EKOLOGIA POLSKA (Ekol. pol.)	34	3	491 – 513	1986

Edward KRZYŻANEK

Hydrobiological Station, Laboratory of Water Biology,
Polish Academy of Sciences, 43 – 230 Goczałkowice, Poland

DEVELOPMENT AND STRUCTURE OF THE GOCZAŁKOWICE RESERVOIR ECOSYSTEM XIV. ZOOBENTHOS

ABSTRACT: The paper contains a description of the zoobenthos and of the process of its formation during the 28-year existence of the Goczałkowice reservoir. Five stages have been distinguished: the first one comprised 1955 and was characterized by the recession of terrestrial and river fauna; the second (1956 – 1959) – by a mass development of Chironomidae; the third (1960 – 1963) – by the growth of other zoobenthic groups; the fourth (1964 – 1973) – by a rapid decrease in numbers; the fifth (since 1974) – by a new growth in numbers and a stabilized specific composition.

KEY WORDS: Reservoir, ecosystem, zoobenthos, succession.

1. INTRODUCTION

The zoobenthos studies represent part of the comprehensive hydrobiological researches that have been carried out on the Goczałkowice dam-reservoir for 28 years. The present paper provides a summarizing elaboration of the results from these studies. The main part of the paper is based on the results from studies carried out by the author in the years 1961 – 1982. The results have already been partially published (K r z y ż a n e k 1965, 1966a, 1966b, 1970, 1973, 1976, 1977). The results from studies carried out during the first six years of the reservoir's existence have been elaborated on the basis of the literature (K y s e l a 1956, 1958, Z a ć w i l i c h o w s k a 1965a, 1965b, 1965c).

2. MATERIAL AND METHODS

In the years 1955 – 1960, zoobenthes samples were collected at 10 – 16 stations on the northern and southern banks and in the central part of the reservoir. In the early 60s, 6 main zones could be distinguished in the water body:

(A) central zone 6 – 10 m deep, with muddy bottom,

(B) river Bajerka bay zone 2 – 3 m deep, with mud-sandy bottom and macrophytes, mainly rushes,

(C) south-western inshore zone 1 – 3 m deep, with muddy bottom, covered with macrophytes,

(D) north-western inshore zone 1 – 4 m deep, with muddy and mud-sandy bottom, overgrown with macrophytes,

(E) south-eastern inshore zone 1 – 2.5 m deep, with muddy bottom and macrophytes,

(F) north-eastern inshore zone 1 – 3 m deep, with sandbank-covered bottom without macrophytes.

When selecting the sampling stations these zones and the 1955 – 1960 sampling stations were taken into account. In the years 1961 – 1975, samples were collected at 16 – 19 stations (Fig. 1). In the years 1976 – 1982, the research was restricted to 4 stations most typical of this water body. These stations corresponded to the following zones: station I – to zone A, II – B, III – C, IV – D (Fig. 1).

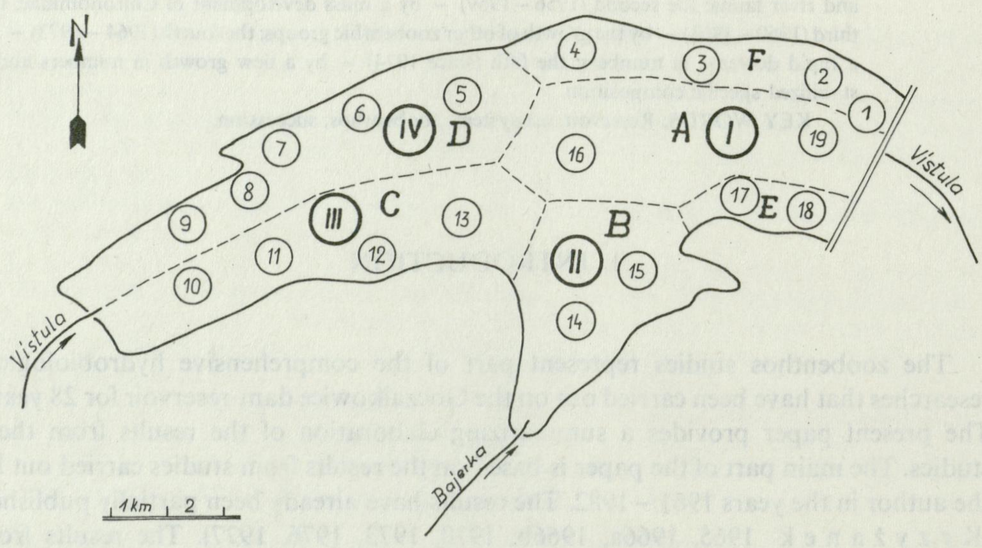

Fig. 1. A map of sampling station distribution in the Goczałkowice reservoir in the years 1961 – 1975 (stations 1 – 19) and in the years 1976 – 1982 (stations I – IV)
A – F – reservoir zones

Up to 1970, only numbers were determined, since 1971 also biomass. For earlier years the larval biomass of *Chironomus* sp. I (? *Ch. plumosus* L.), *Procladius* sp. and Bivalvia was determined on the basis of samples collected by earlier researchers.

Sampling methods were the same all the time. Samples were collected 4 – 5 times a year from May to November, usually at the following dates: end of May-beginning of June, July, August, September and end of October-beginning of November. Samples were collected with an Ekman-Birge grab 225 cm^2 in aperture size (2 – 4 grabs per sample), or a dredge. The contents were washed on a bolting-cloth sieve 0.5 mm in mesh-size. Animals removed from the samples live were preserved in 4% formalin. The results were calculated per 1 m^2 area. Species names are based on "Limnofauna Europaea" (I l l i e s 1978). In the case of Chironomidae the basic material was larvae which cannot always be with certainty indentified to the species. For this reason, the taxa distinguished were in most cases designated with consecutive Roman numbers (K r z y ż a n e k and K r z y ż a n e k 1986).

In 1972, taking advantage of the lowering of the water level and uncovering of 600 ha of the reservoir bottom, a study of bivalves was carried out at 6 stations (at each station 5 sampling spots were established, each of the size of 3 m^2) which corresponded to the following permanent zoobenthos sampling stations: 2, 3, 6, 12, 14, 17 (Fig. 1). The species composition, numbers and biomass were determined and all necessary biometric measurements were made of 2390 specimens.

Similar investigations were carried out, by diving, in the water-filled part of the reservoir where sampling was done at depths of 2, 3 and 6 m (a 1 m^2 frame was used) in 4 sections of the reservoir on its northern and southern sides. Reservoir bottom area for specified depths was taken from tables containing topographical and hydrological parameter data (Silesian Institute of Technology 1956 – unpublished data). Sampling techniques and method of result calculation have been described in detail in a separate paper (Krzyżanek 1976).

3. RESULTS

3.1. DESCRIPTION OF ZOOBENTHIC GROUPS

Larvae of Chironomidae were the dominant group of zoobenthos. Dominant in the Tanypodinae subfamily was the genus *Procladius*. It is the main zoobenthos component in all dam reservoirs (J a n k o v i č 1972, Š i l o v a 1976, P r a t 1980).

In the years 1953, 1954, *Procladius* was often found in small water bodies in the area to be flooded by the Goczałkowice dam-reservoir (B. Grzybowska – unpublished data). After the filling of the reservoir it occurred sporadically, and in 1956 it was not caught even once. From 1957 on, it was encountered more and more often and in ever-increasing numbers. The growth in numbers and biomass of this genus continued

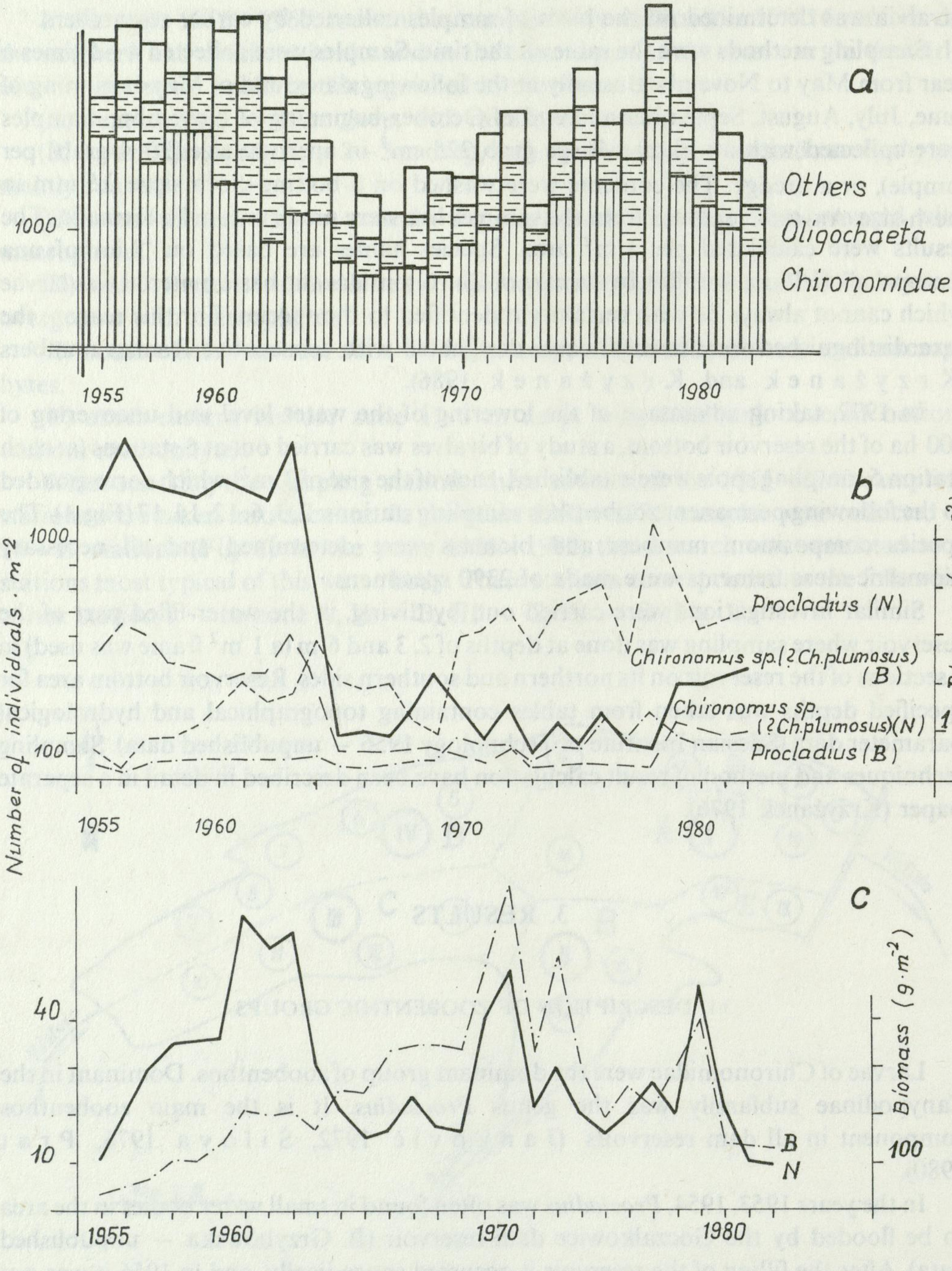

Fig. 2. a – variations in zoobenthos numbers (average annual values for the whole reservoir) in the years 1955–1982, b – variations in numbers (N) and biomass (B) of *Chironomus* sp. I (? *Ch. plumosus*) and *Procladius* sp., c – variations in numbers (N) and biomass (B) of Bivalvia

throughout the study period (Fig. 2). From 1964 on, it was dominant. In its spatial distribution it was found to be more numerous in the central zone, but its contribution to the zoobenthos of this zone was only 5 – 8% higher than in other zones of the water body.

In the years 1958 – 1963, the fairly frequently-encountered forms included: *Clinotanypus* sp. (? *C. nervosus* Mg.) and *Ablabesmyia* sp.; in later years mainly *Tanypus* sp. I (? *T. punctipennis* Meig.).

Most numerous was the subfamily Chironominae, tribe Chironomini. *Chironomus* sp. I (? *Chironomus plumosus*) was dominant. Mass growth of this form was often observed in dam-reservoirs in the years immediately after their filling (Zelinka 1962, Jankovič 1972, Morduchaj-Boltovskoj et al. 1972). In the years 1955 – 1963, it caused a high biomass of Chironomidae larvae in the Goczałkowice reservoir (Fig. 2). In 1964, its numbers and biomass dropped rapidly, and remained at a low level till 1977. Since 1978, there occurred new, though slight, growth in numbers and biomass of this form. Constant zoobenthos components were, in addition to *Chironomus* sp. I (? *Ch. plumosus*), predatory forms of the genus *Cryptochironomus*, mainly *C. defectus* K., pelophilous – *Microchironomus* sp. (? *M. tener* K.), *Polypedilum* sp. III (? *P. nubeculosum* Mg.) and phytophilous – *Microtendipes* sp., *Dicrotendipes* sp. I (? *D. nervosus* Staeg.) and *Glyptotendipes* spp. The Tanytarsini tribe was usually represented by two forms: *Tanytarsus* spp. and *Cladotanytarsus* sp. (? *C. mancus* Wulp.), and the subfamily Orthocladinae by: *Cricotopus sylvestris* (Fabr.) and *Psectrocladius* spp.

In this family, the succession of the particular taxa was fairly clear (Table 1). During the whole history of the reservoir 60 taxa have been identified. Most frequently--encountered were representatives of the Chironominae subfamily (Chironomini – 33, Tanytarsini – 5), followed by Orthocladinae 12 and Tanypodinae – 10.

A total of 22 taxa of phytophilous fauna have been identified (Kuflikowski 1974), therein 5 not found in the zoobenthos (all belonging to Orthocladinae).

The second most numerous group represented in the zoobenthos of the reservoir was Oligochaeta.

All terrestrial oligochaetes became extinct as a result of the filling. But 3 weeks after the filling large numbers of earthworms could still be seen washed to the shore. Two months after the filling of terrestrial Oligochaeta a few Enchytreidae were encountered. More and more often, especially in the central zone, aquatic Oligochaeta were found. They gradually grew in numbers attaining the highest abundance in the years 1961 – 1963. A decrease in their numbers was, however, recorded in 1967 and 1973, probably due to a considerable lowering of the water level in 1965 and 1972. The central bottom zone of the Goczałkowice reservoir was colonized primarily by representatives of Tubificidae, the inshore zone by Lumbricidae and Naididae. Most frequently--encountered were: *Tubifex tubifex* (Müll.), *T.* sp., *Limnodrilus hoffmeisteri* Clap. and *Nais* spp.

Molluscs were the dominant group in the biomass of the zoobenthos. During the first years following the filling gastropods were represented in the inshore zone mainly

Table 1. Succession of selected Chironomidae

Taxa	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Pseudosmittia sp.	+											
Smittia sp.	+											
Chironomus sp. I (? *Ch. plumosus*)	+	+	+	+	+	+	+	+	+	+	+	+
Procladius sp.	+	+	+	+	+	+	+	+	+	+	+	+
Polypedilum sp. III (? *P. nubeculosum*)	+		+	+	+	+	+	+	+	+		
Chironomus sp. II (? *Ch. thummi*)	+	+	+	+	+							
Paratendipes sp.			+	+	+	+	+					
Clinotanypus sp. (? *C. nervosus*)				+	+	+	+	+	+			
Ablabesmyia sp.				+	+	+	+	+	+	+		
Cryptochironomus defectus	+						+	+	+	+	+	+
Microchironomus sp. (? *M. tener*)							+	+	+	+	+	+
Dicrotendipes sp. (? *D. nervosus*)							+	+	+	+	+	+
Tanypus sp. I (? *T. punctipennis*)							+	+		+	+	
Polypedilum sp. IV (? *P. pedestre*)								+	+	+		
Stictochironomus sp. I (? *S. histrio*)								+	+	+		
Stictochironomus sp.										+	+	+
Xenochironomus xenolabis										+	+	+
Micropsectra spp.												
Tanypus sp. II (? *T. Kraatzi*)									+			

by: *Lymnaea stagnalis* L., *Physa fontinalis* L. and *Gyraulus albus* Müll. This zone was later inhabited by representatives of the family Valvatidae: *Valvata piscinalis* Mull.. *V. pulchella* Studer, *V. naticina* Menke; Lymnaeidae: *Lymnaea peregra* Mull., *L. auricularia* L.; Planorbidae: *Planorbis planorbis* L., *Planorbarius corneus* L. This situation has persisted up to the present, with only a slight growth in dominance of the family Valvatidae, mainly in the northern part of the reservoir.

In the second year of the existence of the reservoir there appeared bivalves in it. They were small species of the genus *Pisidium*, mainly *P. amnicum* Mull. In 1958, a representative of the family Unionidae (*Anodonta cygnea* L.) was caught for the first time. Peak development of this species fell on the years 1964–1973. In 1965, the water level in the reservoir was lowered by over 1.5 m. On the reservoir bottom uncovered due to this (about 600 ha) mussels of the family Unionidae were found in large numbers. The investigations carried out at that time (K r z y ż a n e k 1966a) taxa in the years 1955 – 1982

1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
			+	+	+	+	+	+	+	+	+	+	+	+	+
												+	+	+	+
+			+					+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
+	+		+		+	+	+	+	+	+	+	+	+	+	+
+		+													
+	+	+													
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
			+	+			+	+	+	+		+			
					+	+		+	+	+	+	+	+	+	+

revealed the highest densities of these mussels in the northern part of the water body, the dominant species being *Anodonta cygnea.* A similar situation occurred also in 1972. In the 600 ha area of the uncovered reservoir bottom detailed studies of mussels were carried out. An analysis and comparison of the different parts of the reservoir showed the highest abundance and biomass of mussels throughout its northern part, comprising an area of 200 ha, with its bottom being mainly sandy. There were fewer mussels in the southern part, where the bottom is muddy (Table 2). It was found that the uncovered area was inhabited by 18 million mussels of a total of 1114 tons of biomass. To determine the age-structure of the mussel population, biometric measurements were carried out. They demonstrated that age group 6 – 8 years of *Unio pictorum* L. was represented by the highest numbers, whereas the largest numbers of *Anodonta cygnea* represented age group 8 – 10 years.

Table 2. Distribution of mussels in the emergent part of the Goczałkowice reservoir bottom in 1972

Zone	Station	Area (in ha)	Mean no. (indiv. · m^{-2})	Mean biomass ($g \cdot m^{-2}$)	Total no. individuals	Total biomass in tons	Per cent species composition	
Northern	2	30	2	150	600000	45	*Unio pictorum*	58
							U. tumidus Phlps	30
							Anodonta cygnea	10
							A. piscinalis Nills.	2
	3	60	11	352.5	6300000	199.5	*Unio pictorum*	60
							U. tumidus	35
							Anodonta cygnea	5
	6	90	9	840	8060000	770	*Unio pictorum*	70
							U. tumidus	24
							Anodonta cygnea	6
Southern	12	200	0.2	10	400000	20	*Unio pictorum*	6
							U. tumidus	4
							Anodonta cygnea	80
							A. piscinalis	10
	14	150	0.3	11	450000	15	*Unio pictorum*	20
							U. tumidus	20
							Anodonta cygnea	50
							A. piscinalis	10
	17	70	3	94	2100000	65	*Unio pictorum*	10
							U. tumidus	5
							Anodonta cygnea	80
							A. piscinalis	5

Table 3. Distribution of mussels in the underwater zone of the reservoir in 1972

Zone	Sampling depth (in m)	Density (indiv. · m^{-2})	Biomass (g · m^{-2})	Numbers over whole bottom area (in millions of indiv.)	Biomass over whole bottom area (in tons)	Per cent species composition	
Northern	2	16	394	22.5	551	*Unio pictorum* *U. tumidus* *Anodonta cygnea* *A. piscinalis*	60 25 10 5
	4	6	295	18	886	*Unio pictorum* *U. tumidus* *Anodonta cygnea*	55 15 30
	6	2	134	3	201	*Unio pictorum* *Anodonta cygnea*	45 55
Southern	2	6	300	15	780	*Unio pictorum* *U. tumidus* *Anodonta cygnea*	30 20 50
	4	1.5	85	7.5	425	*Unio pictorum* *Anodonta cygnea*	20 80
	6	5	360	15	1080	*Unio pictorum* *Anodonta cygnea*	10 90

Studies carried out in the underwater part of the reservoir showed the highest mussel density at the depth of 2 m (Table 3). At depths below 6 m no mussels of the family Unionidae could be caught. In the northern part of the reservoir the dominant species was *Unio pictorum*, in the southern – *Anodonta cygnea*.

By totalling the results it was found that the whole reservoir bottom was inhabited by 106 mlln. mussels, the biomass of which amounted to 5038 tons, i.e., on an average 4 individuals or 200 g biomass per 1 m^2 (K r z y ż a n e k 1976).

The central zone of the reservoir is at present inhabited almost exclusively by Sphaeridae, mainly *Pisidium amnicum, P. henslowanum* Sh., *P. subtruncatum* Malm., *P. casertanum* Poli, and there are few Unionidae (*Anodonta*). The shore zone is inhabited by Unionidae, primarily *Unio pictorum*.

Of other zoobenthos groups larvae of the following are also found in the near-shore zone of the reservoir: Trichoptera (*Polycentropus flavomaculatus* Pict. and *Oecetis ochracea* Curt.), Ephemeroptera (*Caenis moesta* Brgtss. and *C.* sp.), Hirudinea (*Helobdella stagnalis* L., *Glossiphonia complanata* L. and *Hemiclepsis marginata* O. F. Müll.) and Nematoda, Megaloptera, Isopoda, whereas in the central zone there occur Ceratopogonidae (*Palpomyia* sp. and *Stilobezzia* sp.).

3.2. ZOOBENTHOS DISTRIBUTION IN ZONES

3.2.1. Zoobenthos in the years 1955 – 1960

Zoobenthos studies were started in the reservoir in February 1955 and carried on for a year. In areas gradually covered with water it was possible to observe the escape or dying out of terrestrial forms and forms not adapted to the new conditions (rheophilous river species) of the environment. Predominant among the animals escaping towards the shore and carried away by waves were various coleopteran species. In various stretches of stagnant water the first aquatic organisms, primarily Heteroptera (*Corixa* sp.) could also be seen. During the first three weeks of the gradual filling large numbers of dead Lumbricidae were found. There appeared and developed Chironomidae, mainly *Chironomus* sp. I (? *Ch. plumosus*) and *Ch.* sp. II (? *Ch. thummi* K.) feeding on decomposing terrestrial vegetation. After the completion of the filling of the reservoir benthos formation depended mainly on the quality and quantity of bottom sediments, and the rate at which the inshore zone was overgrown by the macrophytes. In 1955, the average density was 2520 indiv. $\cdot$ m^{-2} (K y s e l a 1956). In the part of the reservoir where before its filling there were fish ponds (the northern part of the water body) a detailed analysis of Chironomidae larvae was carried out in the years 1955 – 1956. Most abundant were: *Endochironomus* sp. I (? *E. impar* Walk.) and *Polypedilum* sp. III (? *P. nubeculosum*). Abundant, especially in the first periods, were also: *Chironomus* sp. I (? *Ch. plumosus*), *Ch.* sp. II (? *Ch. thummi*). The lack of larger numbers of Tanypodinae in this part of the reservoir was remarkable. Terrestrial forms, e.g., *Pseudosmittia* sp. and *Smittia* sp. were still encountered from time to time. A total of 27 chironomid forms were identified out of which 15 were new, not found in this area before the filling of the reservoir. There were 10 forms common to both periods (prior to and after the filling). All of them were ubiquitous, capable of living in small overgrown ponds and in large water bodies. This group included *Cricotopus sylvestris, Procladius* sp., *Chironomus* sp. I (? *Ch. plumosus*).

In 1956 and 1957, also other groups began to play a more and more important role in the zoobenthos, chiefly Oligochaeta and Mollusca (gastropods and small-bodied bivalves of the genus *Pisidium*). In 1956, the average density of the zoobenthos was 2661 indiv. $\cdot$ m^{-2}, and in 1957, 2520 indiv. $\cdot$ m^{-2}.

During the years 1958 – 1960, 4 environment types were distinguished in the inshore zone: beaches and sandbanks, parts of sandy bottom overgrown by aquatic vegetation, clayey bottom covered with plant remnants and parts of bottom covered with a mud layer.

The highest density and species diversity were found on vegetation-covered substrates, the lowest on sandy substrates devoid of vegetation. In all types of environment dominant in the Chironomidae family were: *Chironomus* sp. I (? *Ch. plumosus*) and *Glyptotendipes* spp. The average density was 2723 indiv. $\cdot$ m^{-2}.

In the central, muddy- or mud-sandy substrate zone the density was on the average 1869 indiv. $\cdot$ m^{-2}. Here also the chironomids predominated, primarily *Chironomus* sp. I (? *Ch. plumosus*) and *Procladius* sp. Fairly numerous in this zone were also the Oligochaeta.

The colonization of the reservoir by animals progressed from two directions. From the near-dam part, as the deposition of muddy sediments advanced, up the reservoir – by pelophilous animals, and from the upper, near-bank part, with the advancing macrophyte overgrowth and formation of the detritus layer – mainly by phytophilous animals.

3.2.2. Zoobenthos in the years 1961 – 1982

At the beginning of the 60s the bottom sediments of the reservoir were already formed and spatially-diversified. There already existed stabilized zones, typical of this water body (Fig. 1), and basic zoocoenoses: pelophilous, phytophilous and psammophilous. Consequently, in the formation of zoobenthic communities certain spatial-distribution differences could be seen. These differences were caused, apart from the effect of the substrate type and presence or absence of macrophytes, by a repeated, in the years 1965, 1972, 1978 and 1979, considerable lowering of the water level by nearly 2 m, as a result of which a 600 ha bottom area was each time uncovered. The general tendency of quantitative changes was similar in all the zones studied (Fig. 3). Throughout the study period the richest in bottom macrofauna were stations located in the upper part of the reservoir in zones C and D. During the years 1962 – 1964, the density in both of these zones was high, amounting to about 2000 – 3000 indiv. $\cdot$ m^{-2}. It dropped in 1965 and remained low, about 1000 indiv. $\cdot$ m^{-2}, until 1970. In the years 1971 – 1975, the density increased again, reaching its peak in zone C in 1975, and in

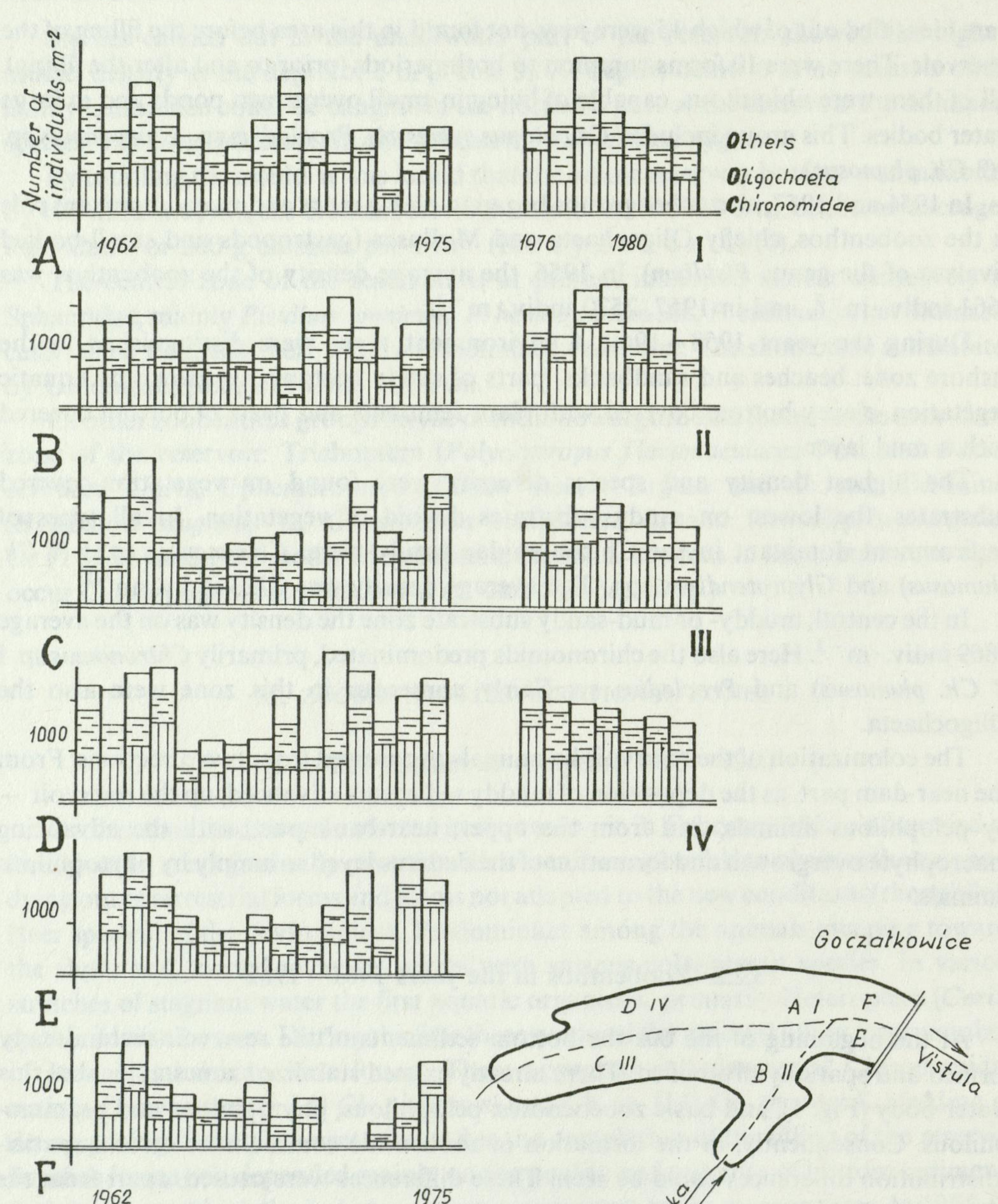

Fig. 3. Variations in zoobenthos numbers in 6 zones of the reservoir (A – F) in the years 1961 – 1975 and at 4 stations (I – IV) in the years 1976 – 1982

zone D in 1978, whereas in the years 1976–1982 it decreased anew, slightly. Most numerous in zone C were the Chironomidae, particularly the larvae of the genus *Procladius*. Fairly numerous were: *Cricotopus sylvestris*, *Psectrocladius* spp., *Polypedilum* sp. III (? *P. nubeculosum*), *P.* sp. II (? *P. convictum* Walk.), *Dicrotendipes* sp. I (? *D. nervosus*), *Glyptotendipes* spp. and Tanytarsini. In this part of the reservoir *Stictochironomus* sp. I (? *S. histrio* Fabr.) appeared in 1962 and it occurred there regularly until 1964, and only sporadically in 1967 and 1969. In the period 1964–1969 *Stictochironomus* spp. occurred regularly. Molluscs were represented by both the gastropods and bivalves. In the latter group by large Unionidae, mainly *Anodonta cygnea*, in addition to small Sphaeridae.

Zone D (north-western) was characterized by a greater species diversity. Larvae of Trichoptera, Ceratopogonidae, Ephemoroptera, Coleoptera and Hirudinea, besides Chironomidae larvae and Mollusca (chiefly *Unio pictorum*), represented a large proportion of the zoobenthos.

The Bajerka river bay zone (B) appeared to be very similar to both the former zones (Fig. 3). It differed by a lower range of variation of annual average numbers and higher values for the years 1970–1975. This zone, too, showed a considerable species diversity. Chironomidae larvae were dominant, attaining their peak numbers in 1975 (2091 indiv. $\cdot$ m^{-2}). The indicator forms were: *Procladius* sp. and *Cryptochironomus defectus*. The oligochaetes were found in small numbers, with their peak abundance in 1979 (812 indiv. $\cdot$ m^{-2}) and lowest in 1973 (90 indiv. $\cdot$ m^{-2}). A frequent component of the zoobenthos was bivalves of the family Unionidae (*Unio pictorum*) and Sphaeridae (*Pisidium amnicum*). Larvae of Trichoptera, Ephemeroptera and Ceratopogonidae occurred temporarily.

Least rich in zoobenthos were both the inshore zones situated in the lower, near-dam part of the reservoir (E–F).

Slightly richer was the south-eastern zone (E), with a muddy bottom, overgrown by macrophytes. In the years 1962–1964, the zoobenthos of this zone was still fairly rich, with its maximum abundance recorded in 1963 (2369 indiv. $\cdot$ m^{-2}). It remained at a very low level for the following 6 years. In 1972, a slight increase began, the peak having been recorded in 1974 (2188 indiv. $\cdot$ m^{-2}). It was only in 1973 that there was a poor zoobenthos, this being attributed, as in the case of other zones, to the lowering of the water level in 1972 and extinction of the bottom animals.

Besides chironomid larvae there occurred, temporarily, large numbers of Ceratopogonidae, Trichoptera and Bivalvia, mainly *Anodonta cygnea*. Most frequent and abundant among the chironomids were: *Procladius* sp., *Cryptochironomus defectus*, *Polypedilum* sp. II (? *P. convictum*), *P.* sp. III (? *P. nubeculosum*) and Tanytarsini.

The north-eastern inshore zone (F), with a sandy bottom, entirely devoid of macrophytes was poorest in bottom organisms. Only in the years 1962, 1963 did their numbers range from 1500 to 2000 indiv. $\cdot$ m^{-2}, but in the period 1964–1970 they rarely exceeded 1000 indiv. $\cdot$ m^{-2}. A slight growth was recorded in 1975, but it was far from the level recorded in other zones. The taxonomic composition of the chironomids was little varied, with the genera *Procladius*, *Cryptochironomus*, *Microchironomus* and Tanytarsi-

Table 4. Zoobenthos biomass of the Goczałkowice reservoir in the years 1971 – 1975

Mean yearly biomass in $g \cdot m^{-2}$ (1) in the particular reservoir zones (A – F; Fig. 1) and standard error of the mean $\frac{\sigma}{\sqrt{n}}$ (2) (O k t a b a 1966, σ – standard deviation estimate, n – number of samples)

Zoobenthos	Year	Zone A		Zone B		Zone C		Zone D		Zone E		Zone F	
		1	2	1	2	1	2	1	2	1	2	1	2
	1971	429.0	131.4	646.1	166.0	650.4	220.0	15.3	6.8	480.8	102.6		
	1972	157.9	114.0	770.3	370.3	6073.5	120.0	226.2	194.6	593.9	229.8		
Total	1973	0.8	0.13	1.6	0.2	257.9	188.4	514.9	124.9	76.4	60.4	648.7	513.2
	1974	739.3	672.3	807.3	417.4	1280.6	711.4	318.3	105.4	523.4	198.2	244.4	179.0
	1975	138.3	126.3	183.3	96.1	649.9	258.0	243.1	115.2	295.1	113.0	305.0	270.2
	1971	1.3	0.2	2.9	0.5	1.4	0.1	3.7	0.9	0.9	0.2		
	1972	6.8	4.5	2.1	0.4	4.2	1.0	2.4	1.1	0.8	2.0		
Chironomidae	1973	0.6	0.15	1.0	0.2	1.3	0.5	1.4	0.3	0.4	0.06	0.5	0.2
	1974	2.0	0.8	1.0	0.4	1.3	0.03	1.5	0.2	3.6	0.7	0.5	0.08
	1975	2.0	0.3	2.4	0.7	2.9	0.5	1.7	0.3	1.3	0.2	1.1	0.15
	1971	0.1	0.04	0.6	0.1	0.6	0.2	0.3	0.04	0.9	0.09		
	1972	0.2	0.1	0.6	0.1	0.5	0.2	0.3	0.15	1.3	0.4		
Oligochaeta	1973	0.1	0.4	0.1	0.03	0.2	0.07	0.3	0.4	0.1	0.03	0.1	0.04
	1974	0.7	0.8	0.7	0.4	0.3	0.6	0.6	0.2	0.9	0.6	0.2	0.2
	1975	0.4	0.09	0.2	0.07	0.4	0.09	1.4	0.7	0.4	0.12	0.2	0.02

	1971	427.4	129.0	642.0	162.0	648.1	116.4	10.6	6.4	478.4	100.9		
	1972	150.8	122.9	767.3	370.1	6068.6	111.9	223.0	192.3	151.2	230.4		
Mollusca	1973	–	–	0.1	0.03	255.9	188.1	512.6	124.7	75.5	60.5	647.5	513.0
	1974	736.3	672.1	804.8	417.6	1278.5	755.1	314.3	105.4	518.4	194.8	242.6	184.6
	1975	135.5	126.5	180.4	96.2	646.0	258.0	238.0	114.9	293.1	110.8	303.1	270.0
	1971	0.2	0.05	0.6	0.1	0.3	0.1	0.7	0.6	0.1	0.1		
	1972	0.1	0.01	0.3	0.15	0.2	0.02	0.5	0.2	0.6	0.1		
Others	1973	0.1	0.03	0.4	0.1	0.5	0.03	0.6	0.03	0.4	0.02	0.6	0.02
	1974	0.3	0.9	0.8	0.2	0.5	0.03	1.9	0.06	0.5	0.4	1.1	0.6
	1975	0.4	0.1	0.3	0.3	0.6	0.06	2.0	2.4	0.3	0.03	0.6	0.2

Table 5. Zoobenthos biomass of the Goczałkowice reservoir in the years 1976 – 1982
Mean yearly biomass in $g \cdot m^{-2}$ (1) in the particular reservoir zones (I – IV; Fig. 1) and standard error of the mean $\frac{\sigma}{\sqrt{n}}$ (2) (O k t a b a 1966, σ – standard deviation estimate, n – number of samples)

Zoobenthos	Year	Zone I 1	Zone I 2	Zone II 1	Zone II 2	Zone III 1	Zone III 2	Zone IV 1	Zone IV 2
Total	1976	19.4	13.2	550.2	314.5	245.0	201.4	449.3	314.8
	1977	113.2	78.5	360.2	256.0	1275.2	908.4	5.0	1.1
	1978	562.3	399.7	459.5	324.7	3.2	0.25	4.8	0.07
	1979	98.2	65.7	8.4	0.5	1216.0	860.7	388.6	273.2
	1980	72.3	49.0	5.6	1.6	225.3	111.4	3.8	0.46
	1981	77.1	59.3	149.0	99.3	234.5	161.5	129.1	80.3
	1982	11.3	4.0	2.9	0.4	219.0	146.2	274.2	250.7
Chironomidae	1976	3.6	0.7	2.2	0.4	1.0	0.4	2.6	0.1
	1977	1.1	0.2	1.0	0.4	0.04	0.07	0.5	0.17
	1978	1.1	2.1	2.9	1.7	2.0	0.4	1.0	0.8
	1979	8.7	3.5	6.4	0.6	6.7	2.0	3.2	0.5
	1980	6.7	0.0	4.0	0.1	2.7	0.2	2.9	0.03
	1981	8.1	2.0	3.2	0.8	6.9	1.4	5.5	1.2
	1982	5.8	2.3	1.2	0.3	5.9	2.4	3.7	0.7
Oligochaeta	1976	0.6	0.2	0.6	1.2	0.6	0.2	1.5	0.1
	1977	1.1	1.0	0.2	0.1	0.8	0.07	1.0	0.07
	1978	0.5	0.07	0.5	0.03	0.6	0.17	0.6	0.07
	1979	0.2	0.2	1.4	0.2	0.8	0.32	0.4	0.2
	1980	0.5	0.2	0.7	0.2	0.2	0.06	0.7	0.4
	1981	0.8	0.2	0.6	0.1	1.0	0.3	0.6	0.1
	1982	0.7	0.3	0.3	0.07	1.7	0.9	0.5	0.2
Mollusca	1976	14.4	12.9	547.2	315.0	243.0	201.8	444.3	316.0
	1977	110.2	78.8	358.2	256.0	1273.2	909.0	3.0	1.1
	1978	560.3	398.0	455.5	324.2	–	–	1.6	0.07
	1979	88.2	62.0	–	–	1208.0	863.0	384.6	273.8
	1980	64.3	49.0	–	–	221.3	106.7	0.1	0.02
	1981	68.1	59.0	145.0	99.7	225.5	162.4	122.1	80.8
	1982	4.3	3.8	0.3	0.04	210.0	140.2	269.2	249.8
Others	1976	0.8	0.05	0.2	0.1	0.4	0.1	0.9	0.1
	1977	0.8	0.02	0.8	0.2	0.5	0.07	0.5	0.14
	1978	0.4	0.1	0.6	0.3	0.6	0.1	1.6	0.07
	1979	0.1	0.02	0.6	0.1	0.5	0.05	0.4	0.07
	1980	0.8	0.04	0.9	0.2	1.1	0.4	0.1	0.01
	1981	0.1	0.07	0.2	0.1	1.1	0.07	0.9	0.03
	1982	0.5	0.07	0.7	0.15	1.4	0.08	0.8	0.02

ni dominating in it. *Anodonta cygnea* dominated among the bivalves up to 1970, and *Unio pictorum* thereafter.

In the central zone (A) a separate community developed. The zoobenthos of this zone was least varied in its taxonomic composition. Apart from chironomids and oligochaetes, only sporadically were bivalves and Ceratopegonidae caught. The family Chironomidae showed some slight changes. The taxonomic composition remained unchanged almost during the whole 20-year period. A total of 17 taxa have been identified, the most frequent being: *Chironomus* sp. I (? *Ch. plumosus*), *Procladius* sp., and during the last decade also *Microchironomus* sp. (? *M. tener*). In this zone, numerous were also oligochaetes.

Variations in the mean annual numbers recorded for this zone were the lowest. Peak numbers were recorded in 1963, 1969 and 1978, the lowest in 1966 and 1973; the latter were probably caused by the lowering of the water level in 1965 and 1972.

In 1971, biomass studies were started. Tables 4 and 5 contain mean annual biomass values in the particular zones of the reservoir, and the standard error of the mean (Oktaba 1966). In the years 1971 – 1975, the highest biomass values were recorded in zone C, the lowest in zone A. In the period 1976 – 1982, the highest biomass levels were recorded for station III, corresponding to zone C of the years 1971 – 1975. At other stations the level of biomass in the particular years was different, usually lower than at station III, except in 1978. The wide variation of biomass, and thereby the high standard error of the mean was caused by the molluscs, mainly the mussels. In the case of other zoobenthos groups, these values were small. In the years 1971 – 1975, the biomass of the zoobenthos was higher than in the 1976 – 1982 period. In the first period, the mean annual value for the whole reservoir ranged from 314.1 to 720.6, and in the second one from 126.7 to 452.7 $g \cdot m^{-2}$. This, too, was caused by the molluscs, for the biomass of the remainder of the zoobenthos was similar. During the years 1971 – 1975, it varied between 3.2 and 9.7, in the period 1976 – 1982 – between 3.1 and 10.9 $g \cdot m^{-2}$.

3.3. SUCCESSION OF ZOOCOENOSES

The process of zoobenthos formation in the Goczałkowice reservoir proceeded by stages. Five stages have been distinguished, corresponding to 3 periods (Table 6).

(I) The first period and at the same time the first stage covered the year 1955.

(1) The first stage started with the filling of the reservoir. It lasted till the end of 1955. In areas gradually flooded the escape and dying out could be seen of terrestrial forms and of forms not adapted to the environmental conditions (rheophilous river species). Two months after the filling of the reservoir among the terrestrial forms found there were few oligochaetes (Enchytreidae) and Chironomidae (*Pseudosmittia* sp. and *Smittia* sp.). The first aquatic organisms were heteropterans (*Corixa* sp.). There appeared the first zoobenthic organisms, i.e., larvae of Chironomidae, primarily of *Chironomus* sp. I (? *Ch. plumosus*), and began to develop fast.

Table 6. Scheme of zoobenthos community development in the Goczałkowice reservoir

Period	Stage	Year	Faunistic description
I	1	1955	escape and extinction of terrestrial animals and of rheophilous forms of the Vistula river; appearance of first aquatic animals – heteropterans (*Corixa* sp.); formation of zoobenthos (Chironomidae)
II	2	1956 – 1959	mass development of chironomids, mainly *Chironomus* sp. (? *Ch. plumosus*); bivalves represented by family Sphaeridae (*Pisidium amnicum*); gastropods represented by Lymnaeidae
	3	1960 – 1963	increased contribution of other zoobenthic groups, mainly oligochaetes in the central zone, and molluscs, trichopterans and ephemeropterans in the inshore zone
III	4	1964 – 1973	rapid decrease in numbers; continuous changes in taxonomic composition of the chironomids; increase in dominance of *Procladius* sp., *Anodonta cygnea* dominant among bivalves, and *Lymnaea peregra* among gastropods
	5	1974 – 1982	increase in zoobenthos numbers; stabilization of chironomid taxonomic composition; further growth in *Procladius* dominance (60% of population); *Unio pictorum* dominant among bivalves, *Valvata piscinalis* among gastropods

(II) The second period covered the years 1956 – 1963. The bottom sediments were not formed yet, the reservoir bottom being covered with a layer of decomposing plants. Two stages were distinguished in this period.

(2) At the second stage (the first stage of the second period), encompassing the years 1956 – 1959, there occurred rapid processes of biochemical decomposition of the flooded vegetation. These processes enriched the water and sediments with organic and inorganic components, which favoured the development of bacterial flora, the food of most benthic organisms. This brought about a mass development of chironomids, primarily *Chironomus* sp. I (? *Ch. plumosus*) which attained its highest density during the period 1956 – 1957. Numerous in the near-shore zone were also: *Glyptotendipes* spp. and *Harnischia* sp., and in the central zone – *Procladius* sp. Besides ubiquitous forms the most numerous were phytophilous forms, as well as forms like *Chironomus* sp. II (? *Ch. thummi*), tolerant of decay processes and oxygen deficiency in the environment. The latter form occurred in large numbers until the end of 1956 and was far less numerous thereafter. The molluscs were represented by gastropods and small bivalves (*Pisidium*). In 1958, a representative of the Unionidae (*Anodonta cygnea*) was caught for the first time.

(3) The third stage (the second stage of the second period) covered the years 1960 – 1963. Other groups began to play a more and more important role, first of all oligochaetes, and in the inshore zone also molluscs, trichopterans, ephemeropterans

and Hirudinea. At this stage, the biomass of the bivavles increased. In the family Chironomidae a large proportion of the biomass was contributed by *Chironomus* sp. I (? *Ch. plumosus*). Throughout the period the density of the zoobenthos was high and did not in principle drop below 2000 indiv. $\cdot$ m^{-2}, attaining the highest level in 1961. In the family Chironomidae 50 taxa were identified, therein 30 representatives of the subfamily Chironominae (27 Chironomini, 3 Tanytarsini), 15 of Orthocladinae and 5 of Tanypodinae. Numbers were not proportionate to the taxonomic diversity. The highest numbers were attained by Tanypodinae, and particularly by *Procladius*.

(III) The third period began in 1964. The reservoir bottom was already formed, and there arose zones specific to the reservoir, and characteristic zoocoenoses. In this period 2 stages were distinguished.

(4) The fourth stage (the first stage of the third period) encompassed the years 1964 – 1973. The characteristic feature of this stage was a rapid fall of numbers in the zoobenthos. The lowest values were recorded in 1967 when the density did not exceed 500 indiv. $\cdot$ m^{-2}. From 1968 on, a slight increase in numbers was observed. Towards the end of the stage in 1973 the zoobenthos was again poor, which should be related to the lowering of the water level in 1972, as well as to the strong flood waves that followed this period. All bottom animal groups, especially molluscs and oligochaetes, were found to have been impoverished.

The taxonomic composition of chironomid larvae continued to vary. Some forms, like *Chironomus* sp. II (? *Ch. thummi*), *Paratendipes* sp., became extinct and new ones appeared: *Stictochironomus* sp. I (? *S. histrio*), *S.* sp., *Tanypus* sp. I (? *T. punctipennis*), *Microchironomus* sp. (? *M. tener*), *Cryptochironomus defectus* and *Xenochironomus xenolabis* K. A total of 49 taxa were identified, including 32 of the subfamily Chironominae (29 Chironomini and 5 Tanytarsini), 10 of Orthocladinae and 7 of Tanypodinae. The genus *Procladius* was found to have grown in numbers. The bivalves were subject to great changes. An initial dominance of *Anodonta cygnea* was towards the end of this stage followed by the dominance of *Unio pictorum*. In 1971, biomass studies were begun. Peak biomass was recorded in 1972 (720 g $\cdot$ m^{-2}), and the lowest biomass value in 1973 (310 g $\cdot$ m^{-2}).

(5) The fifth stage (the second stage of the third period) started in 1974. A gradual growth in zoobenthos numbers was observed throughout the reservoir, with a maximum value recorded in 1978 when the average density for the whole water body was 2957 indiv. $\cdot$ m^{-2}. A particularly clear increase in numbers was recorded for the chironomids. In this family a certain degree of stability in taxonomic composition could be observed. The total number of taxa remained unchanged. A total of 49 taxa were identified, including 31 of Chironominae (26 Chironomini, 5 Tanytarsini), 10 of Orthocladinae and 8 of Tanypodinae. Among new components *Tanypus* sp. II (? *T. Kraatzi* Kieff.) and *Micropsectra* spp. were found. The proportion of *Procladius* larvae was found to have increased, already representing 60% of the population. The second most numerous group was the oligochaetes, followed by the molluscs represented in the inshore zone by Unionidae (Bivalvia) and Valvatidae (Gastropoda), and in the central zone by Sphaeridae (Bivalvia). The dominant component of the Unionidae was *Unio pictorum*.

4. DISCUSSION

An analysis of the process of zoobenthic community formation revealed a clear succession in the particular animal groups. In the family Chironomidae it proceeded from a community dominated by *Chironomus* sp. I (? *Ch. plumosus*)-*Procladius* sp.-*Polypedilum* sp. III (? *P. nubeculosum*) to a community of *Procladius* sp.-*Chironomus* sp. I (? *Ch. plumosus*)-*Microchironomus* sp. (? *M. tener*). Some forms were only found at particular stages. At the first stage: terrestrial forms – *Pseudosmittia* sp. and *Smittia* sp.; at the second: *Chironomus* sp. II (? *Ch. thummi*); at the third: *Polypedilum* sp. IV (? *P. pedestre* Mg.); at the fourth: *Stictochironomus* sp. I (? *S. histrio*) and *S.* sp., and at the fifth stage: *Tanypus* sp. II (? *T. Kraatzi*).

Within the Bivalvia class succession proceeded from a community dominated by the genus *Pisidium* (*P. amnicum*) through *Anodonta* (*A. cygnea*) to a community in which *Unio* (*U. pictorum*) dominated. The family Sphaeridae, dominant at first, was followed from the 60s on by the Unionidae family. Among the gastropods dominant were at first only Lymnaeidae (*Lymnaea stagnalis*), then the following three families: Lymnaeidae (*Lymnaea peregra*), Valvatidae (*Valvata piscinalis* and *V. naticina*) and Planorbidae (*Planorbis planorbis*). Clearly dominant at present is the family Valvatidae (*Valvata piscinalis*).

There is a rich literature on dam-reservoir zoobenthos studies. However, there have been few papers dealing with the long period of faunistic community formation. There have been some comparatively detailed studies on reservoirs on the Volga river in the Soviet Union (Morduchaj-Boltovskoj 1961, Kuzin 1972, Morduchaj-Boltovskoj et al. 1972, Šilova 1976) and on the Dnieper river (Ceeb 1964, Ceeb and Majstrenko 1972).

Studies of this kind were also carried out systematically in Czechoslovakia (Hruška 1973) and Yugoslavia (Jankovič 1972).

Attempts were also made to classify dam-reservoirs among other things on the basis of the zoobenthos. This was initiated by Thienemann's (1911) and Wundsch's (1942, 1949) studies, and continued by Soviet scientists. As an example, Ioffe's (1961) trial, connected with a hydrochemical classification, can be quoted. In Spain, a classification based on bottom animals was worked out by Prat (1980).

In Poland, too, there have appeared many publications dealing with the process of zoobenthos formation in dam-reservoirs (e.g., Kownacki 1963, Grzybowska 1965, Krzyżanek 1971, 1979, Giziński and Wolnomiejski 1982).

The results obtained from studies carried out on the Goczałkowice dam-reservoir permitted an attempt to present a general scheme of zoobenthos formation in this water body (Table 6). The main features of this scheme were:

(1) The period of the recession of the terrestrial animal communities and formation of the first aquatic communities after the filling.

(2) The period of mass development of the zoobenthos, lasting from the second until the eighth year following the filling, in which there was mass-development of chironomids, mainly *Chironomus* sp. I (? *Ch. plumosus*), followed also by that of other groups, particularly the oligochaetes and bivalves (Unionidae).

(3) The period in which there occurred at first a rapid decrease in zoobenthos numbers, followed by a steady growth with a stable taxonomic composition preserved.

This scheme is similar to those obtained for other reservoirs. Each reservoir has, of course, its specific features by which it differs from others. These differences usually concerned the duration of the particular stages and dominance in the various groups, e.g., the genus *Dreissena* in the Bivalvia group (Giziński and Wolnomiejski 1982) or Unionidae (Krzyżanek 1976). Furthermore, in small, deep reservoirs a mass development of oligochaetes immediately followed the filling (Zelinka 1962, Krzyżanek 1971).

5. SUMMARY

Studies of the Goczałkowice dam-reservoir zoobenthos, started immediately after the filling, have been continued systematically throughout the period of existence of the water body to date, i.e., for 28 years. The paper presents a synthesis of the results from these studies, both published (1955 – 1975) and unpublished.

A description is presented of the particular groups (Tables 1 – 3), distribution in the different zones (Figs. 1, 3, Tables 4, 5) and succession of zoocoenoses in the years 1955 – 1982 (Fig. 2, Table 6).

The results have permitted the statement that the zoobenthos formed by stages. Three periods and 5 stages have been distinguished.

(I) The first period and stage corresponded to the year 1955.

(1) At the first stage the old terrestrial and river animal communities receded and there formed aquatic communities there.

(II) The second period corresponded to the years 1956 – 1963 and consisted of 2 stages.

(2) The second stage (the first stage of the second period) corresponded to the years 1956 – 1959. During this stage there occurred a mass development of chironomids, primarily of *Chironomus* sp. I (? *Ch. plumosus*) in the reservoir.

(3) During the third stage, corresponding to the years 1960 – 1963, an intensified development was seen of other zoobenthic groups, mainly of the oligochaetes and bivalves.

(III) The third period started in 1964, and also consisted of two stages.

(4) The fourth stage (the first stage of the 3rd period) corresponded to the years 1964 – 1973. Its feature was at first a decrease in zoobenthos numbers, throughout the reservoir, lasting until 1970, followed by a slight growth. In the family Chironomidae taxonomic-composition changes could be seen, and an increase of dominance of the genus *Procladius*. Among the bivalves the genus *Anodonta*, mainly *A. cygnea*, dominated.

(5) The fifth stage (the second stage of the 3rd period) began in 1974. A slight increase in zoobenthos numbers was seen, attaining its peak in 1978. In the family Chironomidae a taxonomic-composition stabilization was observed. The dominant representative of the family Unionidae was *Unio pictorum*.

6. POLISH SUMMARY

Badania zoobentosu na zbiorniku zaporowym w Goczałkowicach zostały rozpoczęte zaraz po jego napełnieniu i były kontynuowane systematycznie przez cały okres jego istnienia do chwili obecnej, tj. przez 28 lat. W pracy przedstawiono syntezę wyników tych badań na podstawie zarówno prac opublikowanych (lata 1955 – 1975), jak i nie opublikowanych.

Przedstawiono charakterystykę poszczególnych grup (tab. 1–3), rozmieszczenie w poszczególnych strefach (rys. 1, 3, tab. 4, 5) oraz sukcesję zoocenoz w latach 1955–1982 (rys. 2, tab. 6).

Na podstawie otrzymanych wyników badań stwierdzono, że proces formowania się zoobentosu przebiegał etapowo. Wyróżniono 3 okresy oraz 5 etapów.

I. Pierwszy okres, a zarazem etap obejmował rok 1955.

1. Pierwszy etap cechował się ustępowaniem dawnych zespołów zwierzęcych, lądowych i rzecznych i tworzeniem wodnych zespołów zwierzęcych.

II. Drugi okres obejmował lata 1956–1963 i składał się z 2 etapów.

2. Drugi etap (pierwszy drugiego okresu) obejmował lata 1956–1959. W etapie tym nastąpił masowy rozwój *Chironomidae*, głównie *Chironomus* sp. I (? *Ch. plumosus*).

3. Trzeci etap obejmował lata 1960–1963. Nastąpił wtedy wzmożony rozwój innych grup zoobentosu, głównie *Oligochaeta* i *Bivalvia*.

III. Trzeci okres rozpoczął się w 1964 r. i składał się także z 2 etapów.

4. Czwarty etap (pierwszy III okresu) obejmował lata 1964–1973. Jego cechą był najpierw spadek liczebności zoobentosu w całym zbiorniku trwający do 1970 r., następnie niewielki wzrost. W rodzinie *Chironomidae* obserwowano zmiany taksonomiczne oraz wzrost dominacji rodzaju *Procladius*. U *Bivalvia* dominował rodzaj *Anodonta*, głównie *A. cygnea*.

5. Piąty etap (drugi III okresu) rozpoczął się w 1974 r. Nastąpił niewielki wzrost liczebności zoobentosu z maksimum w 1978 r. W rodzinie *Chironomidae* obserwowano stabilizację jakościową. Dominującym przedstawicielem *Unionidae* był *Unio pictorum*.

7. REFERENCES

1. Ceeb Ja. Ja. (Ed.) 1961 – Kachovskoe vodojemišče – Izd. Naukova Dumka, Kiev, 304 pp.
2. Ceeb Ja. Ja., Majstrenko Ju. G. (Eds.) 1972 – Kievskoe vodochranilišče – Izd. Naukova Dumka, Kiev, 460 pp.
3. Giziński A., Wolnomiejski N. 1982 – Zoobenthos of Koronowo dam reservoir in its 10-th and 15-th year of existence – Acta Univ. Nic. Copernici – Limnological Papers, 13: 35–50.
4. Grzybowska B. 1965 – The bottom fauna of the Rożnów dam reservoir 21 years after its filling – Limnological investigations in the Tatra Mountains and Dunajec River Basin – Kom. Zagosp. Ziem Górs. PAN, 11: 281–288.
5. Hruška V. 1973 – The changes of benthos in Slapy Reservoir in the years 1960–1961 – Hydrobiol. Stud. 2: 213–247.
6. Illies J. 1978 – Limnofauna Europaea – G. Fischer Verlag, Stuttgart-New York, Swets and Zeitlinger B. V. Amsterdam, 532 pp.
7. Ioffe C. 1961 – Formirovanie donnoj fauny vodochranilišč SSSR i opyt klassifikacji – Izd. gosud. nauč. issled. Inst. Ozer. reč. ryb. Choz. 50: 341–382.
8. Jankovič M. 1972 – Die Entwicklung der Boden Fauna in den Gebirgsstaubecken – Verh. int. Verein. Limnol. 18: 813–817.
9. Kownacki A. 1963 – The bottom fauna of the dam reservoir in Porąbka of the Soła river – Acta Hydrobiol. 5: 159–172.
10. Krzyżanek E. 1965 – Die Tendipedidaen des Staubeckens von Goczałkowice in Jahre 1961 – Acta Hydrobiol. 7: 362–381.
11. Krzyżanek E. 1966a – Występowanie szczeżui wielkiej (*Anodonta cellensis*) w zbiorniku zaporowym w Goczałkowicach [Occurrence of *Anodonta cellensis* in the Goczałkowice dam reservoir] – Wszechświat, 11: 279–280.
12. Krzyżanek E. 1966b – Veränderlichkeit in der Besiedlungsdichte der Tendipedidaen an einer Untersuchungsstelle im Staubecken von Goczałkowice – Acta Hydrobiol. 8: 17–24.
13. Krzyżanek E. 1970 – Formation of bottom fauna in the Goczałkowice dam reservoir – Acta Hydrobiol. 12: 399–421.

14. K r z y ż a n e k E. 1971 – Bottom fauna in the Tresna dam reservoir in 1966 – Acta Hydrobiol. 13: 335–342.
15. K r z y ż a n e k E. 1973 – Bottom macrofauna in the Goczałkowice dam reservoir in the years 1965–1969 – Acta Hydrobiol. 15: 189–196.
16. K r z y ż a n e k E. 1976 – Preliminary investigations on bivalves (Bivalvia) of the dam reservoir at Goczałkowice – Acta Hydrobiol. 18: 61–73.
17. K r z y ż a n e k E. 1977 – Bottom macrofauna of the dam reservoir at Goczałkowice in the years 1970–1975 – Acta Hydrobiol. 19: 51–67.
18. K r z y ż a n e k E. 1979 – Bottom macrofauna of the dam reservoir at Rybnik remaining under the influence of hot discharged waters from the hot power station – Acta Hydrobiol. 21: 243–259.
19. K r z y ż a n e k E., K r z y ż a n e k M. 1986 – Development and structure of the Goczałkowice reservoir ecosystem. XVIII. List of plant and animal species – Ekol. pol. 34:559–577.
20. K u f l i k o w s k i T. 1974 – The phytophilous fauna of the dam reservoir at Goczałkowice – Acta Hydrobiol. 16: 189–207.
21. K u z i n B. K. 1972 – Rybinskoe vodochranilišče i ego žizn – Izd. Nauka, Leningrad, 364 pp.
22. K y s e l a A. 1956 – Fauna denna zbiornika Goczałkowickiego i występowanie komarów w jego okolicy w 1955 r. [The bottom fauna of the Goczałkowice reservoir and the appearance of the gnats in its area in 1955] – Biul. Kom. do spraw Górnośląskiego Okręgu Przemysłowego, PAN, 8: 79–85.
23. K y s e l a A. 1958 – Fauna denna zbiornika wodnegó w Goczałkowicach i jego zlewni w 1957 r. [The bottom fauna of the Goczałkowice reservoir and its basin in 1957] – Biul. Kom. do spraw Górnośląskiego Okręgu Przemysłowego, PAN, 19: 21–31.
24. M o r d u c h a j - B o l t o v s k o j F. D. 1961 – Process formirovanija donnoj fauny v Gorkovskom i Kujbyševskom vodochraniliščach – Trudy Inst. Biol. Vodochr. 4: 49–177.
25. M o r d u c h a j - B o l t o v s k o j F. D., D z j u b a n N. A., E k z e r c e v V. A. 1972 – Die Ausbildung der Pflanzen und Tierwelt in den Stauseen der Wolga – Verh. int. Verein. Limnol. 18: 837–842.
26. O k t a b a W. 1966 – Elementy statystyki matematycznej i metodyka doświadczalnictwa [Elements of mathematical statistics and experimentation methods] – Państwowe Wydawnictwo Naukowe, Warszawa, 310 pp.
27. P r a t N. 1980 – Bentos de los embalses espanoles – Oecol. aquat. 4: 3–43.
28. Š i l o v a A. I. 1976 – Chironomidy Rybinskogo vodochranilišča – Izd. Nauka, Leningrad, 252 pp.
29. T h i e n e m a n n A. 1911 – Hydrobiologische und fischereiliche Untersuchungen an den westfälischen Talsperre – Landwirtschafl. Jahrb. 4: 535–716.
30. W u n d s c h H. 1942 – Das Neisse Staubecken von Ottmachau O. S. in seiner Entwicklung zum Fischgewässer – Z. Fisch. 40: 339–393.
31. W u n d s c h H. 1949 – Grundlagen der Fischwirtschaft in den Grosstaubecken – Abhandl. Fisch. Lief. 1: 17–186.
32. Z a ć w i l i c h o w s k a K. 1965a – Benthos in the littoral of the Goczałkowice reservoir in 1958–1959 – Acta Hydrobiol. 7: 83–97.
33. Z a ć w i l i c h o w s k a K. 1965b – Benthos in the littoral of the Goczałkowice reservoir in 1960 – Acta Hydrobiol. 7: 155–165.
34. Z a ć w i l i c h o w s k a K. 1965c – Benthos in the profundal of the Goczałkowice reservoir in 1959–1960 – Acta Hydrobiol. 7: 167–178.
35. Z e l i n k a M. 1962 – Vztah zoobentosu udolnich nadrzi k chemizmu vody – Sbornik Vys. Skoly Chem.-Technol. v Praze, 6: 293–312.