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EXPERIMENTALLY INCREASED FISH STOCK
IN THE POND TYPE LAKE WARNIAK
XI. FOOD RESOURCES AND AVAILABILITY
OF THE EULITTORAL ZONE FOR FISH*

(Ekol. Pol. 21: 583-593). The eulittoral zone is on the average 7% of lake surface and has a high biomass of invertebrate fauna used as food by fish. The availability of this zone decreases in summer due to overgrowing, drying and oxygen deficits. The shore zone area inaccessible in some periods for fish is 11% of the lake surface.

I. INTRODUCTION, SITES, METHODS

This is a part of complex studies on the effect of introduction of carp and bream on the biocenosis of a eutrophic, pond type lake Warniak. The experiment was conducted in the years 1967-1969. Each year the fish were introduced in spring and caught in autumn. As not all the fish were caught their numbers increased in successive years (Zawisza and Ciepielewski 1973, Kajak and Zawisza 1973).

* Praca wykonana w ramach problemu węzłowego Nr C9.1.7.

Lake Warniak has a surface 38.4 ha, mean depth 1.5 m, max. depth 3.7 m, the development of the shoreline 1.1. The majority of the lake surface is overgrown with macrophytes, among which *Ceratophyllum demersum* L., *Phragmites communis* Trin. and *Stratiotes aloides* L. dominate (Bernatowicz 1969). The drainage basin covers 382 ha, the annual water exchange is 1.2. The following areas adjoin the lake (in per cents of shoreline length): forests (23%), pastures, meadows and sandy cultivated soils (29%), fertile cultivated soils (48%) and buildings (<0.2%) (Pieczyńska 1972).

The eulittoral is the border zone between the lake and the surrounding land. It includes the area contained between the shoreline marked by the highest and lowest annual water level and the neighbouring areas which are being splashed or exposed during wave action. The range of this zone is conditioned by fluctuations of the water level, configuration of the shore terrace and the processes of shore erosion and accumulation of matter of lake and terrestrial origin (Pieczyńska 1972).

The near-shore shallows in lake Warniak are strongly penetrated by fish, which has been found in direct observations during the catches with the electrical shocker. The data of Prejs (1973) show that this zone is used as feeding grounds for fish. Here, I have determined the food resources and availability of the eulittoral zone for fish.

The changes in the range of eulittoral zone have been analysed by regular measurements of the water level (using a specially constructed staff water gauge) and bathymetrical measurements.

Chemical analyses of water in the submerged eulittoral were made using the classic methods (Standard Methods 1960, Just and Hermanowicz 1964). Water samples were taken with a set being a modification of Vereščagin apparatus (Pieczyńska 1972). Samples of sediments were taken in the submerged and emergent eulittoral using a plastic cylinder, 500 m² in cross-section. The proportions of detritus of autochthonous and allochthonous origin in the sediments were determined by means of microscopical differentiation of the remains and their weight. Organic matter content in dry weight of sediments was estimated by ashing in an electric furnace for 5 hr. at 550°C.

The invertebrate macrofauna in the submerged eulittoral and on the border between land and water, was analysed. Quantitative samples of fauna were taken using the same method as for sediments. The species composition, density and biomass of organisms, were determined. The material was preserved with formalin and sorted without sieving. The biomass of particular groups of organisms was determined on an analytical balance. Detail, regular analyses were made on 5 sites distributed in different parts of the lake.

II. ENVIRONMENTAL CONDITIONS IN THE EULITTORAL ZONE

In lake Warniak the annual fluctuations of the water level in years 1967–1969 were 28, 26 and 31 cm, respectively (Tab. I). The highest water level was recorded in April or May, the lowest – in July or August. As an example the water level fluctuations in 1967 are presented in Figure 1. Depending on the configuration of the areas adjoining the lake and the shore terrace in different parts of the lake, the shoreline moves in the analysed years 7–9 m on the average. In 1969 the shoreline moved the most – 18 m. Water level fluctuations result in drying of some parts of the lake in summer (7% of lake surface on the average for the period examined).

The area of the zone contained between the highest and the lowest water levels in lake Warniak in 1967–1969

Tab. I

Year	Yearly difference in water level (cm)	The distance between the shorelines for the highest and the lowest water levels (m)	
		average	range of variations
1967	28	8	1.2–16
1968	26	7	1.1–15
1969	31	9	0.5–18

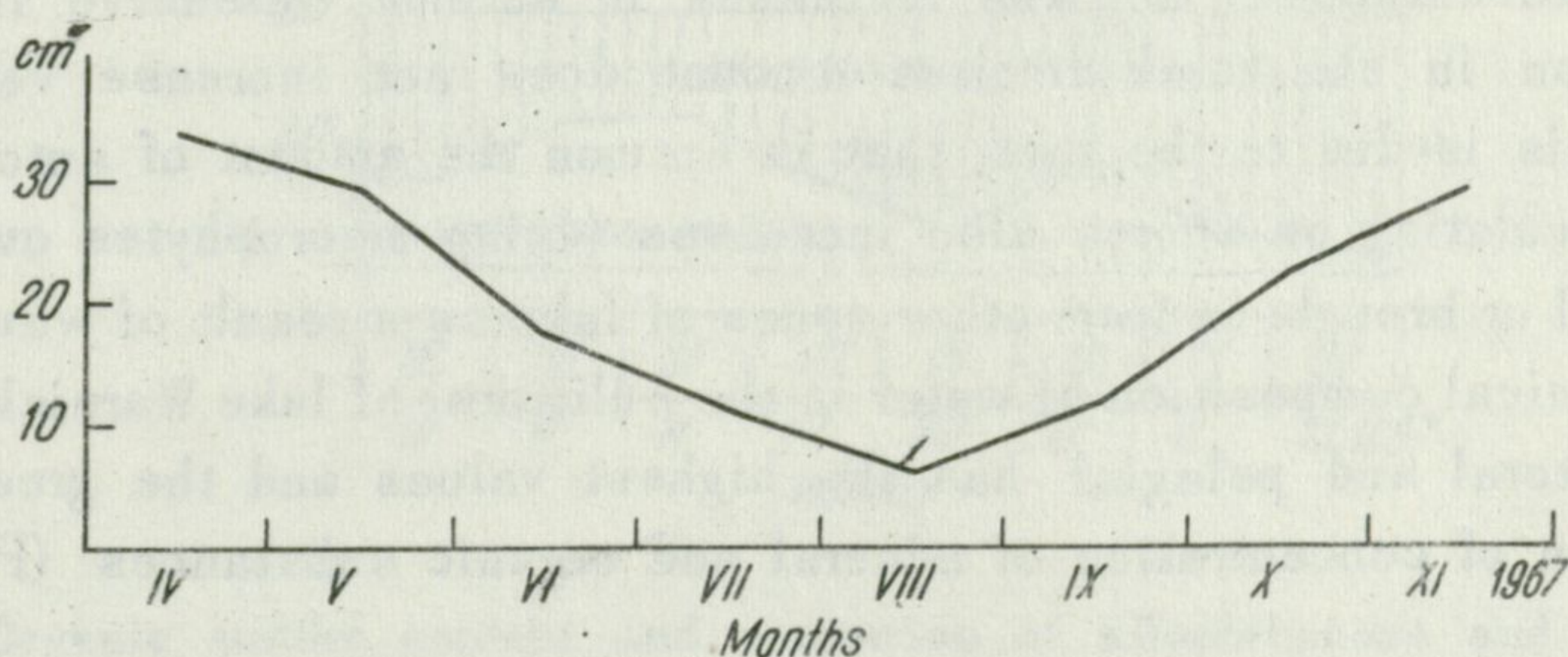


Fig. 1. Water level fluctuations in lake Warniak in the period April–November 1967

The availability of the eulittoral zone for the penetration of fish is limited – apart from periodical drying – by several other environmental conditions. First of all overgrowing by macrophytes and changes in chemical composition of water should be mentioned.

The eulittoral of lake Warniak is overgrown by several macrophyte species

occurring in similar proportions: *Phragmites communis* Trin., *Carex* sp., *Equisetum limosum* L., *Menyanthes trifoliata* L., *Calla palustris* L. and *Cicuta virosa* L. In many places the algae (Pieczyńska 1972) and the *Lemnaceae* (Kobuszevska 1973) develop abundantly. In summer, when the water level decreases, the compact vegetation make the penetration for fish more difficult, and result in partial, periodical „land-like” character of some parts of the lake.

The near-shore shallows vary greatly in their environmental conditions. The light intensity here is in the majority of cases smaller than in other zones of the lake (shading by macrophytes and near-shore trees). The thermal conditions basically differ from those in the central part of the lake, and especially in early spring on sunny days, when the shores are already free of ice, while the central part of the lake still remains frozen. The eulittoral has also the highest absolute values of water temperatures during the year. During the studies the highest temperature was 33.9°C.

Bottom sediments in the eulittoral zone have a considerable amount of allochthonous and autochthonous detritus. The proportion of these types of matter varies. According to the amount of matter accumulated on the shore and its type the organic matter content in sediments also varies (Fig. 2). Despite the considerable differences in time there are sites constantly under the pressure of the allochthonous (site 5) or autochthonous matter (site 1), and also sites with a considerable organic matter content in sediments (considerable layer of accumulated detritus on sandy substrate – sites 1 and 4) or small organic content (very few detritus remains on sandy substrate – site 5). The amount of allochthonous detritus increases in autumn (intensive litter fall). Its proportion in the total detritus amount does not increase very visibly (Fig. 2). This is due to the fact, that in autumn the amount of autochthonous matter accumulating on shores also increases (dying macrophytes overgrowing the eulittoral or brought in from other zones of lake as a result of wave action).

The chemical composition of water in the eulittoral of lake Warniak compared with the littoral and pelagial has the highest values and the greatest range of fluctuation of concentration of mineral and organic substances (Pieczyńska 1972).

A factor considerably limiting the penetration of fish in the eulittoral of the examined lake are the frequent oxygen deficits. Zachwieja (1973) examining the oxygen concentration in lake Warniak says that the oxygen conditions are very good from spring to winter; only during the long and snowy winter periods there are very great oxygen losses causing the „winter-kill” (Zachwieja 1965). In the eulittoral frequent oxygen deficits were observed, mainly in summer. Small water depth, dense vegetation, considerable detritus

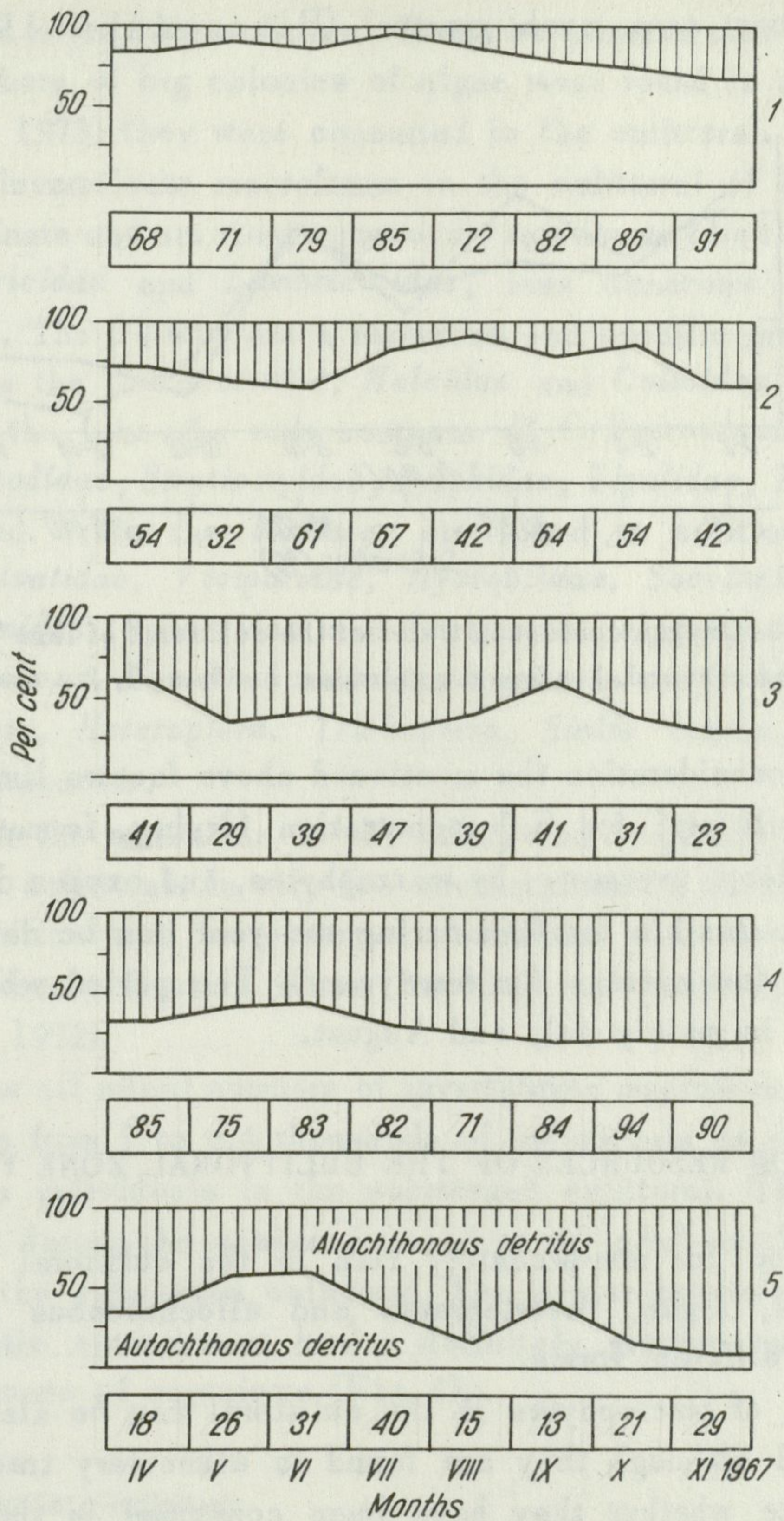


Fig. 2. Organic matter content and proportion of allochthonous and autochthonous detritus in sediments of 5 sites of the eulittoral of lake Warniak

Submerged eulittoral, 0.5–1.0 m from the shoreline; in rectangles under diagrams organic matter contents are given in % dry weight in 10 cm surface layer of sediments; 1–5 sites

amounts in sediments, partial covering of water surface with the *Lemnaceae* and partial isolation from waves – favour the oxygen deficits. The data collected from April to November 1968 shows that over 50% of the examined cases have oxygenation values below 6 mg/l and 60% saturation. In over 20% of

cases the oxygen concentrations were 0–2 mg/l (Fig. 3). In the littoral the concentrations were much greater (Pieczyńska 1972, Zachwieja 1973).

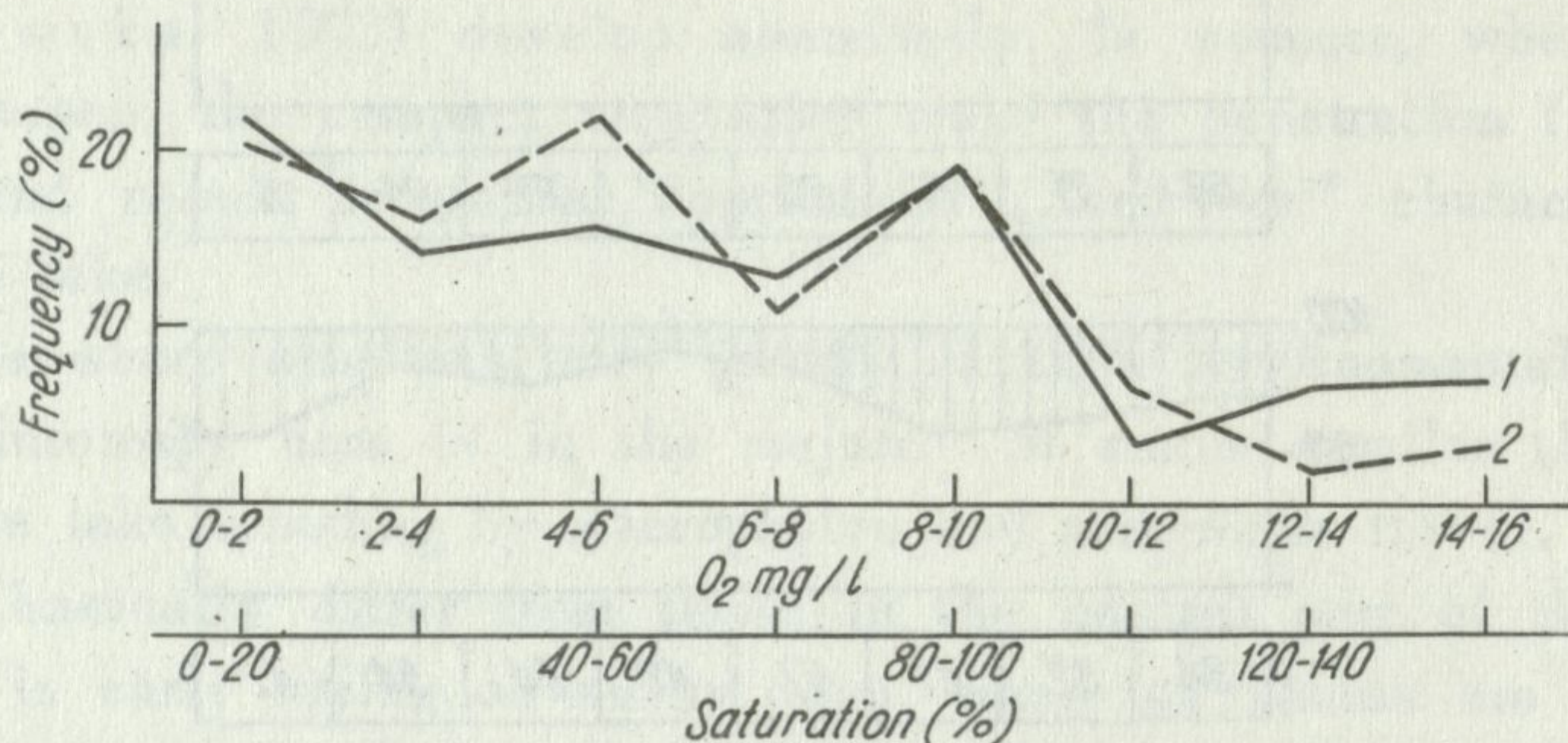


Fig. 3. Oxygen content in water of the eulittoral of lake Warniak. Submerged eulittoral, 1 m from the shoreline; 1 – O₂ mg/l, 2 – saturation (%)

Taking into consideration the mentioned above factors limiting the availability of the eulittoral for fish penetration (drying, formation of shallows less than 5 cm deep, overgrown by macrophytes, and oxygen deficits) the area periodically inaccessible for fish during the year can be determined as 11% of lake surface (an average for few years). The period when the eulittoral is not available is mainly July and August.

III. FOOD RESOURCES OF THE EULITTORAL ZONE FOR FISH

Potential food for non-predatory fish in the eulittoral of lake Warniak are macrophytes, algae, invertebrates and allochthonous matter reaching the eulittoral in different forms.

The species of macrophytes in the eulittoral can be also found in other lake zones, and although they are found in alimentary tracts of fish it is difficult to state whether they have been consumed in the eulittoral. The *Lemnaceae* are specific for the eulittoral, and especially *Lemna minor* L. and *Spirodela polyrrhiza* (L.) Schleiden (Kobuszevska 1973). They have been found, although not numerously, in the alimentary tracts of fish (Prejs 1973).

Mass algal appearances were frequently observed in the eulittoral. They were usually large colonies of *Cladophora* sp., *Spirogyra* sp., *Gloeotrichia natans* (Hedwig) Rabenh. and *Nostoc pruniforme* Agardh. The maximal biomass of algae was recorded in June 1968 – 5940 mg/dcm³ (*Cladophora* and *Spirogyra*,

20 cm from the shore at the depth of 10 cm). Such great amounts of algae were not recorded beyond the eulittoral. It can be assumed that in the instances, where great numbers of big colonies of algae were found in alimentary tracts of fish (Prejs 1973) they were consumed in the eulittoral.

Among the invertebrate macrofauna in the eulittoral of lake Warniak the *Oligochaeta* dominate and are most numerous represented by the *Enchytraeidae*, numerous *Lumbricidae* and *Lumbriculidae*, less numerous *Tubificidae* and *Naididae* scarce. The *Diptera* are a numerous and specific group for the eulittoral. Apart from the *Chironomidae*, *Heleidae* and *Culicidae* recorded in the central part of the lake the representants of *Cylindrotomidae*, *Liriopeidae*, *Muscidae*, *Psychodidae*, *Stratiomyidae*, *Syrphidae*, *Tipulidae*, *Tabanidae*, *Bibionidae*, are found. Also the *Mollusca* are found in eulittoral (*Lymnaeidae*, *Planorbidae*, *Valvatidae*, *Viviparidae*, *Hydrobiidae*, *Succineidae*, *Zonitidae*, *Helicidae*, *Unionidae*, *Sphaeridae* and *Dreissena polymorpha*). And numerous are *Asellus aquaticus*, *Hirudinea* and less numerous the *Gammaridae*, *Collembola*, *Lepidoptera*, *Heteroptera*, *Trichoptera*, *Sialis lutaria*, *Ephemeroptera*, *Odonata* and *Hydracarina*.

The fauna in the sediments is the main, and frequently the only animal community in the eulittoral. In very few environments in the eulittoral simultaneously communities may be observed connected with the vegetation, with sediments, and freely floating fauna, but they are spatially closely related (Pieczyńska 1972).

The mean (for all sites) numbers of invertebrate macrofauna per 1 m² during the season range from 1 to 6.4 thousands of individuals on the shoreline and 1–4.1 thousands individuals in the submerged eulittoral. The mean biomass values fluctuate during the season from 18 to 60 g/m² on the shoreline and 19–27 g/m² in the submerged eulittoral. The border between land and water as a more astatic environment has a definitely greater variability of both numbers and biomass of organisms (Fig. 4).

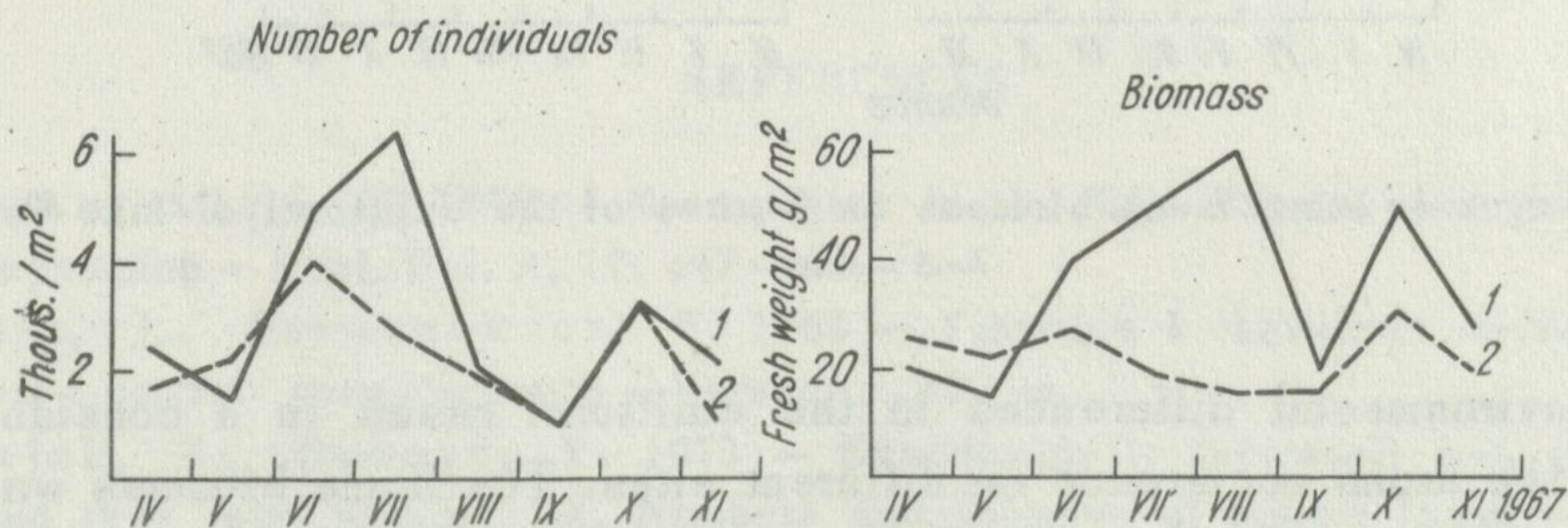


Fig. 4. Changes in macrofauna numbers and biomass in the eulittoral of lake Warniak. Mean values from all sites; 1 – shoreline, 2 – submerged part of eulittoral, 1 m from the shoreline

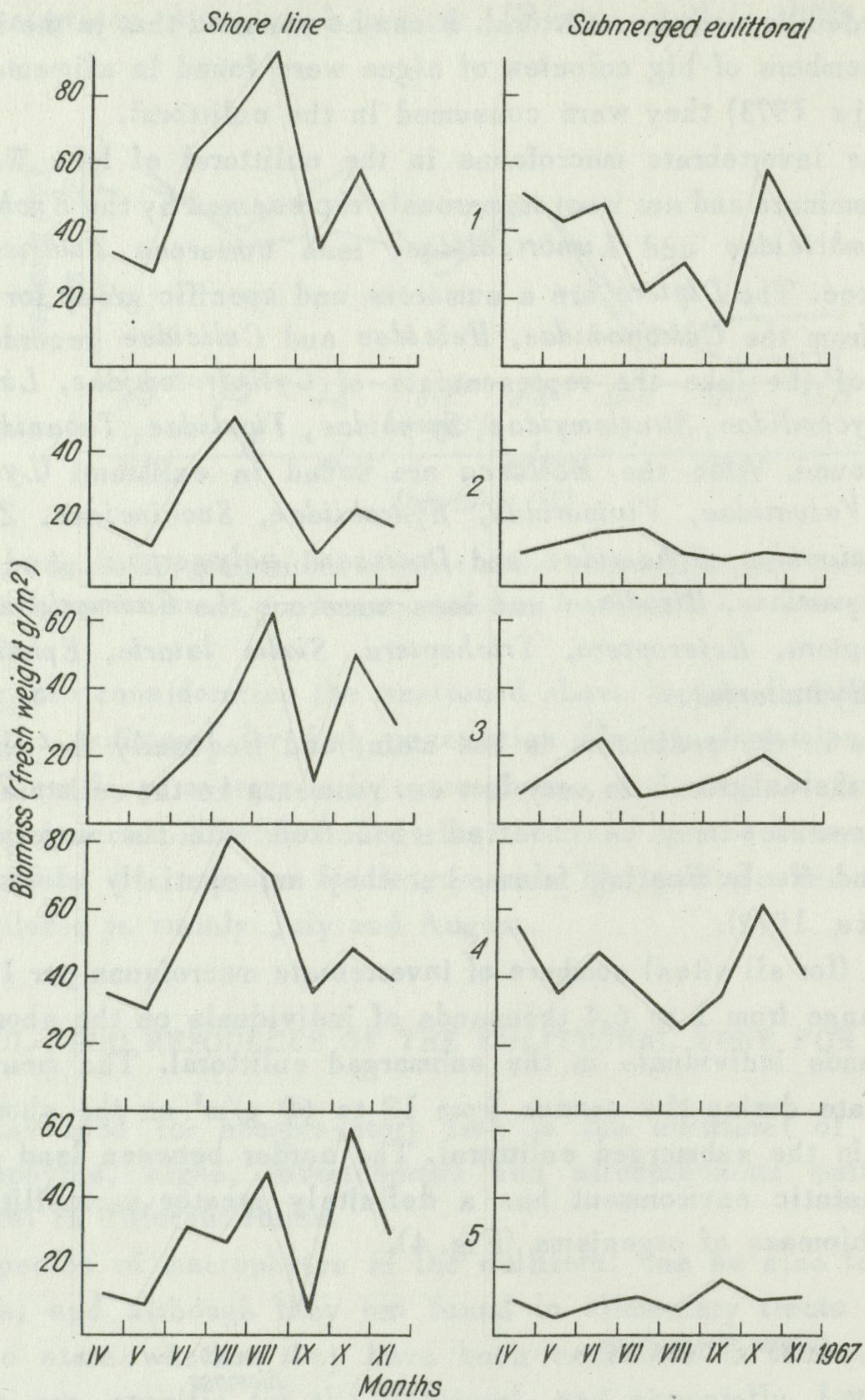


Fig. 5. Changes in macrofauna biomass on 5 sites of the eulittoral of lake Warniak
1-5 - sites

The environmental differences in the eulittoral result in a considerable variety of the fauna occurrence on different sites. The fauna biomass was the highest on sites 1 and 4 (Fig. 5), where was the highest organic matter content in sediments (Fig. 2). The maximal values of biomass were recorded on different sites at different times. No relation was observed between the fauna

composition, their numbers and biomass and the proportion in sediments of allochthonous and autochthonous detritus.

Comparing these results with the data of Kajak and Dusoge (1973) it can be stated that fauna numbers in the eulittoral are approximate or smaller than benthos numbers in other lake environments. However, the biomass is several to several tens higher. This is due to the differences in the qualitative fauna composition; if the *Chironomidae* and *Tubificidae* dominate in the benthos beyond the eulittoral then the big forms (*Enchytraeidae*, *Lumbriculidae*, *Tubificidae*, *Tabanidae* and others) have a considerable share in the eulittoral.

IV. CONCLUSIONS

The eulittoral of lake Warniak is regularly penetrated by fish and used as the feeding grounds. Prejs (1973) found that mainly carp, tench and crucian carp feed in the eulittoral (the presence in their alimentary tracts of organisms not found in other than the eulittoral lake zones — *Cylindrotomidae*, *Liriopeidae*, *Tabanidae*, *Tipulidae* and *Stratiomyidae*). The eulittoral of the examined lake has considerable food resources. The biomass of the invertebrate fauna is considerably higher than the biomass of benthos in the central part of the lake, which is connected with the domination in the eulittoral of big forms, undoubtedly attractive fish food.

The eulittoral in the examined lake is only periodically available for fish. Fluctuations of the water level cause periodical drying of environments, and also overgrowing and oxygen deficits on the shallows make the penetration for fish impossible.

It has been determined that the zone not available for fish (summer period — the lowest water level) is on the average 11% of the lake surface.

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EKSPERYMENTALNE ZWIĘKSZENIE OBSADY RYB W STAWOWYM JEZIORZE WARNIAK

XI. ZASOBNOŚĆ POKARMOWA I DOSTĘPNOŚĆ DLA RYB STREFY POBRZEŻA

Streszczenie

Pobrzeże jeziora Warniak jest strefą penetrowaną przez ryby i wykorzystywaną jako miejsce ich żerowania (Prejs 1973).

Środowisko to charakteryzuje się znaczną zasobnością pokarmową dla ryb. Liczebność makrofauny bezkręgowej jest wprawdzie zbliżona do liczebności bentosu w centralnej części zbiornika, lecz jej biomasa przewyższa biomasę bentosu często wielokrotnie. Związane jest to z licznym występowaniem w pobrzeżu form dużych (*Enchytraeidae*, *Lumbricidae*, *Tipulidae*, *Tabanidae* i inne) nie spotykanych w pozostałych częściach jeziora.

Pobrzeże dostępne jest dla ryb jedynie okresowo. Wahania poziomów wody powodują okresowe osuszanie środowiska, a zarastanie i częste deficyty tlenu na płyciznach przybrzeżnych uniemożliwiają penetrację ryb. W badanym jeziorze roczne wahania poziomu wody w latach 1967–1969 wynosiły odpowiednio 28, 26 i 36 cm (tab. I). Najwyższy stan wody notowano w kwietniu lub maju, najniższy w sierpniu (fig. 1). W kolejnych latach linia brzegowa przesuwa się średnio od 7 do 9 m. W badanym okresie teren okresowo osuszany stanowi średnio 7% powierzchni jeziora.

Biorąc pod uwagę wszystkie czynniki ograniczające bytowanie ryb w badanym środowisku oceniono, że strefa niedostępna dla ryb w okresie letnim (lipiec-sierpień) stanowi średnio 11% powierzchni jeziora.

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