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DEVELOPMENT AND STRUCTURE OF THE GOCZAŁKOWICE RESERVOIR ECOSYSTEM X. MACROPHYTES

ABSTRACT: The paper presents the formation of macrophytes in Goczałkowice dam reservoir over 28 years. Three stages in their development have been distinguished. The first stage (1956 – 1958) was characterized by a great growth of macrophytes and a small number of species. The second stage (1959 – 1972) showed a maximum growth of emergent macrophytes. The third stage from 1973 showed further growth of macrophytes with submerged leaves and a stabilization of their dominance.

KEY WORDS: Reservoir, ecosystem, macrophytes, the effect of decreasing water level, development stages.

1. INTRODUCTION

Complex hydrobiological studies on Goczałkowice dam reservoir included also macrophytes. The studies were conducted from the moment of flooding the reservoir in 1955 till the end of 1982.

The aim here has been a presentation of all information available on vascular vegetation growing in this reservoir. Special attention was paid to the process of overgrowing by macrophytes of the reservoir and the effect of considerable decrease of water level every few years.

The material for this elaboration has been provided by papers of M a z u r et al. (1958), Ć w i e r t n i a (1962, 1966), K u f l i k o w s k i (1968, 1971, 1977) and author's unpublished data.

Preliminary forecasts predicted a considerable development of higher plants in the reservoir. Thus before its construction floristic studies were carried there in 1953 and 1954 (B. Pawłowski 1953–1954)[1]. Special attention was paid to communities of aquatic plants in ponds and small stagnant waters on the area of the future reservoir; the results of these investigations shall be published separately by the staff of the Institute of Botany, Polish Academy of Sciences in Cracow.

2. METHODS

Each year, between 1955 and 1982, during the growth of aquatic vegetation from May to September, the overgrown surface area of Goczałkowice reservoir was estimated, then all macrophytes and the surface area overgrown by dominant species. In case of mixed patches consisting of several species the total surface area of a patch was estimated and within it the percentage of particular species.

Observations were conducted both from water and the shore. Thanks to a relatively great transparency down to 2 m the overgrowth degree was estimated for more submerged plants not reaching the surface water. These observations were verified at a lower water level.

For better orientation in the reservoir and easier mapping the reservoir was divided into smaller parts by drawing lines between characteristic field points.

The observations and mapping technique were conducted identically by all scientists involved. Only at the beginning (1955–1961) species of emergent vegetation were not identified but treated as a zone of rushes.

Thus obtained material was mapped (27 maps) providing the main material. Because of size the maps showed only the dominant species. Other species of macrophytes were given on the list of organisms of Goczałkowice reservoir (K r z y ż a n e k and K r z y ż a n e k 1986).

The material was identified according to the key by S z a f e r et al. (1953), whereas the species nomenclature was based on the papers by C a s p e r and K r a u s c h (1980, 1981).

3. RESULTS

3.1. OVERGROWING OF THE RESERVOIR

The water impoundment began in the first days of July 1955 and at the end of the year 16 km^2 were flooded. Already that year greater abundance of floating vegetation was observed, namely: *Utricularia vulgaris* L., *Lemna minor* L., *Spirodela polyrrhiza*

[1] Sprawozdanie z badań botanicznych przeprowadzonych w latach 1953 i 1954 na terenie zlewni i obrzeża zbiornika wodnego w Goczałkowicach [Report on botanical investigations carried out in 1953 and 1954 in the catchment area and on the borders of Goczałkowice reservoir] – Manuscript.

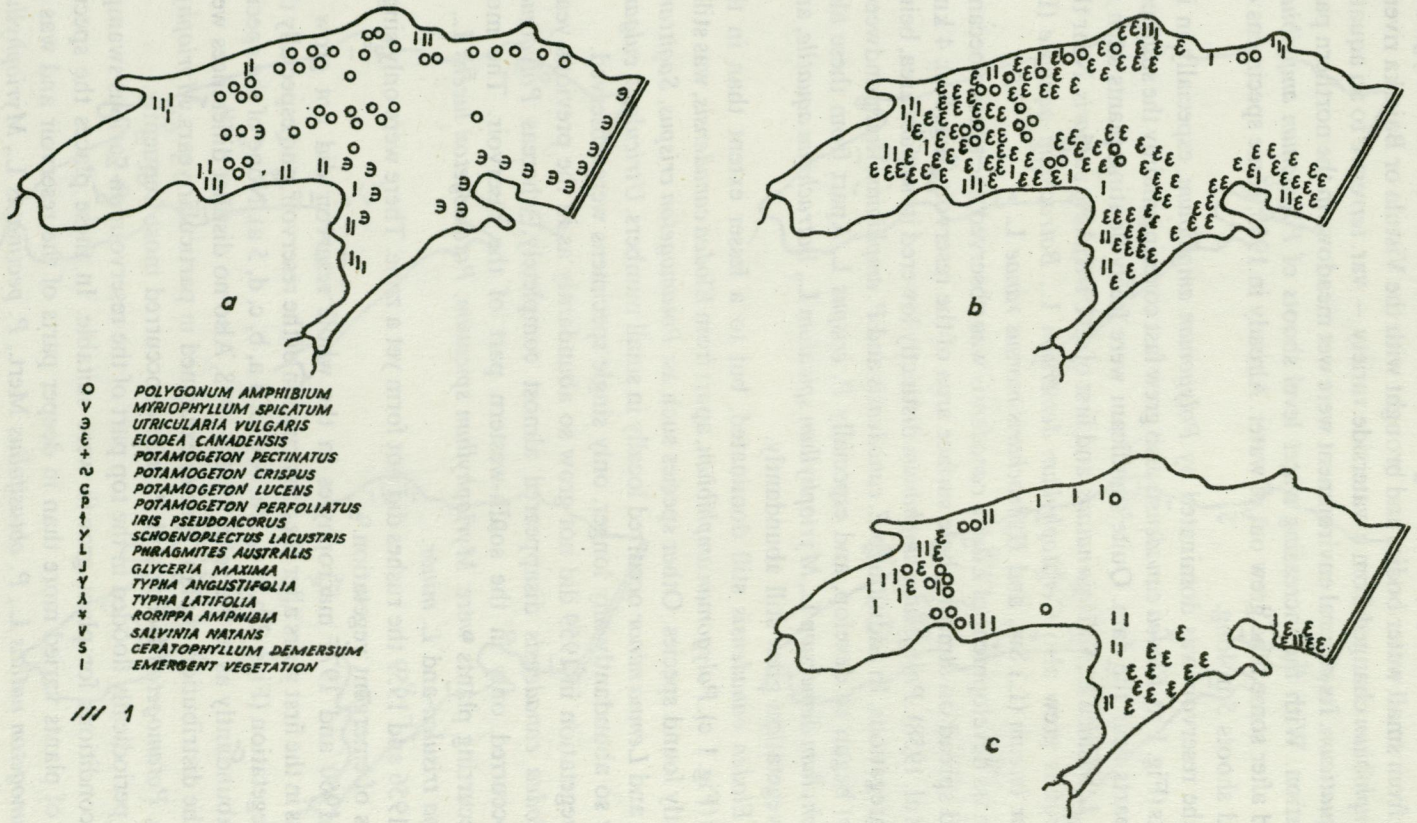

Fig. 1. Overgrowth of Goczałkowice reservoir in the years 1956 – 1958
a – 1956, b – 1957, c – 1958, 1 – emergent area

Schleiden and *Salvinia natans* (L.) All. and also *Elodea canadensis* Rich. and *Polygonum amphibium* L. from small water bodies and brought with the Vistula or Bajerka rivers. *Polygonum amphibium* changed from a waterside variety – var. *terrestre* to an aquatic one – var. *aquaticum*. Its natural environment were wet meadows in the northern part of the inundation. With the increasing water level shoots of *Polygonum amphibium* elongated and after some time grew out of water. Already in 1955, some specimens of this plant had shoots 5 m long.

In 1956, the reservoir was dominated by *Polygonum amphibium*, especially in its northern parts (Fig. 1 a). *Elodea canadensis* also grew fast covering mainly the southern and eastern parts near the dam. Quite significant were freely floating plants such as *Lemna minor*, *L. trisulca* L., *Salvinia natans*, and first of all *Utricularia vulgaris*. Near the former fish ponds grew also *Ceratophyllum demersum* L., *Batrachium aquatile* (L.) Dum., *Nuphar luteum* (L.) Sm. and *Hydrocharis morsus ranae* L.

In 1957, mass development of *Elodea canadensis* was observed; the species became dominant and spread on almost whole surface area of the reservoir (Fig. 1 b): 4 km^2 (M a z u r et al. 1958). *Polygonum amphibium* distinctly lowered its surface area, being in smaller aggregations. In addition to *E. canadensis* and *P. amphibium* first pondweeds (*Potamogeton*) begun to develop, and especially *P. crispus* L. Apart from these also were: *Ceratophyllum demersum* L., *Myriophyllum spicatum* L., *Batrachium aquatile*, and free floating vegetation grew still abundantly.

In 1958, *Elodea canadensis* still dominated, but to a lesser extent than in the previous year (Fig. 1 c). *Polygonum amphibium*, apart from *Elodea canadensis*, was still a most frequently found species. Other species such as: *Potamogeton crispus, Sagittaria sagittifolia* L. and *Lemna minor* occurred locally in small numbers. *Utricularia vulgaris* did not grow so abundantly any longer, only single specimens were observed.

Aquatic vegetation in 1959 did not grow so abundantly as in the previous years (Fig. 2 a). *Elodea canadensis* disappeared almost completely, whereas *Polygonum amphibium* occurred only in the south-western part of the reservoir. The most frequently occurring plants were: *Myriophyllum spicatum, Potamogeton lucens* L., *P. crispus, Lemna trisulca* and *L. minor*.

Between 1956 and 1959 the rushes did not form yet a zone. There were only single small patches of emergent vegetation.

Between 1960 and 1971 macrophytes in the whole reservoir did not grow as abundantly as in the first years after the construction of the reservoir, and especially the submerged vegetation (Figs. 2 b, c, d, 3 a, b, c, d, 4 a, b, c, d, 5 a). None of the species occurred as abundantly as in the years 1956–1958. Also no distinct differences were observed in the distribution of plant species examined in particular years. *Myriophyllum spicatum, Potamogeton lucens* and *P. crispus* occurred most frequently.

On areas periodically flooded in the top part of the reservoir, on various swamps, ditches, the conditions for plant growth were suitable. In these places the species composition of plants varied more than in deeper parts of the reservoir and was as follows: *Potamogeton natans* L., *P. obtusifolius* Mert., *P. pectinatus* L., *Myriophyllum*

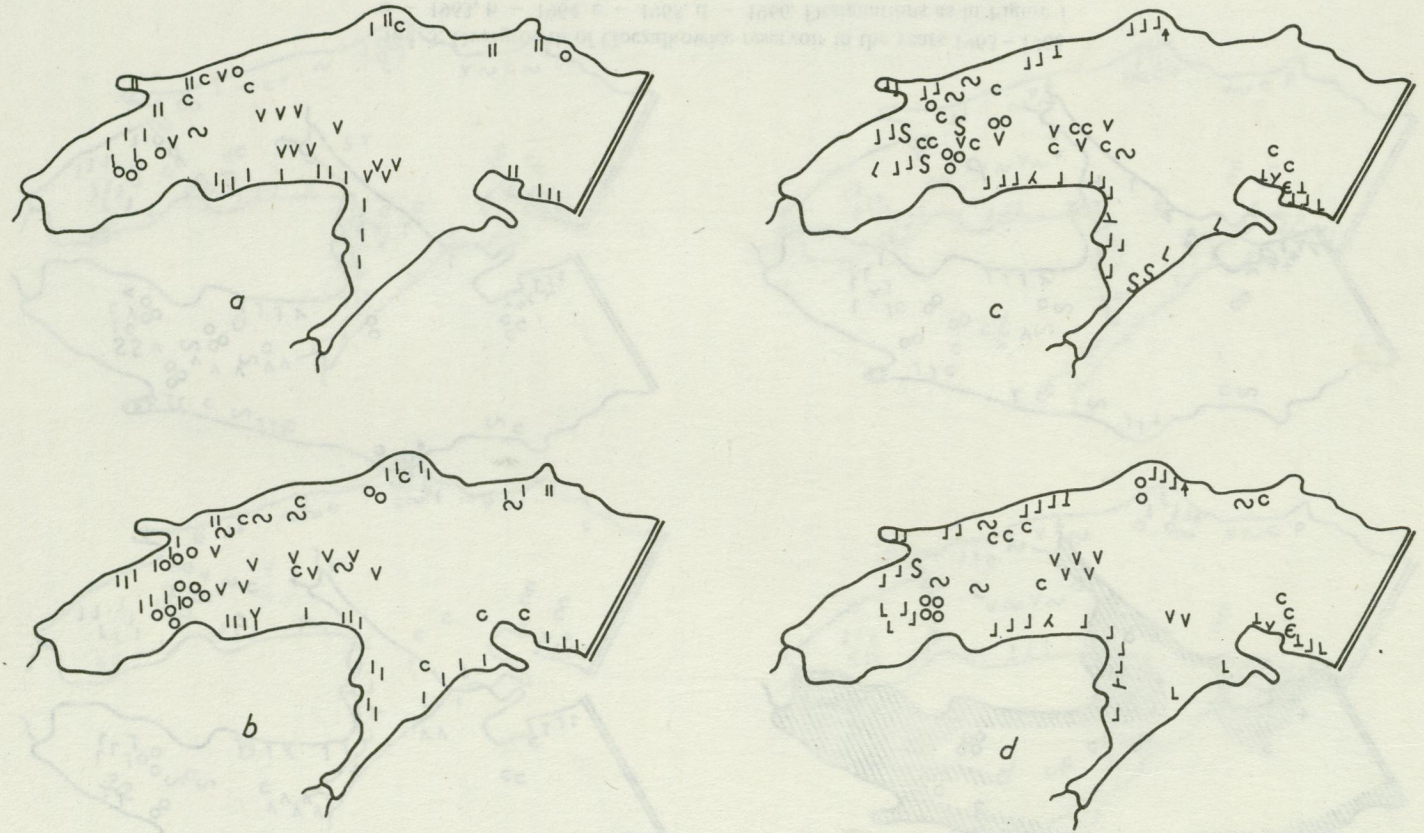

Fig. 2. Overgrowth of Goczałkowice reservoir in the years 1959 – 1962
a – 1959, b – 1960, c – 1961, d – 1962. Designations as in Figure 1

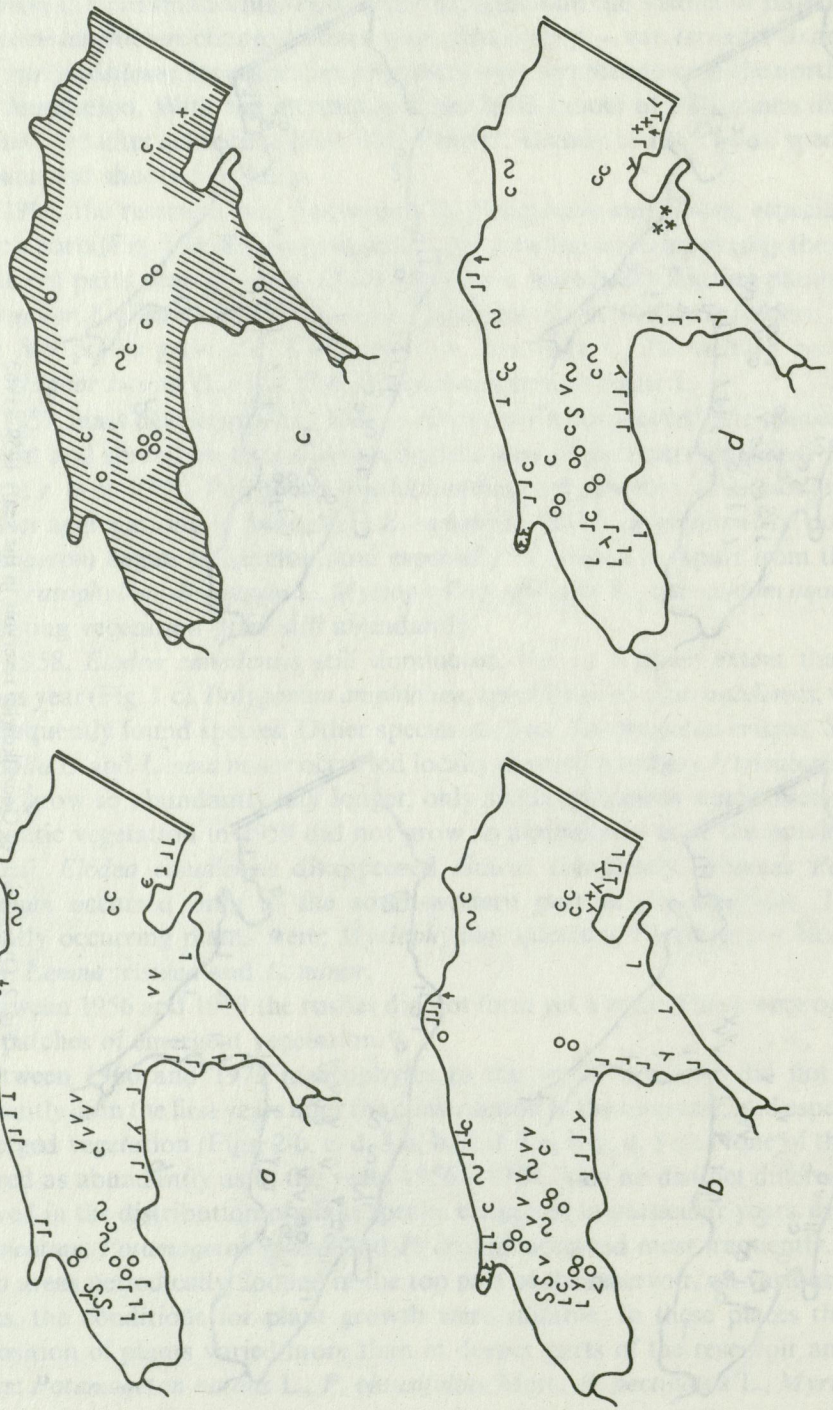

Fig. 3. Overgrowth of Goczałkowice reservoir in the years 1963 – 1966
a – 1963, b – 1964, c – 1965, d – 1966. Designations as in Figure 1

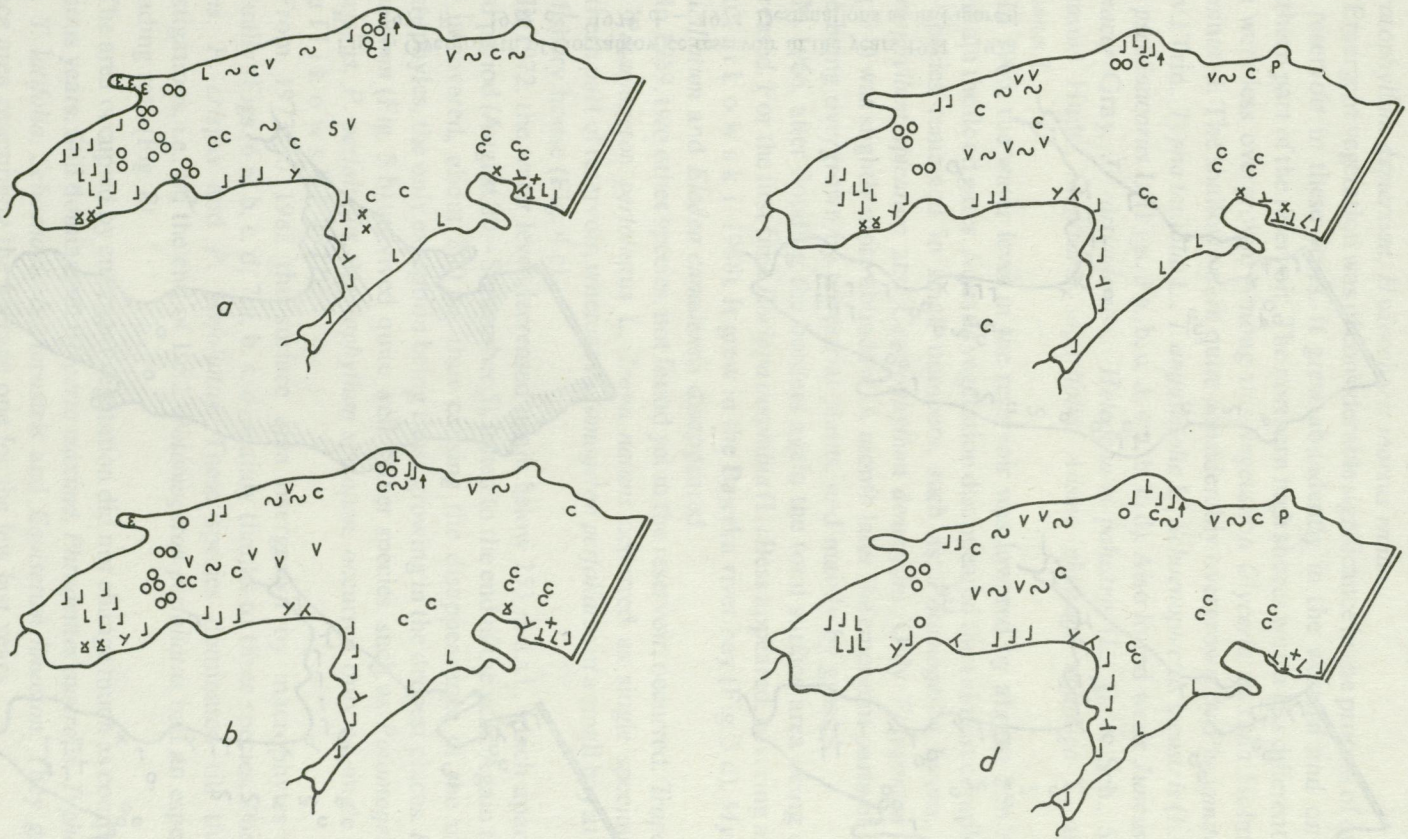

Fig. 4. Overgrowth of Goczałkowice reservoir in the years 1967 – 1970
a – 1967, b – 1968, c – 1969, d – 1970. Designations as in Figure 1

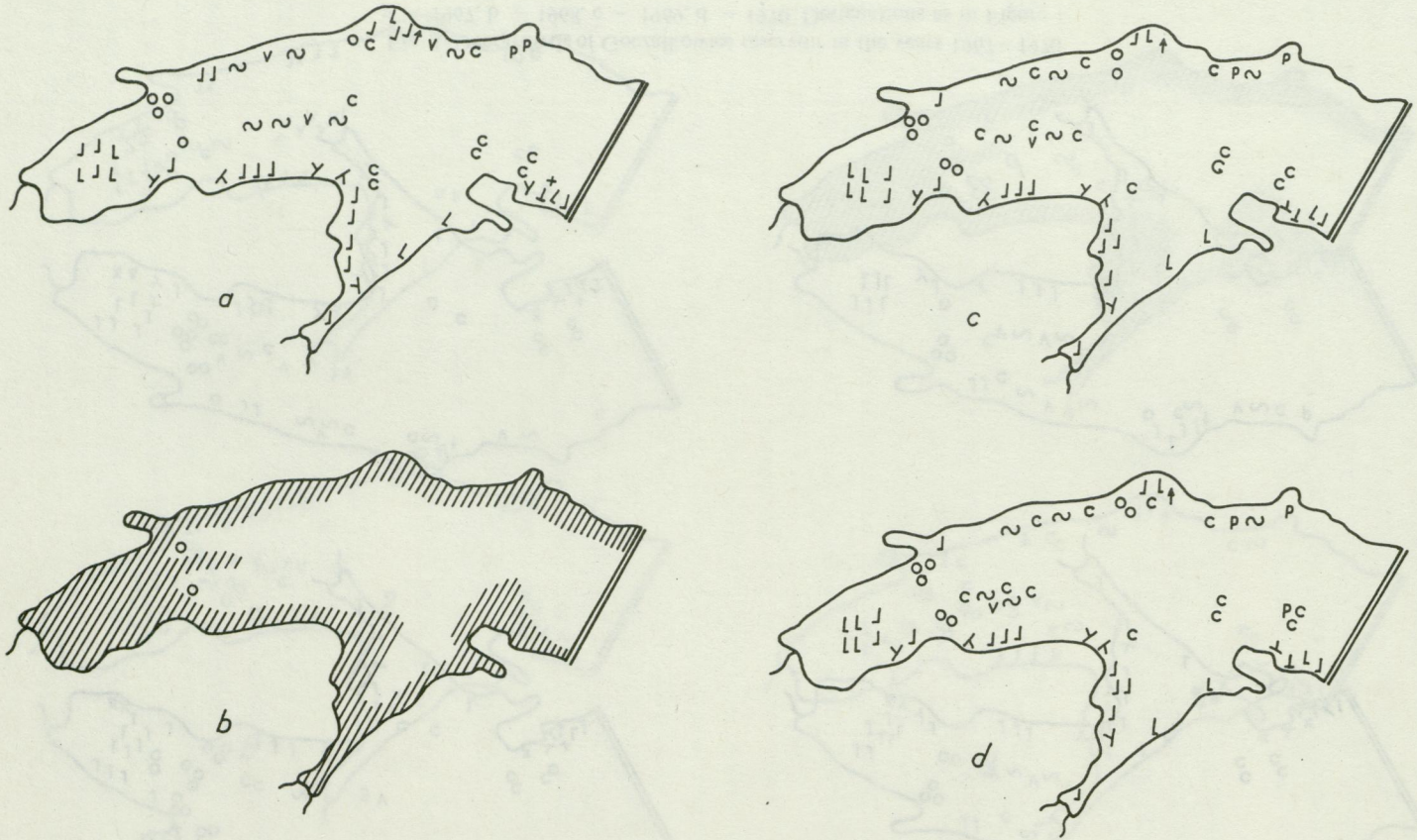

Fig. 5. Overgrowth of Goczałkowice reservoir in the years 1971 – 1974
a – 1971, b – 1972, c – 1973, d – 1974. Designations as in Figure 1

verticillatum L., *M. spicatum, Batrachium aquatile, Hottonia palustris* L., *Callitriche* sp., *Ceratophyllum demersum, Hydrocharis morsus ranae.*

Emergent vegetation was of considerable significance in the process of overgrowing the reservoir in these years. It grew abundantly in the western and on the whole southern part of the reservoir. The northern high shores with a less differentiated shore line were less overgrown. Among this vegetation *Glyceria maxima* Holm. distinctly dominated. The shallows were quite considerably overgrown by *Phragmites australis* (Cav.) Trin., *Typha latifolia* L., *T. angustifolia* L., *Schoenoplectus lacustris* (L.) Palla and *Iris pseudoacorus* L. (Figs. 3 a, b, c, d, 4 a, b, c, d). Also found were: *Juncus effusus* L., *J. macer* Gray, *J. articulatus*., *Heleocharis palustris* (L.) E. et Sch., *Sparganium ramosum* Huds., *Sagittaria sagittifolia, Alisma plantago aquatica* L. and *Acorus calamus* L.

In 1965, the water level in the reservoir was lowered by almost 2 m in order to maintain the flood gates. Aquatic vegetation disappeared then almost completely. Only few species remained in small numbers, such as: *Potamogeton lucens, P. crispus, Myriophyllum spicatum* and *Ceratophyllum demersum.* Only *Polygonum amphibium* (Fig. 3 c) was slightly more abundant. A month later the emergent parts of the bottom were being overgrown by terrestrial plants, and mainly by grasses.

In 1966, after flooding the borders again the total surface area being overgrown decreased. For the first time *Rorippa amphibia* (L.) Bess appeared, covering almost 1 ha (K u f l i k o w s k i 1968). It grew in the Bajerka river bay (Fig. 3 d). *Myriophyllum verticillatum* and *Elodea canadensis* disappeared.

In 1969, two other species, not found yet in the reservoir, occurred: *Trapa natans* L. and *Potamogeton perfoliatus* L. *Trapa natans* occurred as single specimens in the southern part of reservoir, whereas *Potamogeton perfoliatus* in a small bay at Łąka near the fishery house (Fig. 4 c).

In 1972, the water level decreased again below 253 m a.s.l., which apart from the flood period (August 20 – September 5), lasted to the end of the year. Again the bottom was uncovered, about 800 ha, thus causing the disappearance of the majority of macrophytes, the only exception being those growing in the deepest places. *Polygonum amphibium* (Fig. 5 b) survived quite well. Other species, such as *Potamogeton lucens, P. crispus, P. perfoliatus, Myriophyllum spicatum*, occurred only as single specimens (K u f l i k o w s k i 1977).

From 1973 to 1982 the surface area overgrown by macrophytes increased gradually (Figs. 6 a, b, c, d, 7 a, b, c, d) mainly thanks to three species: *Potamogeton lucens, P. crispus* and *P. perfoliatus.* These species dominated till the end of investigations, i.e., till the end of 1982. *Potamogeton perfoliatus* had an especially fast spreading rate (Fig. 8).

The area occupied by emergent vegetation did not change much as compared with previous years. Still dominated: *Glyceria maxima, Phragmites australis, Typha angustifolia, T. latifolia, Schoenoplectus lacustris* and *Equisetum limosum.* They grew on a surface area resembling the average one for the few last years.

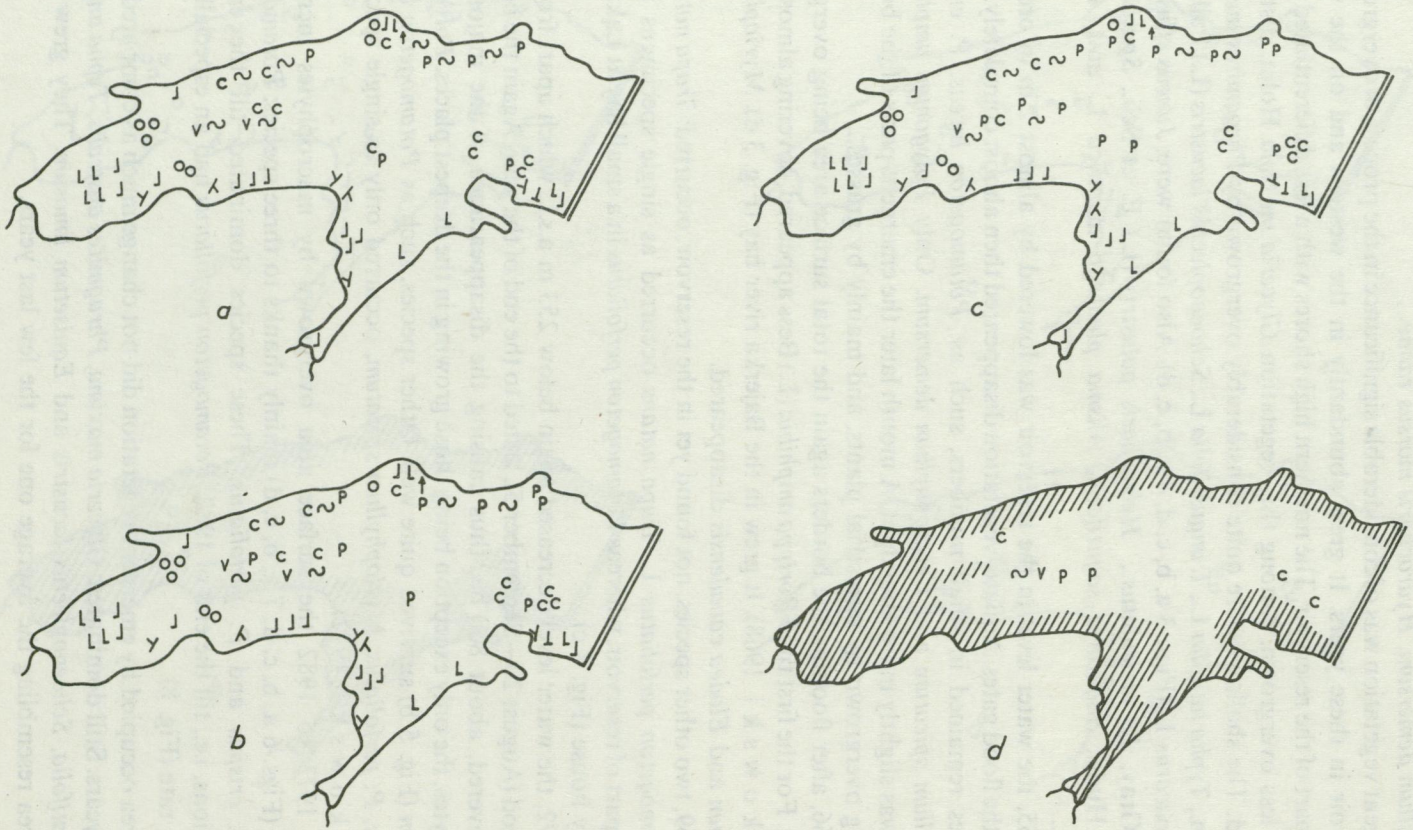

Fig. 6. Overgrowth of Goczałkowice reservoir in the years 1975 – 1978
a – 1975, b – 1976, c – 1977, d – 1978. Designations as in Figure 1

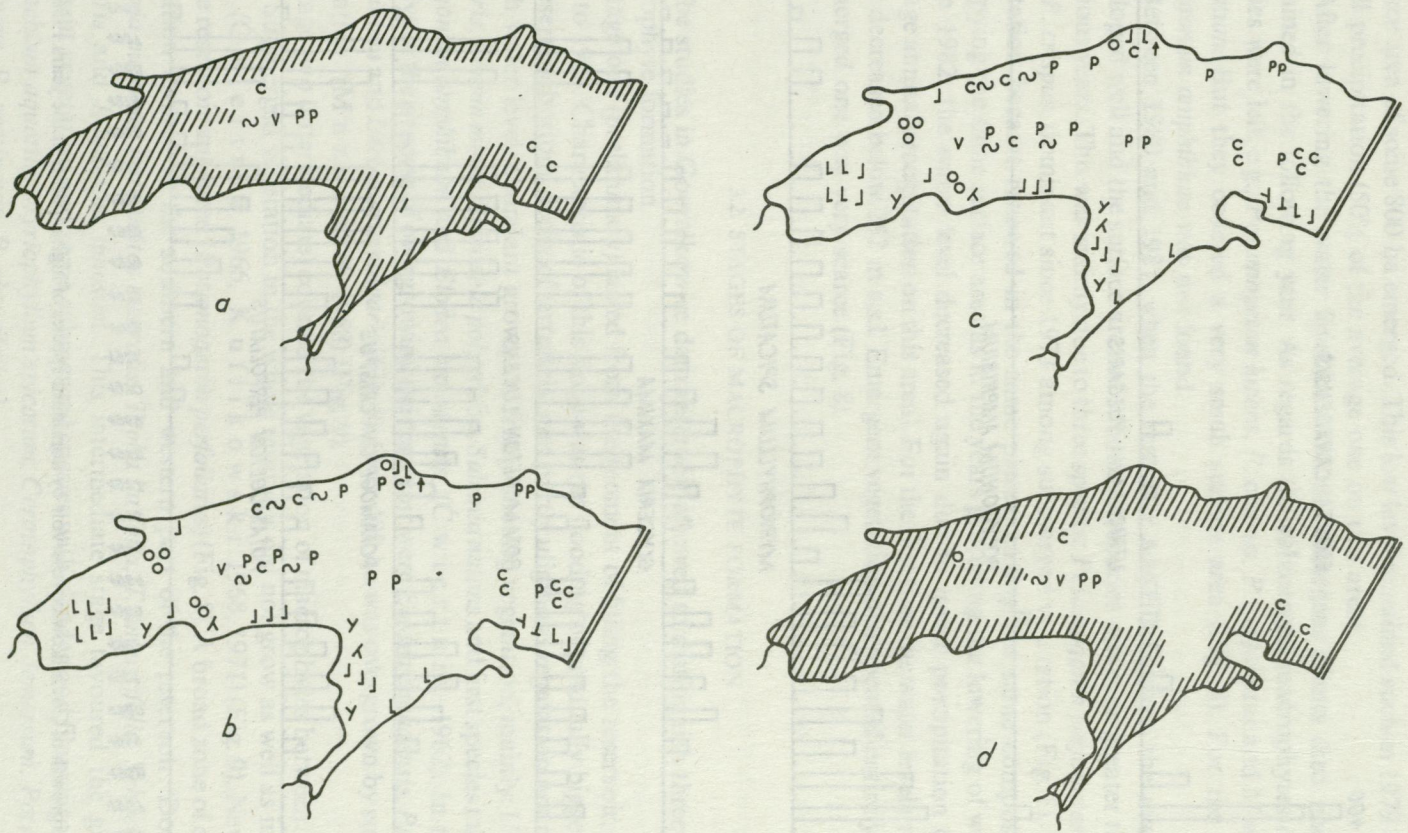

Fig. 7. Overgrowth of Goczałkowice reservoir in the years 1979–1982
a – 1979, b – 1980, c – 1981, d – 1982. Designations as in Figure 1

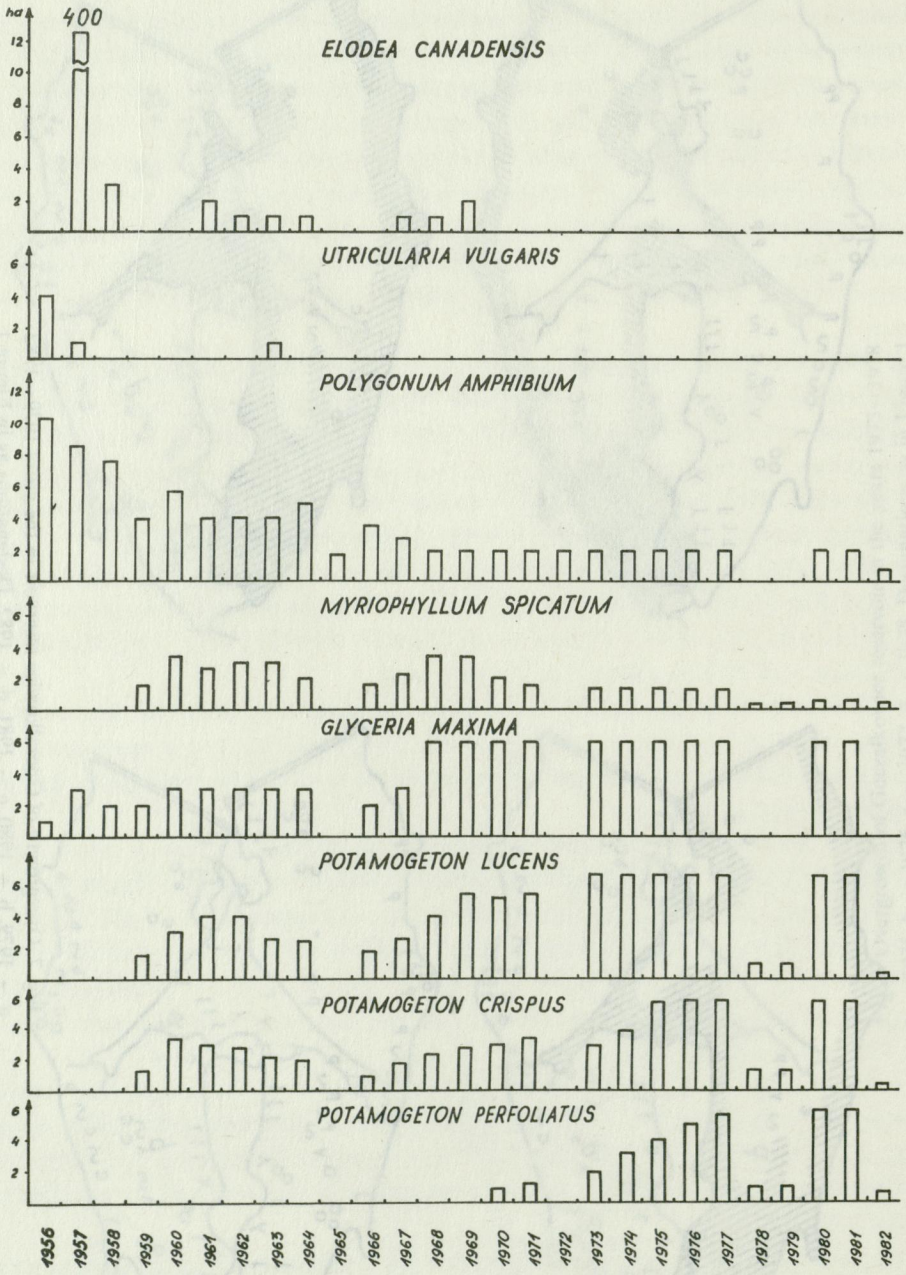

Fig. 8. Overgrowth of Goczałkowice reservoir by dominant species of higher plants in the years 1956 – 1982

In 1978, the water level in the reservoir was lowered for the third time. A bottom surface area of some 800 ha emerged. This low level remained such in 1979 because of small precipitation (50% of the average one on this area).

After lowering the water level in 1978 the emergent plants died and nothing remained in the following year. As regards the submerged macrophytes only some species were left, e.g., *Potamogeton lucens, P. crispus, P. perfoliatus* and *Myriophyllum spicatum.* But they covered a very small surface area (Fig. 8). For the first time *Polygonum amphibium* was not found.

Between 1980 and 1981, when the reservoir was filled again, the macrophytes developed well and the surface area of submerged species was even greater than in the previous years. This was mainly due to three species: *Potamogeton perfoliatus, P. lucens* and *P. crispus*, dominant since 1973 among submerged vegetation (Fig. 8). Emergent vegetation became renewed in the same places, having the same composition and occupying the same surface area as in the years preceding the lowering of water level.

In 1982, the water level decreased again due to lower precipitation (less than average annual precipitation on this area). For the first time the water level in the water body decreased below 252 m a.s.l. Emergent vegetation disappeared entirely, whereas submerged one was very scarce (Fig. 8).

3.2. STAGES OF MACROPHYTE FORMATION

The studies in Goczałkowice dam reservoir allowed to distinguish three stages of macrophyte formation.

Stage one (preliminary) lasted from the moment of filling the reservoir, i.e., from 1956 to 1958. Characteristic of this stage was the flooding of gradually bigger parts of the reservoir bottom, decay of terrestrial and partly uliginose vegetation not tolerating a high water level, abundant growth of freely floating vegetation, mainly: *Utricularia vulgaris, Lemna minor, Spirodela polyrrhiza, Salvinia natans* and first species taking root *Polygonum amphibium* and *Elodea canadensis* (Ć w i e r t n i a 1962). In this stage decisive in the process of overgrowing the reservoir were *Elodea canadensis, Polygonum amphibium* and *Utricularia vulgaris* (Fig. 8). Over 400 ha was overgrown by submerged vegetation (M a z u r et al. 1958) (Fig. 9).

Stage two (intermediate) covered the vegetation of macrophytes between 1959 and 1972. Submerged vegetation in the whole reservoir did not grow as well as in the first years (Ć w i e r t n i a 1966, K u f l i k o w s k i 1968, 1971) (Fig. 9). New species for the reservoir appeared (*Potamogeton perfoliatus*) (Fig. 8). A broad zone of emergent vegetation formed in the southern and western part of the reservoir. Dominated: *Glyceria maxima, Phragmites australis, Typha latifolia, T. angustifolia, Schoenoplectus lacustris* and *Equisetum limosum.* This intermediate stage favoured the growth of emergent vegetation and some submerged species with slender and filamentous leaves (*Batrachium aquatile, Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton gramineus, P. pectinatus, P. obtusifolius*).

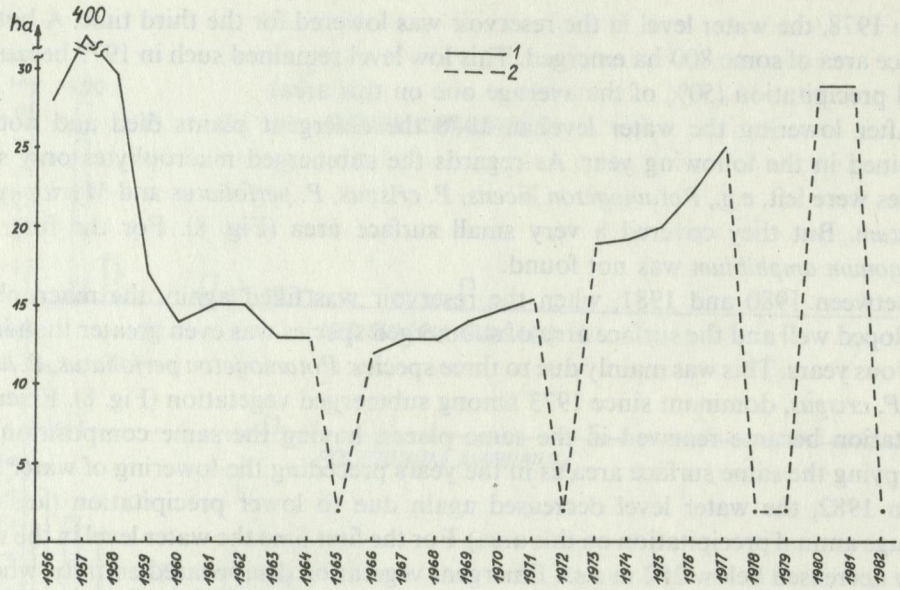

Fig. 9. Changes in total surface area of Goczałkowice reservoir overgrown by submerged macrophytes in the years 1956 – 1982

1 – overgrowth of reservoir at normal water level, 2 – overgrowth of reservoir at a lower water level

Stage three (stabilization) began around 1973. The surface area of submerged vegetation started to increase thanks to three species: *Potamogeton lucens, P. crispus, P. perfoliatus*, dominant in the reservoir (Fig. 8). These species did not grow at the sacrifice of other species as it happened previously (K u f l i k o w s k i 1977). At this stage the right of priority as the basic factor conditioning the distribution of communities in a newly constructed reservoir was substituted by the rule of force, where less expansive vegetation made room for macrophytes having a broader ecological amplitude. This can be shown on the example of total disappearance of macrophytes occurring in stages one and two: *Utricularia vulgaris, Elodea canadensis, Lemna trisulca, Salvinia natans, Myriophyllum verticillatum* and the appearance of new ones, such as *Potamogeton perfoliatus* which together with other pond-weed species grew abundantly in stage three (Fig. 8).

4. DISCUSSION

Similar has been the process of overgrowing the Volga and Dnieper reservoirs in USSR. There also were three development stages (Z e r o v 1976, K o r e l j a k o v a 1979). The only difference was in the duration of particular stages. The first stage in these reservoirs lasted 5 – 10 years, whereas in the Goczałkowice one only 3 years. This is because USSR reservoirs have great surfaces, e.g., Kievskoe 92 thous. ha, Gorkovskoe 157 thous. ha, Kremencugskoe 225 thous. ha, Volgogradskoe

311 thous. ha, Rybinskoe 445 thous. ha, Kujbyševskoe 645 thous. ha, and it takes several years to fill them. Goczałkowice reservoir has a surface area of 3.2 thous. ha and was filled in one and half a year.

Aquatic vegetation of the Dnieper reservoirs in 1976, i.e., till the publication of monograph (Z e r o v 1976), was in its second stage, with the exception of Zaporožskoe reservoir which finished its third stage. This reservoir was filled again in 1947 (constructed in 1931 – 1934) and being overgrown for 20 years. Other reservoirs were much younger, e.g., Kremenčugskoe was constructed in 1961, Kievskoe in 1966, Dneprodzeržinskoe in 1968 and macrophytes were in the second stage of their formation.

These studies have confirmed that the main factor affecting the rate and character of aquatic vegetation growth in dam reservoirs is the depth, shore line development and wave intensity. This vegetation grows in reservoirs usually to the depth of 2.5 m. The degree of overgrowth depends mainly on the surface of their shallows.

Total surface area overgrown by macrophytes in Goczałkowice reservoir was 6% in 1973 and 8% (about 250 ha) in 1982. The degree of overgrowth of the Volga and Dnieper reservoirs is following: Kujbyševskoe 0.1%, Volgogradskoe 0.9%, Rybinskoe 1.3%, Gorkovskoe 1.4%, Kremenčugskoe 6.8%, Ivankovskoe 16.7%, Kievskoe 32% (B e l a v s k a j a and K u t o v a 1966, E k z e r c e v 1966a, 1966b, Z e r o v 1976, K o r e l j a k o v a 1979).

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5. SUMMARY

The aim here has been an observation of macrophyte growth in Goczałkowice dam reservoir. This subject could be undertaken thanks to many years of uninterrupted investigations from the moment of construction of the reservoir. Three stages of macrophyte growth were distinguished.

Stage one (1956 – 1958) was characterized by a dynamic growth of macrophytes and a small number of species. The reservoir at the time was dominated by *Polygonum amphibium*, *Elodea canadensis* and *Utricularia vulgaris* (Fig. 1 a, b, c).

Stage two (1959 – 1972) was characterized by slower growth and a greater number of species. Emergent plants achieved then maximum development (Figs. 2 a, b, c, d, 3 a, b, c, d, 4 a, b, c, d, 5 a). Among submerged macrophytes plants with slender and filamentous leaves had the best conditions.

Stage three, which began in 1973, was distinguished by an increasing surface being overgrown by submerged macrophytes (*Potamogeton lucens*, *P. crispus*, *P. perfoliatus*), which became dominant in the reservoir (Figs. 5 c, d, 6 a, b, c, d, 7 a, b, c, d, 8).

Overgrowth of Goczałkowice dam reservoir resembled that of Volga and Dnieper reservoirs, also with three stages of macrophyte growth. The difference was only in the duration of particular stages. Total surface area of macrophytes in Goczałkowice reservoir in 1982 was about 250 ha (8% of surface area of the reservoir).

6. POLISH SUMMARY

Celem pracy było prześledzenie rozwoju makrofitów w zbiorniku zaporowym w Goczałkowicach. Wieloletnie i nieprzerwane wyniki badań od początku utworzenia zbiornika posłużyły do opracowania tego tematu. W wyniku tych badań wyróżniono 3 stadia formowania się makrofitów.

Pierwsze stadium – obejmujące lata 1956–1958 – charakteryzujące się dynamicznym rozwojem makrofitów i niewielką liczbą gatunków. Zbiornik w tym okresie został zdominowany przez *Polygonum amphibium, Elodea canadensis* i *Utricularia vulgaris* (rys. 1 a, b, c).

Drugie stadium – przypadające na lata 1959–1972 – cechujące się powolniejszym zarastaniem i zwiększającą się liczbą gatunków. Rośliny wynurzone doszły w tym okresie do swojego maksymalnego rozwoju (rys. 2 a, b, c, d, 3 a, b, c, d, 4 a, b, c, d, 5 a). Z makrofitów zanurzonych optymalne warunki miały rośliny o liściach wiotkich i nitkowatych.

Trzecie stadium – rozpoczynające się od 1973 r. i wyróżniające się wzrostem powierzchni zarastania przez makrofity zanurzone (*Potamogeton lucens, P. crispus, P. perfoliatus*), które stały się gatunkami dominującymi w zbiorniku (rys. 5 c, d, 6 a, b, c, d, 7 a, b, c, d, 8).

Proces zarastania zbiornika Goczałkowickiego był zbliżony do zbiorników wołżańskich i dnieprzańskich. W zbiornikach tych wyróżniono również 3 stadia rozwoju makrofitów, a różnica polegała jedynie na czasie trwania poszczególnych stadiów. Całkowita powierzchnia makrofitów w zbiorniku Goczałkowickim w 1982 r. wynosiła ok. 250 ha (8% powierzchni zbiornika).

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