135 125–137	88 83–100
Cl	2.3 2.1–2.7	-
SO_4	12.5 10.8–14.3	13.4 7.5–20.0
Electrolytic conductance ($\mu S\ cm^{-1}$)	252 240–264	154 122–198

A comparison of chemical composition of lake water in spring and summer showed great seasonal differences in these compounds which were of primary importance for phytoplankton production and resulted from intensity of this process (Table 1). First of all this concerned the concentrations of organic and of total phosphorus and nitrogen which increased due to the decomposition of bottom sediments during summer. Very high primary production of planktonic algae resulted in high oxygen concentrations and in high intensity of biological decalcification. What followed was lack of free carbon dioxide, high pH during the whole vegetation season and substantial reduction of calcium, carbonates and conductivity during summer. Very low transparency (down to 0.25) indicated to high primary production, too. The bottom sediments contained outstandingly high amount of organic matter (average 60.2 %, Table 2), hence they can be classified as of an organic type. Great differences of the examined characteristics at particular sites indicated dissimilar sedimentation conditions at various parts of the lake (Table 2). Prevailing western winds were conducive to settling and, hence, to shallowing the northern and the east- northern zone of the lake. Large content of iron in the sediments correlated with similarly large concentrations of this element in the water column. It is likely that iron precipitated as hydroxide in well oxygenated water and fixed a substantial amount of phosphates dissolved in water.

TABLE 2

Chemical composition of sediments in Lake Pogubie Wielkie (percent of dry matter) in 1981 through 1984

Items studied	% dry matter
Organic matter	60.2
	24.2–82.9
Total phosphorus	0.31
	0.05–0.97
Organic phosphorus	1.65
	0.11–3.0
Calcium	8.3
	1.5–27.9
Total iron	2.4
	1.1–5.2

BIOMASS AND STRUCTURE OF PHYTOPLANKTON AND CHLOROPHYLL CONTENT

The lake phytoplankton was very abundant. During the vegetation season of 1982 (April to November) the mean biomass amounted to 33 mg $\cdot$ dm^{-3} and the mean chlorophyll a concentration to 110 mg $\cdot$ dm^{-3}. Both biomass and chlorophyll concentration were low in spring, up to 10 mg $\cdot$ dm^{-3} and up to 30 mg $\cdot$ dm^{-3}, respectively. At the end of June and till the end of September the biomass was about or much more than 30 mg $\cdot$ dm^{-3} and the chlorophyll a - 120 mg $\cdot$ dm^{-3}. Considerable decrease in biomass and chlorophyll, down to the spring levels, was observed in autumn (October-November, Fig. 5). Similar changes occurred in 1981; the biomass in May amounted to 6.4, in June - 37.4 and in September - 30 mg $\cdot$ dm^{-3} and the chlorophyll was 31.2, 65.8, 67.3 mg $\cdot$ dm^{-3}, respectively.

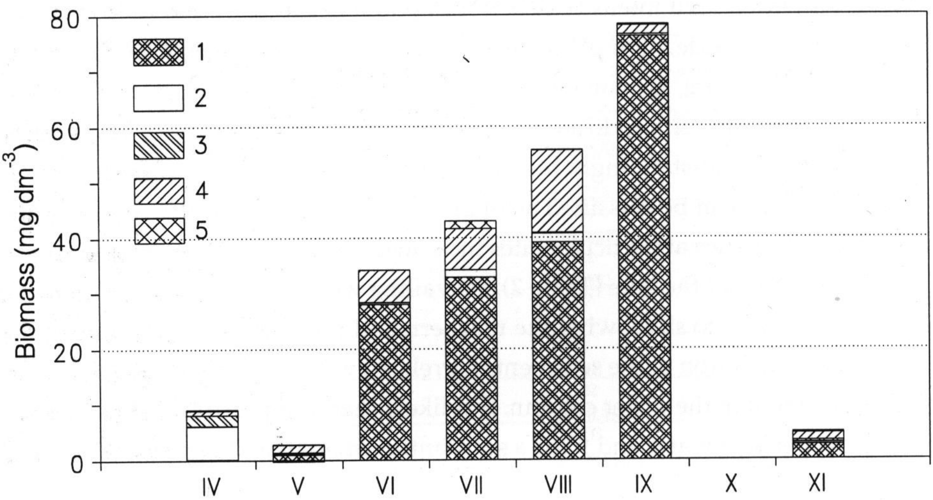

Fig. 5. Phytoplankton biomass in the Pogubie Wielkie and its components: 1 - blue-green algae, 2 - diatoms, 3 - cryptophytes, 4 - green algae, and 5 - other algae.

Blue-green algae distinctly dominated in summer phytoplankton, As of mid June to the end of September they constituted from 70 % (in August) to 97% (in September). They co-dominated with *Aphanizomenon flos-aquae* (L.) Ralfs (35% of biomass), with *Anabaena affinis f. viguieri* (Denis et Fremy) Komarek (33%) and with *Anabaena flos-aquae* Breb. (8%). From July until September *Microcystis aeruginoza* Kütz constituted from 35 to 44% of the total phytoplankton biomass and *Aphanizomenon flos-aquae* - from 9 to 35%. *Gomphospheria cf naegeliana* (Unger) Lemm. co-dominated in July (18%) but *Lyngbya limnetica* Lemn. in August (11%) and in September (16%).

The second important component of the summer phytoplankton was green algae, genus Scenedesmus in particular. Numerous species' of this genus constituted from 7 to 23% of the total biomass. *Tetraedron minimum* (A.Br.) Hansg. and *Cosmarium* sp. were very abundant in May, too.

Diatoms (mainly of *Fragilaria genus*) dominated only in the spring plankton (April) reaching the highest biomass (6.1 mg $\cdot$ dm^{-3}).

Nannoplankton contributed about 30% to the biomass in spring. In April, there was substantial development of little *Cryptomonas*, but in May green algae were the major contributors. Considerably more abundant nonnoplankton in June and in July constituted merely about 15% of the total biomass. The highest biomass (about 18 mg $\cdot$ dm^{-3}, 32% of total biomass) of nannoplankton was recorded in August. Nannoplankton of September contributed merely 1% to the total biomass. By November, due to distinct drop of plankton biomass the fraction of nannoplankton increased again to 33%.

SPECIES COMPOSITION, BIOMASS AND ABUNDANCE OF ZOOPLANKTON

There were 45 taxons recorded in this study, among them 24 taxa of *Rotatoria*, 15 of *Cladocera* and 6 of *Copepoda*. *Protozoa*, *Ostracoda* and *Nematoda* occurred sporadically. *Rotatoria* and *Cladocera* were represented by a fairly large number of species, however, no distinct dominance of rotifers was recorded. *Keratella cochlearis* contributed usually about 1% of zooplankton biomass but in a few cases its relative abundance was from 4 to 28%. Among *Cladocera*, *Daphnia longispina* (O. F. M.) and *Bosmina longirostris* (O.F.M.) clearly dominated. *Sida cristallina* (O. F. M.) and *Diaphanosoma brachyurum* (Lievin) were found once only in 1981 and then they contributed 10% to the total biomass. *Graptoleberis testudinaria* (Fisch) and *Simocephalus vetulus* (O. F. M.) occurred sporadically, mainly as dead remnants. Among *Copepoda*, *Eudiaptomus graciloides*, (Lillj.) and *Mesocyclops leukarti* (Claus) dominated (Table 3).

Analysis of zooplankton distribution in space (May 1981) showed small differences of biomass in the mid-lake area from 8.3 to 11.5 mg $\cdot$ dm^{-3}. Somewhat lower biomass was recorded in the shallow part of the lake at site A (6.8 mg $\cdot$ dm^{-3}) and at site E near the outlet (5.0 mg $\cdot$ dm^{-3}).

In 1982, the zooplankton biomass fluctuated between 6.8 and 16.6 mg $\cdot$ dm^{-3} (Fig. 6). The biomass in the previous year placed itself within a similar range (5.0 - 11.6 mg $\cdot$ dm^{-3}). Maximum biomass occurred during the warmest period (July, Au-

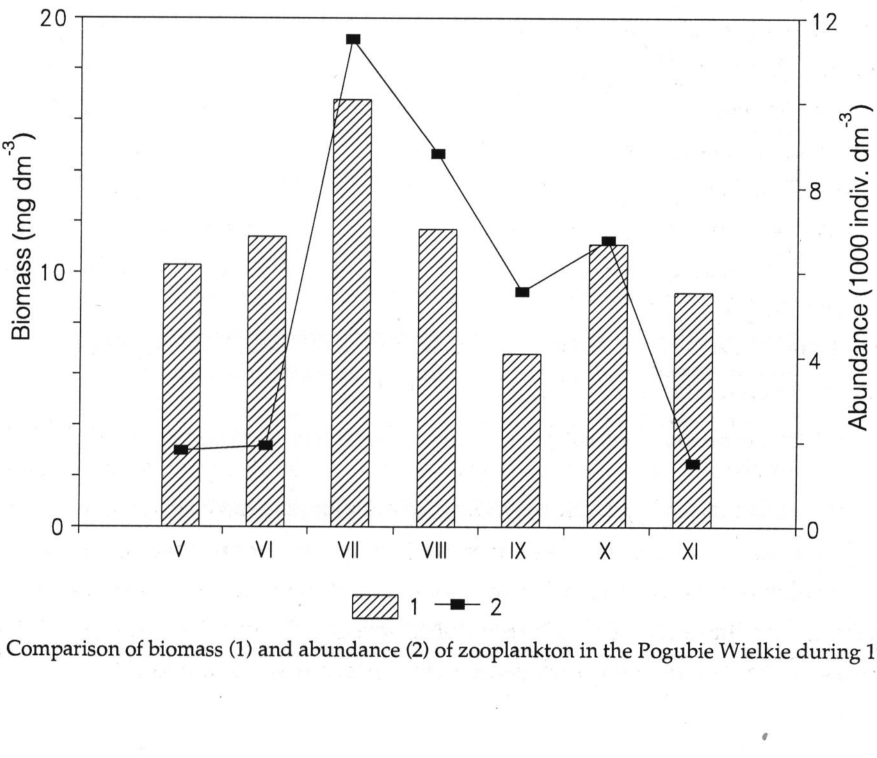

Fig. 6. Comparison of biomass (1) and abundance (2) of zooplankton in the Pogubie Wielkie during 1982

TABLE 3

Zooplankton composition in Lake Pogubie Wielkie during in 1981 and 1982 showing dominance of taxa

	1981	1982
ROTATORIA		
Philodina sp	*	-
Cephalodella sp.	*	-
Trichocerca pusilla (Lauterborn)	*	*
Trichocerca cylindrica (Imhof)	*	*
Trichocerca capucina (Wierz. et Zacharias)	*	*
Trichocerca similis (Wierz.)	*	-
Trichocerca n. det.	*	-
Synchaeta kitina Rousselet	*	*
Polyarthra sp.	*	*
Asplanchna priodonta Gosse	xx	*
Lecane sp.	*	*
Proales micropus (Gosse)	-	*
Lepadella sp.	*	-
Brachionus calyciflorus Pallas	*	*
Brachionus angularis Gosse	*	*
Keratella cochlearis typica Gosse	*	*
Keratella cochlearis tecta Gosse	*	*
Keratella quadrata (Muller)	*	*
Kellicottia longispina (Kellicott)	*	*
Notholca sp.	*	*
Conochilus unicornis Rousselet	x	*
Filinia longiseta (Ehrenberg)	*	*
Collotheca sp.	*	-
Rotatoria n. det.	*	*
CLADOCERA		
Diaphanosoma brachyurum (Lievin)	x	-
Sida crystallina (O.F.M.)	x	-
Ceriodaphnia quadrangula (O.F.M.)	*	*
Daphnia cuculata Sars	x	x
Daphnia longispina (O.F.M.)	xx	x
Daphnia sp.	x	*
Simocephalus vetulus (O.F.M.)	-	*
Bosmina longirostris (O.F.M.)	xx	xxx
Bosmina coregoni Baird	x	*
Alona quadrangularis (O.F.M.)	*	*
Alona rectangula Sars	*	x
Alonella nana (Baird)	-	*
Chydorus sphaericus (O.F.M.)	x	*
Graptoleberis testudinaria (Fisch)	-	*
Leptodora kindti (Focke)	x	x
COPEPODA		
Eudiaptomus graciloides (Lillj.)	xxx	xxx
Cyclops vicinus Ulj.	*	*
Mesocyclops leuckarti (Claus)	xxx	xxx
Thermocyclops oithonoides (Sars)	*	*
Kopepodites	x	x
Nauplii	xx	x
OTHER		
Protozoa	*	*
Ostracoda	-	*
Nematoda	-	*

*Explanation of the symbols: xxx - over 10% of zooplankton biomass, xx - rarely over 10%, x - most frequently 1 to 10%, * - less than 1%, - (minus sign) - taxa not recorded in the respective season*

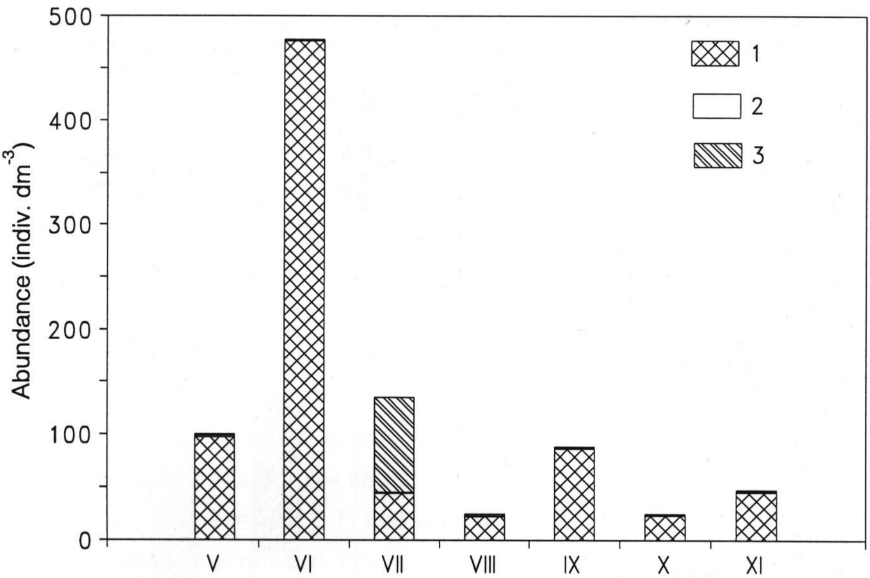

Fig. 7. Abundance of predatory copepods (1), rotifers (2) and cladocerans (3) in the Pogubie Wielkie during 1982

gust) and then copepods dominated: 49 % of the total biomass in July and 75% - in August. Rotifers reached peak development at that time (13 and 16%, respectively), whereas the biomass of cladocerans constituted 37% in July and only just 9 % in August. The second culmination of the biomass appeared at the end of October due to intensive development of cladocerans (82% of biomass), mainly of *Bosmina longirostris*. Biomass was changing roughly parallel to the abundance of zooplankton (Fig. 6).

Predatory taxa constituted merely 5% of the total abundance (maximum of 25% in June) and the most numerous were copepods (maximum 477 individuals per dm^{-3}), Fig. 7). The non-predatory zooplankters definitely dominated this community, the rotifers contributed to the total abundance 90% in July and 96% in August (Fig. 8). The maximum abundance of non-predatory rotifers appeared in July and it reached 12400 individuals per dm^{-3}. Cladocerans dominated from August, and their maximum abundance of 6200 indiv. dm^{-3} (90% of total abundance) was attained in October (Fig. 8)

COMPOSITION AND BIOMASS OF BOTTOM FAUNA

The bottom fauna was very poorly diversified and consisted almost exclusively of *Oligochaeta*, *Chironomidae* larvae and *Heleidae* larvae. *Trichoptera*, *Ephemeroptera*, *Hydracarina* and *Hirudinea* were represented in the samples sporadically only.

The mean total biomass of the benthic fauna amounted to 30 - 40 kg · ha^{-1} ; in summer it was at its minimum not exceeding 20 kg and during the remaining period - 115 kg · ha^{-1}

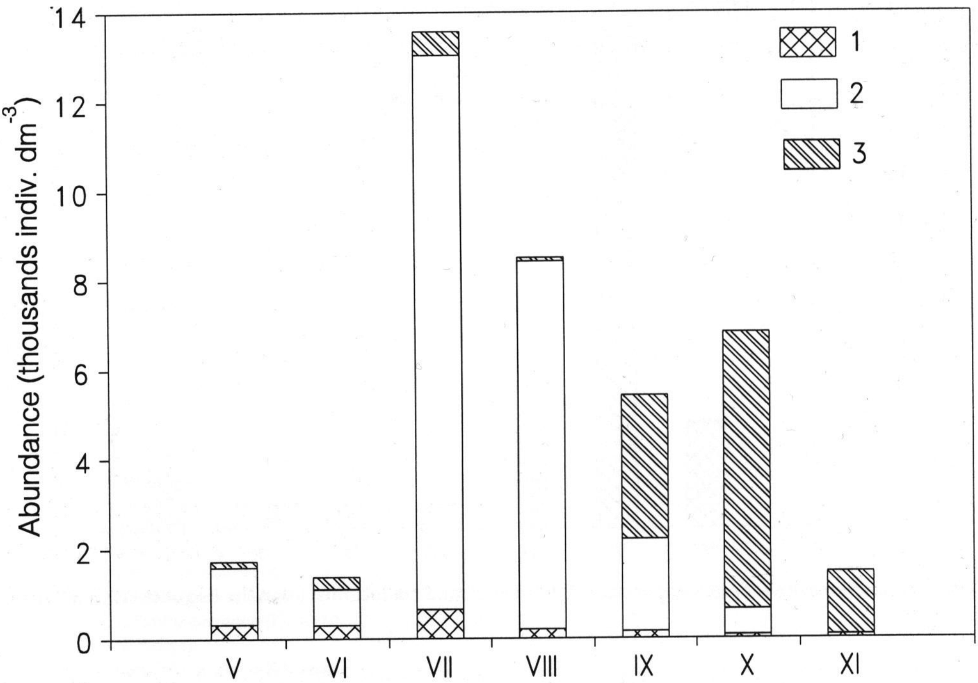

Fig. 8. Abundance of non-predatory copepods (1), rotifers (2) and cladocerans (3) in the Pogubie Wielkie during 1982

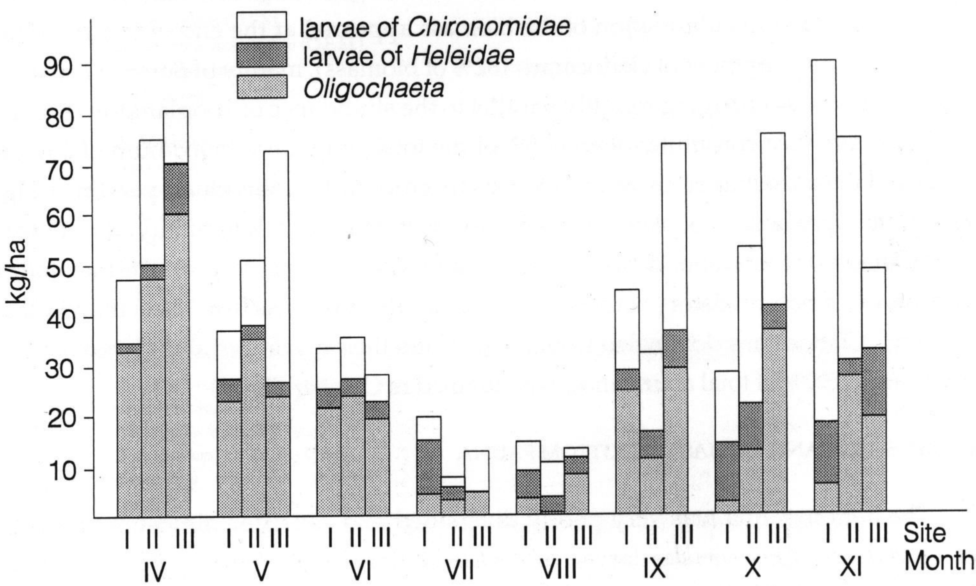

Fig. 9. Total biomass of bottom fauna and its components: 1 - *Chironomidae* larvae, 2 - *Heleidae* larvae, and *Oligochaeta* at three sites (I - III) in the Pogubie Wielkie during 1982

(Fig. 9). In spring, *Oligochaeta* dominated with a biomass of 19 - 60 kg · ha^{-1}. Biomass of that group made up from 62 to 75% of the total benthic biomass at three sites, exceptionally at site III in May it was 33%. This resulted from a considerable development of *Chironomidae* larvae - 46.4 kg · ha^{-1}, and 63% of biomass. These larvae made up one of the main constituents of the bottom fauna in autumn and their biomass at three sites ranged from 13.6 to 72.1 kg · ha^{-1} (34 - 80% of total biomass, Fig.9).

Among the *Chironomidae* larvae, *Procladius* only occurred in all periods and at all sites demonstrating some decrease in biomass (about 5 kg · ha^{-1}) and abundance from May on, and a distinct increase in biomass (up to 20 - 25 kg · ha^{-1}) from September onward. Other species of this group appeared periodically, e.g. *Eifeldia ex gr. carbonaria* (Meig.) was found until June (2 kg) and then late autumn (up to 5 kg · ha^{-1}), *Cryptochironomus ex gr. conjugens* (Kieff.) was abundant (7 - 17 kg · ha^{-1}) in May but disappeared during summer, and *Tendipes f. l. semireductus* Lenz. appeared abundantly (10 - 30 kg · ha^{-1}) from September onward. *Tendipes f. l. plumosus* (L.) was recorded at various sites in different periods showing much variable densities (0 - 17 kg · ha^{-1}). Larvae of *Heleidae* occurred in quantities from 1 to 10 kg · ha^{-1} from April to November.

With respect to the distribution of benthos biomass (May 1981), the lowest levels were found at site A, in the northern shallow part of the lake (20.6 kg · ha^{-1}), and at site E at the outlet (28.3 kg · ha^{-1}) whereas the highest biomass levels (53.2, 59.7, 54.3

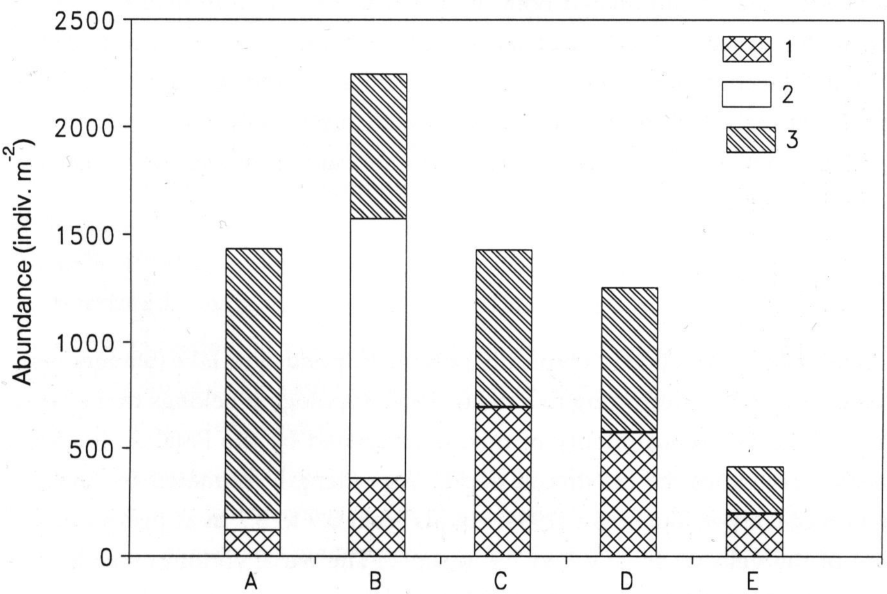

Fig. 10. Total biomass of bottom fauna at five sites A - E in May 1981 and its components: 1- *Chironomidae* larvae, 2 - *Heleidae* larvae, and 3 - *Oligochaeta*

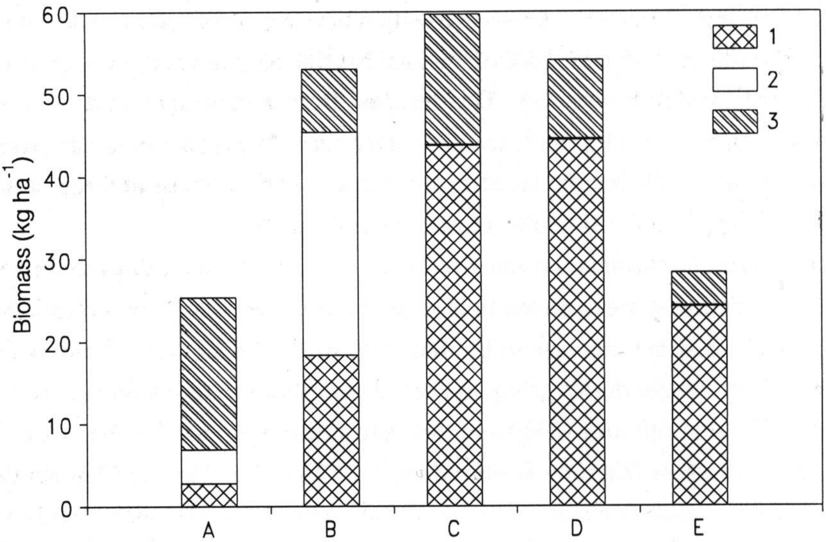

Fig. 11. Density of benthos at five sites A - E in May 1981, as in figure 10. Table 1. Chemical composition of water in the Lake Pogubie Wielkie in years 1981 - 1984 during spring (a) summer (b)

kg · ha^{-1}) appeared at intermediate sites (Fig. 10). Similar distribution was found with regard to the numbers of specimens per m^{-2} of bottom (Fig. 11). There was, however, a greater difference between the extreme sites A and E in favor of the former, in which *Chironomidae* larvae dominated both in numbers (88%) and in biomass (73%). Fractions of the larvae in totals decreased to the advantage of *Oligochaeta* along with southward location of the sites; the relative biomass of the worms increased rapidly from 11% at site A to 85% at E but with respect to numbers there was not such a trend. The main fraction of benthos at site B, numerically and mass-wise, consisted of *Heleidae* larvae.

DISCUSSION

Lake Pogubie Wielkie is a typically polymictic pond-type lake (Stangenberg 1936, Wiszniewski 1953). According to Patalas (1960) typology it belongs to the I degree of stability. The theoretical ability of mixing estimated by the Patalas (1960) formula exceeds three times the maximum depth. Wave length estimated by means of the equation of Carper, Buchman (1984) equals from 0.9 to 3.7 m at prevailing western winds of the velocity from 2.1 to 7.9 m sec^{-1}. The wave bottom exceeds the mean depth even at small wind velocity of 2.1 m sec^{-1}.

Vanishing of the hydrophytes exposed the lake bottom during the nineteen seventies. The sediments were being raised by strong waves and their low consistency caused considerable interface between water and bottom. Hence, the open water area was not isolated from the influence of bottom sediments.

Physico-chemical data revealed a hydrochemical spectrum of a kind characterizing fertile wetlands with high pH and rich in humic organic matter of oligotrophic type (Wiszniewski 1953). Phosphorus and nitrogen contents in sediments were typical for lakes of high trophy (Zdanowski 1983b).

During these investigations, chemical composition of water remained within the range typical for the most lakes of the Mazurian Lakeland (Patalas 1960, Korycka 1969, 1991, Zdanowski 1982, 1983a). A continuous inflow of calcium to the lake prevented distrophication. During summer, Pogubie Wielkie Lake was characterized by lower concentrations of main chemical components than other water bodies and lower electrolytic conductivity (Korycka 1991). Concentrations of ammonia nitrogen and of nitrate nitrogen corresponded to the averages in lakes deeper than 2.5 m. About seven times lower concentration of phosphates indicates their intensive utilization by phytoplankton. The phosphorus and nitrogen compounds released from the sediments enriched lake water in summer, resulting in an intensive bloom of phytoplankton. Intense production kept oxygen concentration high and caused high intensity of biological decalcification during summer, what in turn resulted in elevated pH of water and in significant diminishing of carbonate ions and of electrolytic conductivity. A substantial amount of mineral compounds , hitherto incorporated in the tissues of submerged vegetation, was included in the production process and deposited in bottom sediments as a slowly decomposing fraction of organic matter.

The Pogubie Wielkie environment created, first of all, suitable condition for phytoplankton development. Spring domination of diatoms and aestival blooms of blue-greens along with the development of green algae are characteristic for shallow and fertile lakes of the Mazurian Lakeland (Pótoracka 1962, Sosnowska 1974, Spodniewska 1978, 1979). Development of phytoplankton during the vegetative season was characterized by extraordinary intensity. The maximum biomass (August, September) highly exceeded 50 mg $\cdot$ dm^{-1}, i.e. the level recorded sporadically only in Mazurian lakes during the summer stagnation (Spodniewska 1978, 1979). Consequently, transparency was very low.

Intensive development of the blue-green algae: *Microcystis aeruginosa, Anabaena flos-aquae, A. spiroides, Aphanizomenon flos- aquae,* as well as of the green algae: *Pediastrum boryanum, P. duplex* and many species of the *Scenedesmus* genus point to a high degree of eutrophication.

The composition and structure of zooplankton were typical of those found in polymictic water bodies of pond-like type (Patalas 1963, Karabin 1981). The high abundance of minute green algae and lack of submerged plants affected formation of zooplankton community. A definite trend of vanishing rotifers and crustaceans associated with vegetation was recorded as well as there was a substantial fraction of small pelagic animals in this community. A similar reconstruction of zooplankton had been observed in the pond-like lake Warniak where the grass carp eradicated hitherto luxuriant vegetation (Hillbricht-Ilkowska, Węgleńska 1973, Węgleńska et.al. 1979).

The zooplankton biomass was shaped by rotifers and cladocerans in spring, and by small cladocerans in summer, mainly by *Bosmina longirostris*. Bittel (1974) and Widuto (1979) related mass appearance of *B. longirostris* to an increase in trophy of water bodies. A large fraction of small plankters in the total biomass could be characteristic of high trophy water bodies according to Pijanowska (1980) and to Karabin (1981).

Predatory plankters constituted a minor fraction of the total abundance during the whole vegetative season. On the contrary, non- predatory zooplankters, for which the green-algae formed a suitable feeding ground, decidedly dominated the community. In turn, intensive development, therefore a large biomass of zooplankton (over 5 mg $\cdot$ dm^{-3} during the whole vegetative season) and high abundance (often exceeding 6000 individuals per dm^{-3}) created beneficial feeding conditions for planktonivorous fish. This, however, resulted from an exceptionally low pressure of these fish on zooplankton.

The bottom fauna was hardy diversified. Although the Pogubie Wielkie was classified as a pond-like type of lake, its bottom fauna, both qualitatively and quantitatively, was not typical. The likely cause of the above described situation was the winter kills (Olszewski, Paschalski 1959). Lack of submerged flora and turbulent sediments limited occurrence of bottom organisms especially of the insect larvae and of *Isopoda* and *Amphipoda*. It is difficult to explain the considerable drop of *Oligochaeta* biomass in summer but by the oxygen deficiency in lower layers of the sediments.

The dominance of *Oligochaeta* and of *Tendipedidae* larvae suggests that the fauna of the Pogubie Wielkie was typical for the highly eutrophicated water bodies (Starmach 1969). The limited occurrence of *Heleidae* larvae and the overall presence of predatory larvae of *Procladius* indicated bad environmental conditions in this water body.

The essential problem is that of the causes of changes in the lake. In the already quoted paper by Polakowski et.al.(1989, see Introduction) it was suggested that the transformations were, after all, of natural origin. „The character of the catchment area and the activities undertaken in this area as well as in the lake itself do not provide any basis for relating the vanishing of aquatic flora to the economic activities of man". However, these authors did not take into consideration fluctuations of the lake water level. The latter were an essential factor determining functioning of the ecosystem. This is clearly demonstrated by the dependence of fish catches on water levels (Fig. 3). Distinct decreases in the catches were observed at periods of prolonged subsidence of water levels, escalating possibilities of winter kills. The vanishing of elodeids and of pleustonic plants as well as the above described transformations of the ecosystem structure have to be related to the lake water levels. Unfortunately, lack of hydrochemical and biological data for the crucial years in the lake history prevents any unequivocal acceptance of the thesis that the drop of water level was the only determining factor. Also, this lack does not allow for exclusion of the influence of increasing trophy on the eradication of submerged plants.

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SHORT COMMUNICATION

Water relations in the catchment area of Lake Pogubie Wielkie have been regulated in 1991. Natural flow of the Rybnica River (about 0.46 m^3 sek.$^{-1}$), which carries the water to Lake Pogubie Małe and then to the Pisa River, as well as construction of a new bed for the Barłoga River which takes the excess of water directly to the Pisa River result in the fact that it is now possible to maintain constant, average water level in the lake at the height of 117.07 m above the sea level. This ensure good protection of the adjacent forest areas and enables the restoration of the natural lake structure and functioning. The plants will be able to develop again after the bottom sediments have been reestablished and this, in turn, should induce the presence of fish and water fowl. Studies carried out in summer 1993 suggest that this is really the case. There were no water blooms and the lake water was of good quality, while phosphorus and nitrogen levels decreased. Chlorophyll content did not exceed 10 μg dm^{-3} and water oxidability was below 17 mg O_2 dm^{-3}. Total phosphorus content amounted to 0.085 mg dm^{-3} and total nitrogen to 1.5 mg dm^{-3}.

REFERENCES

Bittel L. 1974 - Pelagiczny plankton zwierzęcy jezior szczycieńskich - Zesz. Nauk. ART Olsztyn 3: 81–94

Carper G.L., Bachmann R.W. 1984 - Wind resuspension of sediments in a prairie lake - Can.J.Fish.Aquat.Sc. 41: 1763–1767

Faber H.A., Hatfield W.D., McCrady M.H. (Ed.) 1955 - Standard methods for the examination of water, sewage, and industrial wastes - American Public Health Association, INC, New York

Hermanowicz W., Dożańska W., Dojlido J., Koziorowski B. 1976 - Fizyczno-chemiczne badania wody i ścieków - PWN, Warszawa

Hillbricht-Ilkowska A., Węgleńska T. 1973 - Experimentally increased fish stock in the pond type lake Warniak. VII. Numbers, biomass and production of zooplankton - Ekol. pol. 21(33): 533–552

Kajak Z., Kacprzak K., Polkowski R. 1965 - Chwytacz rurowy do pobierania prób dna - Ekol.pol. 11: 153–165

Karabin A. 1981 - Analiza zmienności strukturalnych i ilościowych cech zespołów zooplanktonowych w procesie eutrofizacji jezior dla potrzeb monitoringu ekologicznego - Instytut Ekologii PAN, Dziekanów Leśny, praca doktorska

Korycka A. 1969 - Seasonal changes in water chemical composition in seven lakes - Pol. Arch. Hydrob. 16: 1–29

Korycka A. 1991 - Charakterystyka chemicznego składu wody w jeziorach północnej Polski - Rocz.Nauk Rol. Ser.H 102(3): 1–112

Kosova A.A. 1961 - Vycislennye vesa nekotorych form zooplanktona nizov'ev del'ty Volgi - Trudy Astrach. Zapov. 5: 151–159

Lorenzen C.J. 1967 - Determination of chlorophyll and pheopigments: spectrophotometric equations - Limnol. Oceanogr. 12: 343–346

Morduchaj-Boltovskoj F.D. 1954 - Materialy po srednemu vesu vodnych bespozvonocnych bassejna Dona - Trudy Probl.Temat.Sovesc. ZIN 11: 223–243

Olszewski P., Paschalski J. 1959 - Wstępna charakterystyka limnologiczna niektórych jezior Pojezierza Mazurskiego - Zesz. Nauk. WSR Olsztyn 4: 1–109

Patalas K. 1960 - Mieszanie wody jako czynnik określający intensywność krążenia materii w różnych morfologicznie jeziorach okolic Węgorzewa - Rocz.Nauk Rol. Ser.B 77(1): 223–242

Patalas K. 1963 - Sezonowe zmiany w pelagicznym planktonie skorupiakowym sześciu jezior okolic Węgorzewa - Rocz. Nauk Rol. Ser.B 82(2): 209–234

Pijanowska J. 1980 - Zooplankton communities in nine Masurian lakes - Ekol.pol. 28(3): 451–465

Polakowski B., et al. 1989 - Up-to-date state of plants in the Pogubie Wielkie Sanctuary compared to habitat seats conditions - Acta Acad.Agric.Techn.Olszt. 48: 1–35

Półtoracka J. 1962 - Sezonowe zmiany planktonu roślinnego pięciu jezior okolic Węgorzewa - Acta Soc.Bot.Pol. 34(4): 667–681

Sosnowska J. 1974 - Zbiorowiska planktonowe trzech jezior mazurskich i zawartość chlorofilu w ich fitoplanktonie - Monogr. Bot. 42: 1–128

Spodniewska J. 1978 - Phytoplankton as the indicator of lake eutrophication. I. Summer situation in 34 Masurian lakes in 1973 - Ekol.pol. 26: 53–70

Spodniewska J. 1979 - Phytoplankton as the indicator of lake eutrophication. II. Summer situation in 25 Masurian lakes in 1976 - Ekol.pol. 27: 481–496

Stangenberg M. 1936 - Szkic limnologiczny na tle stosunków hydrochemicznych Pojezierza Suwalskiego - Rozpr.Spraw.Inst.Badaw.Lasów Państw. 16: 7–85

Starmach K. 1955 - Metody badania planktonu - PWRiL, Warszawa

Starmach K. 1969 - Wody śródlądowe. Zarys hydrobiologii - Kraków

Widuto J. 1979 - Zooplankton Jeziora Długiego w Olsztynie zanieczyszczonego ściekami gospodarczo-bytowymi - Zesz. Nauk. ART Olsztyn 9: 93–103

Węgleńska T., et al. 1979 - Effect of winters kill and changing fish stock on the biocenose of the pond - type lake Warniak - Ekol.pol. 27(1): 39–70

Wiszniewski J. 1953 - Uwagi w sprawie typologii jezior polskich - Pol. Arch. Hydrob. 1: 11–23

Zdanowski B. 1982 - Variability of nitrogen and phosphorus contens and lake eutrophication - Pol. Arch. Hydrob. 29(3–4): 541–597

Zdanowski B. 1983 - Ecological characteristics of lakes in northeastern Poland versus their trophic gradient. III. Chemistry of the water in 41 lakes - Ekol.pol. 31: 287–308

Zdanowski B. 1983 - Ecological characteristics of lakes in northeastern Poland versus their trophic gradient. IV. Chemistry of bottom sediments in 37 lakes - Ekol.pol. 31: 309–331

STRESZCZENIE

WARUNKI ŚRODOWISKOWE I TROFICZNE W JEZIORZE POGUBIE WIELKIE PO ZANIKNIĘCIU ROŚLINNOŚCI ZANURZONEJ

Przeprowadzone w latach 1981 - 1984 badania fizyczno-chemiczne wody, osadów dennych, fitoplanktonu, zooplanktonu i fauny dennej miały określić stan troficzny oraz wskazać zmiany w strukturze ekosystemu jeziora Pogubie Wielkie po obniżeniu poziomu lustra wody (rys. 3).

Większość badanych wskaźników chemicznych wody układała się w typie oligo lub mezo. W typie eu i poli występowały związki decydujące o produkcji pierwotnej (rys. 4, tab. 1). Zanik roślinności naczyniowej dennej uaktywnił latem proces dopływu związków fosforu i azotu z osadów do wody (tab. 1). Wysoka produkcja fitoplanktonu utrzymywała alkaliczny odczyn wody oraz prowadziła do obniżenia zawartości wapnia, węglanów i przewodnictwa elektrolitycznego (tab. 1).

Latem obserwowano bardzo silny rozwój fitoplanktonu. Dominacja sinic i licznych drobnych zielenic świadczyła o wysokiej trofii jeziora (rys. 5). Skład zooplanktonu był charakterystyczny dla politroficznych zbiorników typu stawowego (tab. 3). Wiosną i latem biomasę zooplanktonu tworzyły wrotki i wioślarki, jesienią drobne wioślarki, głównie *Bosmina longirostris*. W sezonie wegetacyjnym zdecydowanie dominowały formy niedrapieżne (rys. 7 i 8). Biomasa i struktura planktonu zwierzęcego świadczyły o niskiej presji ryb na ten zespół.

Fauna denna była słabo zróżnicowana. Tworzyły ją głównie *Oligochaeta* (prawie wyłącznie *Tubificidae, Tendipedidae, Heleidae*, rys. 9). Struktura bentosu była typowa dla zbiorników bardzo silnie zeutrofizowanych o złych warunkach środowiskowych z punktu widzenia fauny dennej.

Zakwity fitoplanktonu, duża żyzność wody i ruchliwość osadów dennych stworzyły trwałe niekorzystne warunki siedliskowe dla roślinności zanurzonej. Brak roślin ograniczył warunki tarłowe dla ryb fitofilnych.

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