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MACROFAUNA OF ELODEIDS OF TWO LAKES OF DIFFERENT TROPHY. I. RELATIONSHIPS BETWEEN PLANTS AND STRUCTURE OF FAUNA COLONIZING THEM

ABSTRACT: Macrofauna colonizing six elodeid species has been analysed: *Myriophyllum alternifolium* DC., *M. spicatum* L., *Ceratophyllum demersum* L., *Potamogeton praelongus* Wulfen, *P. lucens* L. and *Elodea canadensis* Rich. in mesotrophic and eutrophic lakes. The preference of several fauna taxons for specific groups of elodeids is reflected by its composition and degree of species diversity and by dominance structure. As regards density and biomass of fauna the differences are greater in relation to fresh plant weight and bottom surface overgrown by them. Also the site and food conditions connected with the trophy of water bodies affect the qualitative and especially the quantitative character of epiphytic fauna.

KEY WORDS: Epiphytic macrofauna, elodeids, lake trophy.

1. INTRODUCTION

The relations between macrohydrophytes and the species composition and abundance of fauna colonizing them are frequently investigated but still controversial. Very little is known about the influence of lake fertility upon these relations. Only W o l n o m i e j s k i's (1967) report deals with the subject.

The aim of the present work has been to find whether, and if so, to what degree the elodeid species differing in habitat and life cycle, determine the composition and abundance of macrofauna living on them, and how these relations can be affected by environmental conditions at various stages of lake eutrophication.

2. AREA AND METHODS OF INVESTIGATIONS

The studies have been conducted in mesotrophic Lake Piaseczno and in eutrophic Lake Głębokie (eastern Poland) of the Łęczna-Włodawa Lakeland (Fig. 1).

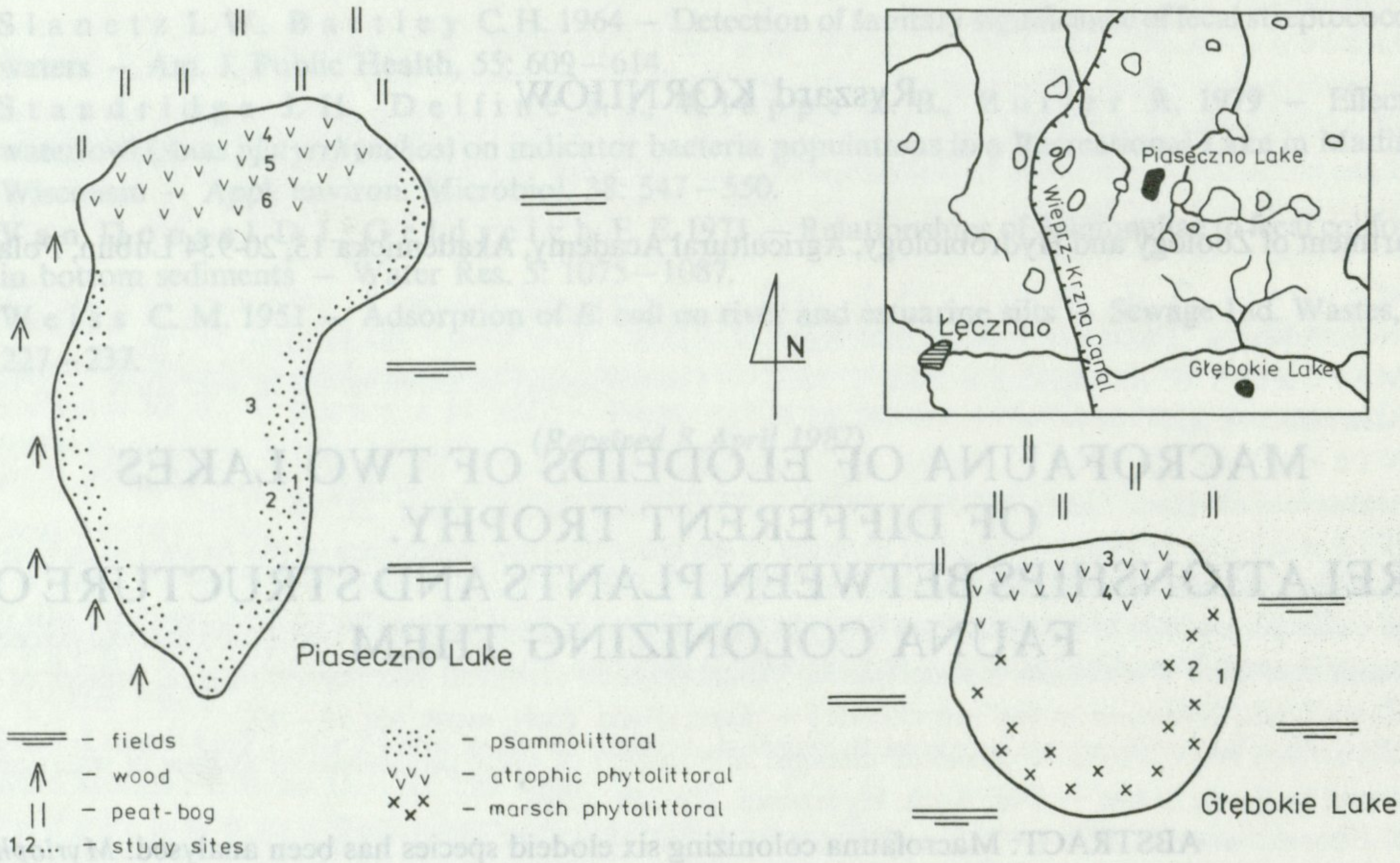

Fig. 1. Sketch indicating the locality of lakes examined indicating the sampling stations

Lake Piaseczno has a surface area 84.7 ha and maximal depth of 38.8 m. The shoreline is poorly developed and is elongated towards the meridian. To the south the lake adjoins the intermediate peat-bog. The remaining shore forms sandy beach surrounded from the west and the south by woods and from the east – by arable fields. The littoral goes down to the depth of about 5 m. According to Bernatowicz and Zachwieja's (1966) classification one can distinguish there atrophic psammolittoral and phytolittoral, covering 75 and 25% of its total surface area, respectively.

Lake Głębokie of a surface 12 ha, and maximal depth 6 m, has an oval-shaped basin. It is surrounded by arable fields and pastures, and from the north – also by an intermediate peat-bog. The lower littoral border is about 2.5 m deep. About 60% of the littoral is occupied by marsh phytolittoral, whereas the remaining part – by atrophic phytolittoral.

Physico-chemical properties of littoral waters of lakes examined are given in Table 1. Observations in each lake were conducted in two different, representative for both water bodies, types of littoral (Fig. 1). For each type of littoral, research station were chosen at the depth of 0.5 and 2 m, whereas in Lake Piaseczno also at the depth of 4 m. They varied as to the kind of bottom sediments, vegetational cover and intensity of

Table 1. Physico-chemical factors of near-bottom water layers in the littoral of lakes Piaseczno and Głębokie (mean values and ranges for stations investigated in 1983 and 1984)

Parameters	Lake Piaseczno	Lake Głębokie
t (^oC)	10.3 1.2 – 22.2	11.3 1.0 – 24
Transparency (m)	6.20 5.35 – 8.00	0.73 0.48 – 1.12
pH	7.32 6.30 – 8.10	7.93 6.55 – 8.60
O_2 (mg/dm^3)	11.26 5.24 – 20.69	10.10 3.20 – 18.1
O_2 (%)	95.8 52.9 – 152.2	85.8 23.1 – 127.6
BZT_5 (mgO_2/dm^3)	1.71 0.05 – 7.4	5.4 0.2 – 12.2
PO_4^{3-} (mg/dm^3)	0.0146 0.0 – 0.0538	0.0146 0.0 – 0.2892
N-NH_4^+ (mgN/dm^3)	0.0729 0.0121 – 0.1451	0.3604 0.0556 – 1.0400
N-NO_3^- (mgN/dm^3)	0.0799 0.0 – 0.5324	0.0856 0.0 – 0.3704
Ca^{++} (mg/dm^3)	9.6 5.2 – 14.8	43.4 21.2 – 50.7
Mg^{++} (mg/dm^3)	1.92 1.24 – 3.16	5.85 5.1 – 6.8
K^+ (mg/dm^3)	2.09 0.0 – 8.00	5.49 0.0 – 12.0

wave action (Table 2). No significant differences were found between particular stations as regards physico-chemical properties of water.

Field investigations were conducted in monthly intervals between January 1983 and December 1984. The plants together with fauna were sampled by means of a self-made apparatus (K o r n i j ó w 1987) of a sampling area 1520 cm^2. At one station 3 – 6 samples were taken each time. Out of each sample from Lake Piaseczno, about 150 g of plants were taken, and from Lake Głębokie – 50 g, in order to select the invertebrates. Macroscopically selected organisms were fixed in 4% formalin. The biomass of animals was determined by weighing on a torsion balance with an accuracy to 0.2 mg. Before weighing, the specimens were dried on filter paper. Molluscs were weighed with shells.

The plants from which the fauna was selected and the remaining lot, after being filtered from water, were weighed on apothecary balance with an accuracy to 500 mg. The surface of macrophytes collected in summer was measured by means of a prototype apparatus for measuring the photosynthetical surface of plants at the Institute of Cultivation, Fertilization and Pedology at Puławy, which allowed to determine the light retained by plants. The measurements ($n = 7 - 10$) allowed to calculate plant

Table 2. Characteristics of stations investigated in lakes Piaseczno and Głębokie

Lake	Type of littoral	Station	Depth (m)	Plant species and the degree of bottom overgrown by them (%)		Kind of bottom sediments	Effect of wave action
Piaseczno	psammo-littoral	I	0.5	*Myriophyllum alternifolium*	10	sandy	strong
		II	2	*M. alternifolium*	100	sandy with a small detritus content	poor
		III	4	*Ceratophyllum demersum*	20	sandy with plenty of detritus	poor
				Elodea canadensis	50		
				Potamogeton praelongus	+		
	atrophic phytolittoral	IV	0.5	*M. alternifolium*	50	slime with plenty of poorly decomposed plant remains	poor
		V	2	*M. alternifolium*	40	slime with plenty of poorly decomposed plant remains	poor
		VI	4	*C. demersum*	40	slime with plenty of poorly decomposed plant remains	poor
Głębokie	marsh phytolittoral	I	0.5	*C. demersum*	70	slime with plenty of poorly decomposed plant remains	poor
				P. lucens			
		II	2	*M. spicatum*	+	slime with plenty of weel decomposed plant remains	average
				C. demersum	80		
				P. lucens	10		
	atrophic phytolittoral	III	0.5	*C. demersum*	30	slime with plenty of poorly decomposed plant remains	poor
				P. lucens	5		
				Nymphaea alba	60		
		IV	2	*C. demersum*	5	well decomposed slime	average
				P. lucens	5		
				N. alba	80		

surface dispersion coefficients, indicating surface area in cm^2 occupied by 1 g dry wt of plants. Also at the turn of August in 1984 the amount of organic matter and calcium deposits was determined after C a s t e n h o l t z' (1961) method.

Simultaneously with biological material collected, water temperature was measured using mercurial thermometer (20 – 30 cm above the bottom) and its transparence was determined by Secchi's disc, taking also water samples for chemical analysis. In these samples determined were: pH, oxygen content and BZT_5 (once a month) and concentration of ions: orthophosphate, nitrate, ammonium, calcium, magnesium and pottasium (once in a season). Oxygen, BZT_5, pH, phosphorus and nitrogen were determined by standard methods acc. to H e r m a n o w i c z et al. (1976), whereas the content of metals was investigated using a spectrophotometer of atomic absorption.

Quantitative analysis of fauna living on plants allowed to determine their species diversity, dominance structure, density and biomass in relation to 100 g fresh plant weight and 1 m^2 of bottom surface.

Species diversity (*H'*) was determined acc. to Shannon-Weaver's (1963) function:

$$H' = - \sum_{i=1}^{S} p_i \ln p_i$$

where: S – number of species, $p_i = \frac{n_i}{n}$, n_i – number of *i*-species, n – total density of individuals in the zoocenosis.

Dominance (*D*) was expressed by the percentage of individuals of a given species in the total number of individuals of all species found. Coefficients of dominance allowed to divide these species into three classes: (1) dominants (D = over 20%), (2) subdominants ($D = 5 - 20\%$), (3) adominants (D = below 5%).

The significance of differences in mean densities and biomass of fauna between elodeids were checked using the test of t-Student. The confidence level of mean values was calculated at 95% of confidence level.

Here the results are presented jointly for all stations examined. The distribution of fauna and its differentiation, due to various locality of stations, will be the subject of the next part of this paper (K o r n i j ó w 1989).

3. CHARACTERISTICS OF ELODEIDS EXAMINED

In Lake Piaseczno the fauna colonizing: *Myriophyllum alternifolium*, *Ceratophyllum demersum*, *Potamogeton praelongus* and *Elodea canadensis* was investigated, whereas in Lake Głębokie: *Myriophyllum spicatum*, *Ceratophyllum demersum* and *Potamogeton lucens* L. The reason for chosing these macrophytes was their abundance (usually dominant species among submerged plants), external habit and the period of their occurrence in the form of aboveground shoots.

The highest and approximate coefficient of surface dispersion had: *Myriophyllum alternifolium* (1786 ± 925 $cm^2 \cdot g^{-1}$ dry wt of plants), *Ceratophyllum demersum*

(1370 ± 1142 $cm^2 \cdot g^{-1}$ dry wt of plants), it was much smaller for *Myriophyllum spicatum*, *Potamogeton praelongus* and *P. lucens* (867 ± 197, 803 ± 56 and 558 ± 239 $cm^2 \cdot g^{-1}$ dry wt of plants, respectively) and the lowest for *Elodea canadensis* (193 ± 25 $cm^2 \cdot g^{-1}$ dry wt). These results suggest a greater differentiation of macrophytes and a slightly different order as regards the degree of surface dispersion than acc. to data of Kořinkova (1971) and Kowalczewski (1975).

Pond weeds are plants with annual aboveground shoots. They appeared in Lake Głębokie in May, whereas in Lake Piaseczno one month later. Maximal growth of pond weeds in Lake Głębokie was observed in July or August, whereas in Lake Piaseczno – in August or September. These plants started to wither in both lakes at the end of September, total decay took place in November. Aboveground shoots of other elodeids occurred all the year round, becoming only partly moribund during the winter. Maximum biomass of these elodeids in both lakes was achieved in August or in September.

The periphyton together with calcium deposits and detritus may have a significant influence upon the living conditions of fauna colonizing the macrophytes. In Lake Głębokie mean contents of calcium carbonate and organic matter in periphyton and detritus on pond weeds were several times higher than in Lake Piaseczno (34.7 and 2.8 g dry wt $\cdot$ 100 g^{-1} fresh wt of plants, respectively). Also quite different was the percentage of calcium deposits in dry periphyton weight. It was 11.7% in Lake Piaseczno and 67.6–81.2% in Lake Głębokie, which may be due to different lake trophy (Kowalczewski 1975 after Szczepański 1968). In the periphyton of Lake Mikołajskie the percentage of calcium deposits was similar to that in Lake Głębokie, because it was 70–87% of their dry wt (Kowalczewski 1975).

4. RESULTS

4.1. QUALITATIVE COMPOSITION AND DOMINANCE STRUCTURE

The fauna dwelling elodeids in both lakes had 91 taxons varying as to their systematic rank, 75 of which were found in Lake Piaseczno, and 63 in Lake Głębokie (Table 3). The majority of them are typical epiphytic forms, commonly occurring in lakes (Entz 1947, Giziński 1958, Wolnomiejski and Dunajska 1966, Soszka 1975a, Dvořak and Best 1982). Other, such as: *Acentropus niveus*[1], *Phytotendipes* gr. *gripekoveni*, *Limnochironomus* sp. may periodically lead also a mining way of life (Soszka 1974, Urban 1975, Kornijów 1986).

Some eurytopic taxons, as for example: *Bithynia tentaculata*, *Asellus aquaticus*, *Cyrnus* sp., *Limnochironomus* sp. and *Tanytarsus* gr. *gregarius* occurred also in bottom sediments of water bodies examined (Kornijów 1988).

[1] Authors of species are given in Tables.

Table 3. Qualitative composition and species diversity (*H'*) of macrofauna colonizing elodeids in lakes Piaseczno and Głębokie (January 1983 – December 1984)

1 – *M. alternifolium*, 2 – *C. demersum*, 3 – *E. canadensis*, 4 – *P. praelongus*, 5 – *M. spicatum*, 6 – *P. lucens*

Taxon	Piaseczno Lake				Głebokie Lake		
	1	2	3	4	5	2	6
1		2				3	
Hydrozoa							
Hydra sp.		+	+	+		+	+
Nematomorpha							
Cordius sp.						+	+
Turbellaria	+	+				+	
Turbificidae	+	+	+		+	+	
Naididae							
Chaetogaster sp.	+	+	+	+			
Nais barbata Müll.	+				+	+	+
Nais sp.		+	+	+		+	+
Ophidonais serpentina Müll.	+						
Ripistes parasita (Schmidt)	+	+		+			
Slavina appendiculata (Od.)	+	+	+				
Stylaria lacustris (L.)	+	+	+	+		+	+
Naididae n. det.	+	+				+	+
Hirudinea							
Glossiphonia heteroclita (L.)	+	+			+	+	+
Helobdella stagnalis (L.)	+		+		+	+	
Herpobdella octoculata (L.)					+	+	
Piscicola geometra (L.)	+						
Hirudinea n. det.	+	+		+		+	
Crustacea							
Asellus aquaticus (L.)	+	+	+	+	+	+	+
Gammarus sp.	+						
Hydracarina	+	+	+	+	+	+	+
Ephemeroptera	+	+	+		+	+	+
Zygoptera	+	+	+		+	+	+
Trichoptera							
Athripsodes sp.	+	+			+		
Cyrnus sp.	+	+	+	+	+	+	+
Orthotrichia sp.	+	+		+			
Oxyethira sp.	+	+		+	+		
Setodes tineiformis Curt.	+	+	+		+	+	
Triaenodes bicolor Curt.	+	+	+			+	
Trichoptera n. det.	+	+				+	+
Lepidoptera							
Acentropus niveus Oliv.	+					+	+
Paraponyx stratiotata L.	+				+	+	+
Lepidoptera n. det.	+				+	+	
Coleoptera							
Donacia sp.	+		+				
Heleidae	+	+	+	+	+	+	+

cd. tab. 3

1	2				3		
Chironomidae							
Ablabesmyia curticalcar Kieff.						+	
A. fulva Kieff.	+	+	+				
A. gr. *lentiginosa* (Fries)	+	+					
A. monilis (L.)	+	+	+		+	+	+
Acricotopus lucidus (Staeg.)	+						
Allochironomus Kieff.	+	+					
Anatopynia plumipes (Fries)	+					+	
Chironomus gr. *plumosus* (L.)	+					+	
Ch. gr. *thummi* (Kieff.)	+	+	+			+	
Cladotanytarsus gr. *mancus* (Walk.)	+	+					
Corynoneura scutellata Winn.	+	+	+	+		+	+
Cricotopus gr. *algarum* Kieff.						+	
C. latidentatus Tshern.	+		+				+
C. gr. *silvestris* Fabr.	+	+	+	+	+	+	+
Cryptochironomus gr. *defectus* (Kieff.)	+	+					
Einfeldia gr. *pagana* (Meig.)		+				+	
Endochironomus albipennis (Meig.)	+	+	+	+	+	+	+
Guttipelopia guttipennis (V. d. Wulp)	+						
Harnishia viridula (Fabr.)		+	+			+	
Lauterborniella agrayloides (Kieff.)	+						
Limnochironomus sp.	+	+	+	+	+	+	+
Macropelopia nebulosa Meig.		+					
Microcricotopus bicolor (Zett.)	+			+			+
Microtendipes gr. *chloris* (Meig.)	+	+	+		+	+	
Orthocladius consobrinus (Holm.)	+		+	+			
O. sexicola Kieff.	+		+	+			
Parachironomus vitiosus Goetgh.	+			+			
P. gr. *varus* (Geotgh.)	+		+	+	+	+	+
Parakiefferiella bathopila (Kieff.)	+	+	+				
Pentapedilum ceciliae Tshern.	+	+	+	+	+	+	+
Phytotendipes gr. *gripekoveni* (Kieff.)	+			+	+	+	+
Ph. barbipes Staeg.					+	+	+
Polypedilum gr. *convictum* (Walk.)	+	+				+	+
P. gr. *nubeculosum* (Meig.)	+	+	+		+	+	+
P. pedestre (Meig.)	+				+		
P. gr. *scalaenum* (Schr.)	+	+	+			+	
Potthastia campestris (Edw.)	+						
Procladius Skuse	+	+	+			+	
Psectrocladius gr. *psilopterus* Kieff.	+	+	+	+	+	+	+
P. simulans Joh.	+		+				
Pseudochironomus gr. *prasinatus* (Staeg.)	+	+					
Tanytarsus gr. *gregarius* (Kieff.)	+	+	+			+	
T. gr. *lauterborni* Kieff.	+	+	+	+	+	+	+
T. gr. *lobatifrons* Kieff.	+	+				+	
Chironomidae n. det. (larvae et pupae)	+	+	+	+	+	+	+
Gastropoda							
Acroloxus lacustris (L.)						+	+

cd. tab. 3

1	2				3		
Anisus vortex L.					+		
Armiger crista L.	+	+	+		+	+	
Bithynia leachi Sheep.						+	
B. tentaculata L.					+	+	+
Gyraulus sp.	+	+			+	+	+
Lymnaea peregra O. F. Müll.	+	+			+	+	+
Physa fontinalis L.		+	+			+	
Planorbis carinatus C. F. Müll.							+
Segmentina nitida O. F. Müll.		+			+	+	
Valvata cristata O. F. Müll.						+	
V. piscinalis O. F. Müll.						+	+
Gastropoda n. det.	+	+	+			+	+
Bivalvia	+	+					
Total taxons	69	52	41	24	34	57	38
H'	2.97	2.38	2.58	2.33	1.45	2.65	2.24

In both lakes the fauna colonizing particular elodeids was distinctly differentiated as regards the species abundance (Table 3). In Lake Piaseczno the greatest number of taxons occurred on water nimfoil, much less on hornwort and water-thyme, and the least on pond weed. In Lake Głębokie the greatest number of taxons was found on hornwort, but less on water nimfoil and pond weed. Despite considerable differences in the qualitative composition among fauna colonizing different macrophytes there were no species occurring exclusively, and at the same time regularly only on one plant species. But some species showed distinct preference for specific elodeid groups, avoiding other. And so, for example: *Triaenodes bicolor*, *Arthripsodes* sp. and *Setodes tineiformis* frequently occurred in both lakes on hornwort and water nimfoil, but did not occur on pond weeds. Also larvae of *Cyrnus* sp., Tanypodinae and Zygoptera occurred less frequently and abundantly on pond weeds than on other elodeids, which may be due to various usefulness of these plants as a substrate for proper hunting of this prey, i.e. setting a trap.

Dominance structure of fauna living on plants in Lake Piaseczno on water nimfoil, hornwort and water-thyme was similar (Fig. 2). Only the fauna colonizing pond weeds had a slightly different dominance structure. In Lake Głębokie dominance structure was relatively similar on water nimfoil and pond weed, but slightly different on hornwort (Fig. 2). In successive years of investigations, in both lakes, the differences in the dominance structure of fauna living on plants were relatively small.

Species diversity of fauna is closely connected with its dominance structure. It varied both for different elodeids and different lakes (Table 3). Usually higher coefficients of species diversity were obtained by fauna colonizing plants having a greater degree of surface dispersion (Table 4). Mean coefficient of species diversity of

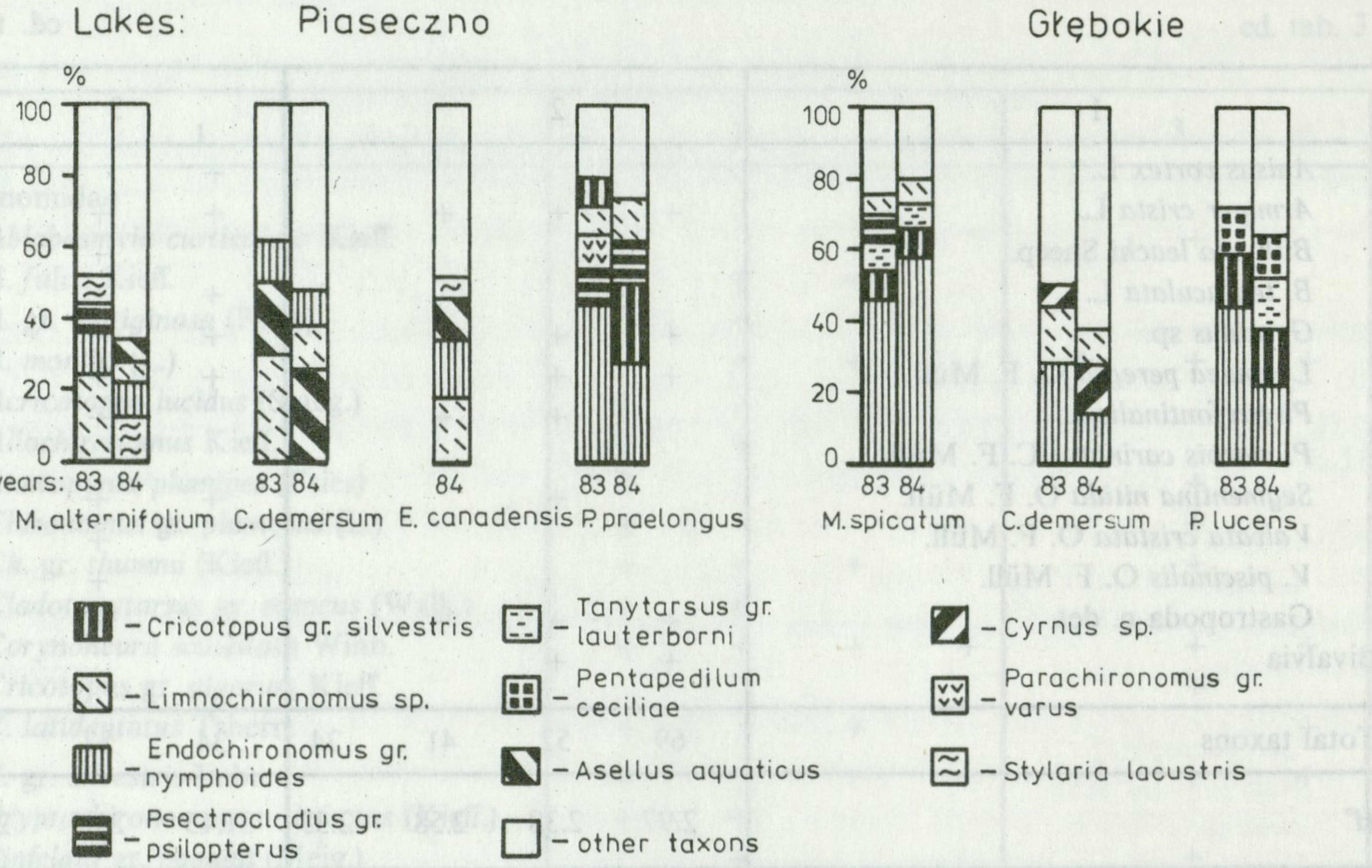

Fig. 2. Dominance structure of fauna colonizing elodeids in lakes Piaseczno and Głębokie. Mean values from stations between May and October 1983 and 1984

Table 4. Tabulation of elodeid surface dispersion coefficients (*SI*), number of species (*S*) and species diversity coefficients (*H'*) of fauna colonizing plants in lakes Piaseczno and Głębokie. Elodeids growing in the same parts of lakes at approximate depths were taken into consideration (May-October, 1983, 1984)

Parameters	Piaseczno Lake				Głębokie Lake		
	M. alternifolium	*C. demersum*	*E. canadensis*	*P. praelongus*	*M. spicatum*	*C. demersum*	*P. lucens*
SI	1786	1370	193	803	867	1370	558
S	41	31	36	26	26	40	19
H'	2.99	2.39	2.58	2.33	1.44	2.26	2.08

fauna living on all macrophytes examined was higher in mesotrophic Lake Piaseczno than in eutrophic Lake Głębokie (2.57 and 1.93 bits/individual, respectively). These values are relatively low as compared with data obtained by Marsh (1973) for *Zostera marina* epifauna in the York river (3.04 bits · ind.$^{-1}$ on the average). This parameter has not been investigated yet in relation to fauna living on plants in lakes.

4.2. DENSITY

Chironomidae were the most abundant in both lakes on all plant species examined (Fig. 3). Their percentage was especially high on pond weeds, about 90% of total fauna density. On hornwort in Lake Piaseczno *Asellus aquaticus* was also abundant, and in Lake Głębokie — Trichoptera.

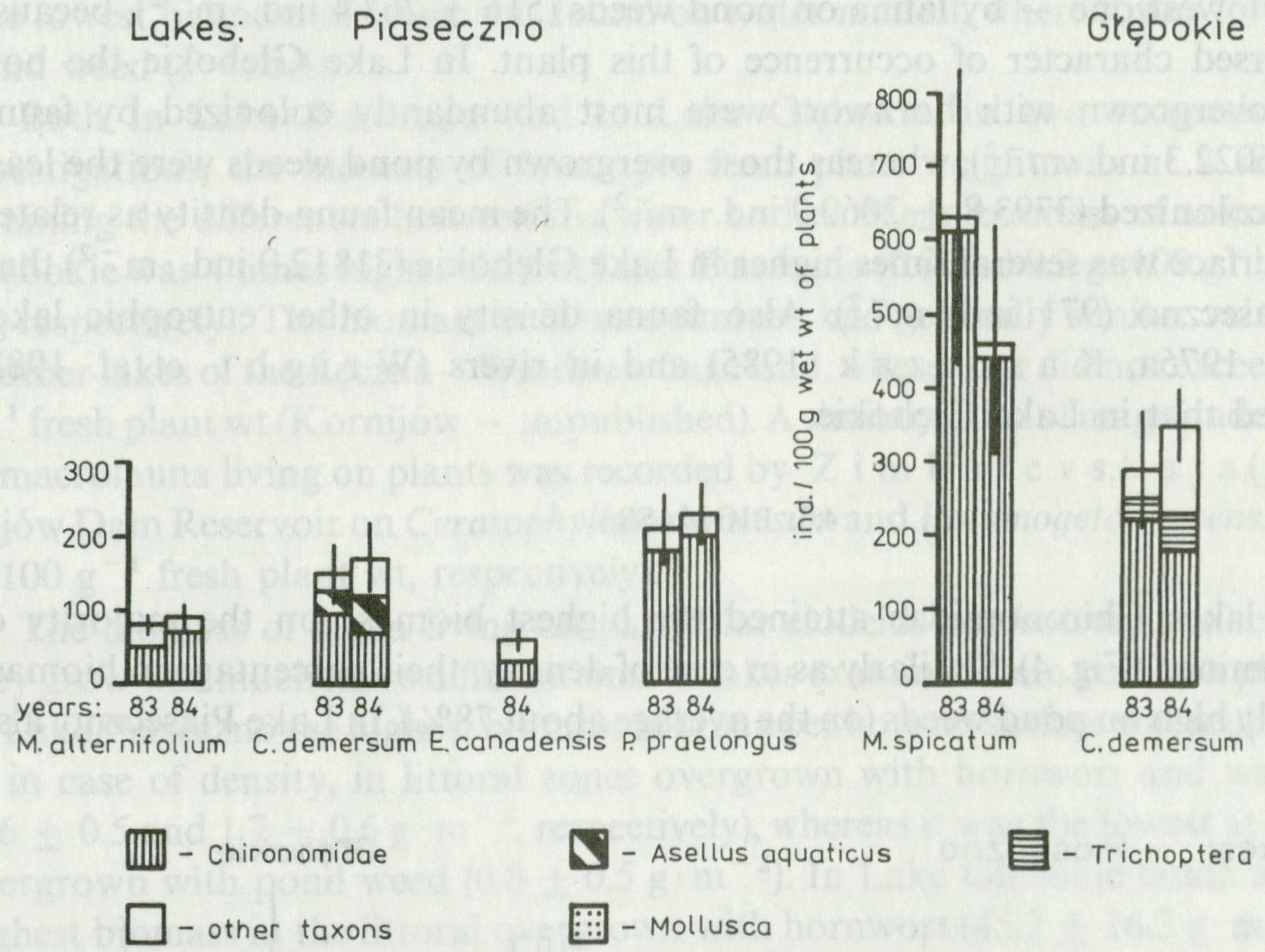

Fig. 3. Mean density (±95% C.L.) of fauna colonizing elodeids in lakes Piaseczno and Głębokie; May – October 1983, 1984

Mean fauna densities per 100 g fresh plants weight on particular macrophytes in both lakes were usually different (Fig. 3). In Lake Piaseczno, during the vegetation period, pond weed and hornwort were colonized the most. The fauna density was lower on water nimfoil ($P = 0.01$), on which animal abundance was greater than on water-thyme ($P = 0.05$). In Lake Głębokie significant differences concerning mean fauna density were observed only between pond-weed and hornwort, on which the density was much lower ($P = 0.01$).

In successive years of investigations mean epifauna density was similar, having characteristic levels for lakes examined (Fig. 3). Mean density of invertebrates was constantly several times lower in the mesotrophic Lake Piaseczno than in the eutrophic Lake Głębokie (138 and 507 ind. 100 g^{-1} fresh plant wt, respectively).

The density of fauna colonizing elodeids in lakes Piaseczno and Głębokie approximated much that in other lakes of Łęczna – Włodawa Lakeland having similar trophy (Kornijów — unpublished). Still, it was several tens lower than density of fauna colonizing the same or allied elodeid species in Masurian lakes – Mikołajskie (S o s z k a 1975a) and Warniak (P i e c z y ń s k i 1973).

The density of fauna living on plants per 1 m^2 of bottom surface, overgrown by plants examined, depended on fauna density per 100 g fresh plant wt and, first of all, on biomass attained by these plants. In Lake Piaseczno the highest mean density per 1 m^2 of bottom was attained by fauna living on densely growing in this lake hornwort and water nimfoil (1491.7 ± 584.7 and 1286.5 ± 514.3 ind. · m^{-2}, respectively), whereas the lowest one – by fauna on pond weeds (516 ± 263.4 ind. · m^{-2}), because of the dispersed character of occurrence of this plant. In Lake Głębokie the bottom zones overgrown with hornwort were most abundantly colonized by fauna (28019.0 ± 6022.3 ind. · m^{-2}), whereas those overgrown by pond weeds were the least abundantly colonized (3793.8 ± 2060.9 ind. · m^{-2}). The mean fauna density as related to bottom surface was several times higher in Lake Głębokie (31812.0 ind. · m^{-2}) than in Lake Piaseczno (971 ind. · m^{-2}). Also fauna density in other eutrophic lakes (S o s z k a 1975a, K a s p r z a k 1985) and in rivers (W r i g h t et al. 1983) approximated that in Lake Głębokie.

4.3. BIOMASS

In both lakes Chironomidae attained the highest biomass on the majority of elodeids examined (Fig. 4). Similarly as in case of density, their percentage in biomass was especially high on pond weeds (on the average about 78%). In Lake Piaseczno, also

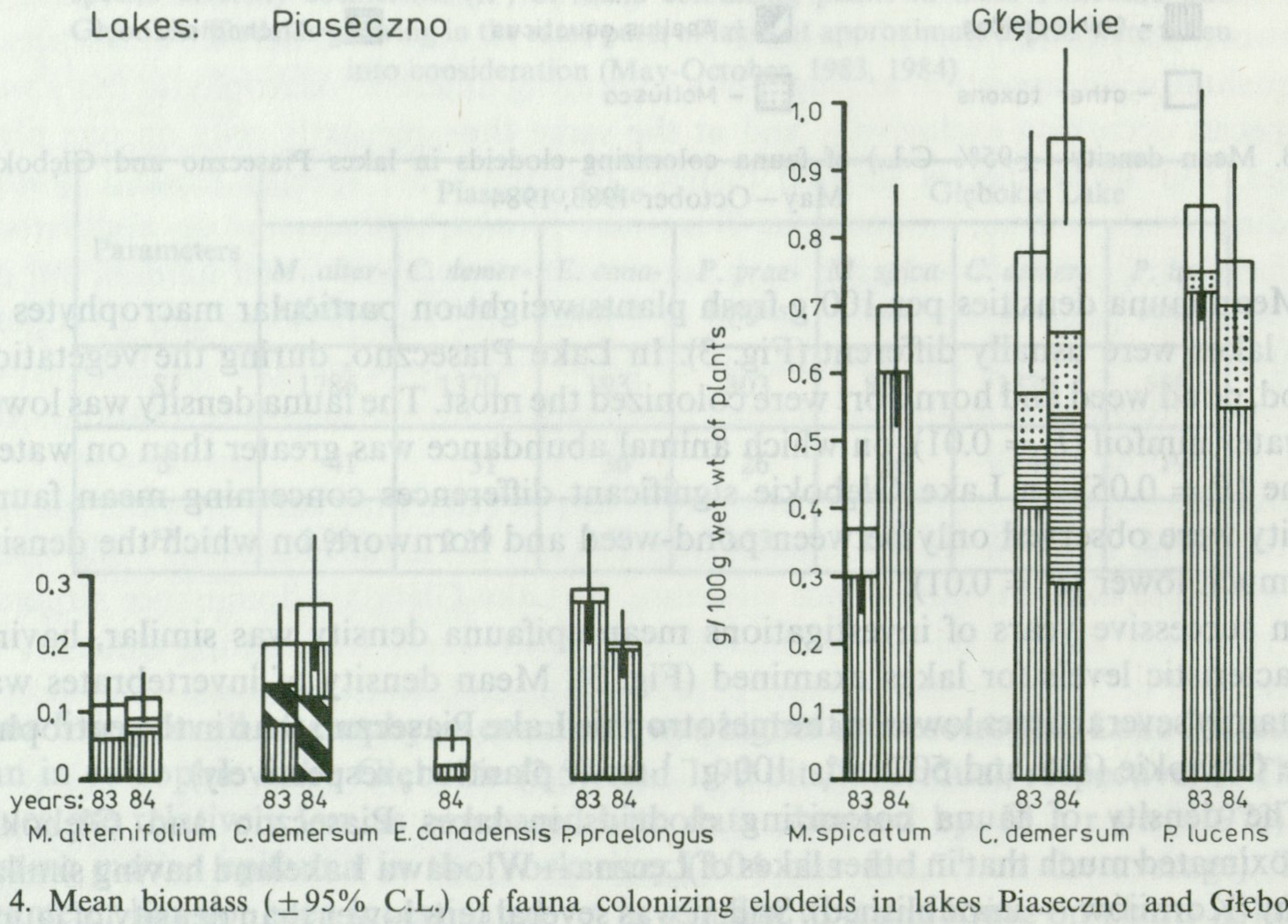

Fig. 4. Mean biomass (±95% C.L.) of fauna colonizing elodeids in lakes Piaseczno and Głębokie: May–October 1983, 1984. For explanations see Figure 2

Asellus aquaticus had a considerable biomass, especially on hornwort, whereas in Lake Głębokie – Trichoptera and Mollusca.

In Lake Piaseczno the pattern of fauna biomass per 100 g fresh plant wt resembled that of density (Fig. 4); it was the highest on pond weed and hornwort, lower on water nimfoil ($P = 0.01$) and the lowest on water-thyme ($P = 0.05$). In Lake Głębokie the highest mean density of fauna was on hornwort (Fig. 4), but the differences between the biomass of fauna on this plant and on other elodeids were statistically unsignificant. The lowest biomass of fauna was found on water nimfoil, where it was lower than on pond weed ($P = 0.1$).

Both in Lake Piaseczno and in Lake Głębokie, in two successive years of investigations, the biomass of fauna per fresh plant weight was at a similar level, retaining the differences between the water bodies. Mean biomass of animals in Lake Głębokie was 4 times higher than in Lake Piaseczno (0.8 and 0.2 $g \cdot 100\ g^{-1}$ fresh plant wt, respectively). The biomass in lakes examined had generally similar values to those in other lakes of the Łęczna – Włodawa Lakeland, where they did not exceed 1.0 $g \cdot 100\ g^{-1}$ fresh plant wt (Kornijów – unpublished). A similar order of magnitude of biomass of macrofauna living on plants was recorded by Zimbalevskaja (1981) in the Kijów Dam Reservoir on *Ceratophyllum demersum* and *Potamogeton lucens* (1.3 and 0.8 $g \cdot 100\ g^{-1}$ fresh plant wt, respectively).

The biomass of fauna living on particular elodeids per bottom surface on which they grow was much more differentiated in lakes examined than per fresh plant weight. In Lake Piaseczno the highest biomass of fauna per bottom surface was found, similarly as in case of density, in littoral zones overgrown with hornwort and water nimfoil (1.6 ± 0.5 and $1.7 \pm 0.6\ g \cdot m^{-2}$, respectively), whereas it was the lowest at the bottom overgrown with pond weed ($0.8 \pm 0.5\ g \cdot m^{-2}$). In Lake Głębokie fauna attained the highest biomass in the littoral overgrown with hornwort ($45.2 \pm 16.3\ g \cdot m^{-2}$) and the lowest in habitats with pond weed ($4.5 \pm 2.0\ g \cdot m^{-2}$).

Mean biomass of fauna living on plants in the eutrophic Lake Głębokie (71.1 $g \cdot m^{-2}$) was several times higher than in the mesotrophic Lake Piaseczno (1.9 $g \cdot m^{-2}$). There is little literature data concerning the biomass of epifauna as related to bottom surface. Among others, Wright et al. (1983) has found in a river habitat a 4 times lower biomass of fauna living on plants, and Kuflikowski (1977) in ponds fertilized with sugar industry wastes – a twice higher biomass than in Lake Głębokie.

5. DISCUSSION

Relations between fauna living on plants and aquatic macrophytes generally are not due to trophic relations (Tokeshi and Pinder 1985), because their tissues are a direct food only for very few invertebrates (Gaevskaja 1966, Soszka 1976). Thus, the aquatic plants are mainly considered as life substrate, which for a considerable part of fauna colonizing it can be even substituted by an artificial substrate (Pieczyńska and Spodniewska 1963, Soszka

1975b, M a c a n 1977, H i g l e r 1981). However, according to many authors, there are significant relations between the qualitative and quantitative structure of fauna and the vegetation colonizing them. Among others, K r e c k e r (1939), R o s i n e (1955), D v o ř a k and B e s t (1982) expressed an opinion that the greater the fragmentation of macrophyte leaves the greater is the qualitative and quantitative abundance of fauna colonizing them. Other authors have indicated a lack of such correlation (E n t z 1947, S o s z k a 1975a, V i n c e n t et al. 1982).

Results of present investigations indicate a positive relation only between the degree of plant surface dispersion and the qualitative epifauna abundance and their general species diversity (Table 4). This relation may be connected with habitat variety, occurrence of hinding places and of the amount of available food in the form of detritus, periphyton (K o w a l c z e w s k i and P i e c z y ń s k a 1976) and bacteria (K u d r j a c e v 1978). However, here it is not easy to find simple relations. They may be disturbed, amongst other things, by the qualitative and quantitative character of phytoperiphyton and the amount of calcium deposits on plants (E n t z 1947, H a r r o d 1964, K o n s t a n t i n o v 1970), or by the influence of biochemical substances excreted by macrophytes (Z i m b a l e v s k a j a 1981). G u r z ę d a (1959) and D v o ř a k and B e s t (1982) also indicate similar conditions.

Probably the much higher percentage of Chironomidae in the total density of fauna living in pond weeds than on other elodeids is also connected with the morphological structure of plants. Also, in other works conducted at different latitudes and in different water bodies, the authors indicate a distinctly higher percentage of Chironomidae in total fauna density on pond weeds than on other macrophytes (H i l l b r i c h t 1953, M a t l a k 1963, K u f l i k o w s k i 1970, M c L a c h l a n 1969, K o r n i j ó w 1984). H i l l b r i c h t (1953) has tried to explain this phenomenon by the presence of calcium deposits and phytoperiphyton abundantly occurring on leaves of pond weeds. However, in Lake Piaseczno the amount of calcium deposits and phytoperiphyton was several tens times lower on leaves of pond weeds than in Lake Głębokie, and despite this, Chironomidae in both lakes attained over 90% of total fauna density. Thus it seems that this prevalence has a character of general regularity due to the specific character of the habitat, its surface configuration and small degree of segmentation of leaves of these plants. It may be also caused by the short vegetation cycle of pond weeds, during which the greatest possibilities of fast colonization have larvae of insects and especially of Chironomidae, periodically leading a planktonic way of life. This probably explains the high percentage of this group in fauna density on pond weeds and water nimfoil in Lake Głębokie (Fig. 2), where water nimfoil becomes almost totally moribund in winter.

In lakes examined significant differences were observed as regards density and biomass between fauna colonizing different elodeid species in relation to fresh plant biomass. Quantitative differentiation of fauna living on plants due to colonization by different substrates has been pointed out by many authors (E n t z 1947, W o l n o- m i e j s k i and D u n a j s k a 1966, K o ř i n k o v a 1971, Z i m b a l e v- s k a j a 1981, D v o ř a k and B e s t 1982 and others). In lakes Piaseczno and Głębokie differences as regards quantitative colonization of elodeids seem to be connected, amongst other things, with their biomass; on macrophytes growing at points and considerably dispersed, the density and biomass of fauna as related to fresh plant weight were much higher than on plants growing at the bottom in the form of compact carpets occurring on large areas. Similar relations are also indicated by results of investigations of Kořinkova (1971), Marsh (1973), Zimbalevskaja (1981) and Nichols and Shaw (1986). One may thus conclude that plant biomass may influence significantly the density and biomass of fauna living on plants, although these relations are not simple nor univocal. This is probably caused by the fact that although greater plant biomass creates better living conditions for invertebrates, protecting them against wave motion, grazing by fish etc., still, on the other hand, the increasing plant biomass is accompanied by increasing density and biomass of fauna in relation to bottom surface, and increasing animal pressure on food resources of the habitat. Thus the density and biomass of animals as related to fresh plant weight is probably closely connected with the density and biomass of animals as related to bottom surface, and the relations between these parameters depend on the qualitative and quantitative structure of food base of the habitat.

The influence of trophy on fauna living on plants in lakes examined has been indicated by its species composition, dominance structure, degree of species diversity and by density and biomass. Smaller quantitative abundance of fauna in Lake Głębokie can be connected with different habitat conditions existing there, making it impossible to colonize in this lake invertebrates having narrower ecological requirements. It is also understandable that under different conditions of both lakes the dominance structure and species diversity of fauna, generally smaller in eutrophic Lake Głębokie, were different. Differences in density and biomass of fauna between the lakes examined were probably due to food factors. The main source of food of the majority of representatives of fauna living on plants are phytoperiphyton, phytoplankton and detritus (Soszka 1975b, Soszka 1976, Higler 1977, Kołodziejczyk 1984). In Lake Głębokie on leaves of pond weeds there was several times more periphyton and detritus than in Lake Piaseczno. Simultaneously in Lake Głębokie there was over ten times more bacteria and about 25 times more planktonic algae (Szember – unpublished). Better food conditions in Lake Głębokie are undoubtedly connected with higher nutrient content in its water, and especially of phosphorus and nitrogen (Table 1). Trophic conditions in lakes examined have been reflected mainly by the density and biomass of fauna living on plants as related to bottom surface. Whereas in Lake Piaseczno mean fauna density and biomass of littoral zones most abundant in fauna living on plants did not exceed 2.0 thous. ind.$\cdot m^{-2}$ and 4.0 $g \cdot m^{-2}$, respectively, in Lake Głębokie in bottom zones overgrown with hornwort they reached 67.4 thous. ind.$\cdot m^{-2}$ and 100.2 $g \cdot m^{-2}$. Benthic fauna may attain such values only under exceptional habitat conditions (Kajak 1966). For the purpose of comparison the mean density and biomass of benthos in the same zone of Lake Głębokie was 6057 ind.$\cdot m^{-2}$ and 36.9 $g \cdot m^{-2}$ (Kornijów – unpublished). These facts indicate how significant is the role of fauna living on plants in food chains of biocenoses of lake littoral zones.

6. SUMMARY

The aim here has been an analysis of qualitative and quantitative relations between different elodeid species and the macrofauna colonizing them and investigations of the influence of lake trophy on these relations. Studies were conducted between January 1983 and December 1984 in the eutrophic Lake Głębokie and mesotrophic Lake Piaseczno (Łęczna – Włodawa Lakeland) differing significantly as to the physico-chemical properties of water (Table 1). Analysed was the fauna colonizing *Myriophyllum alternifolium* and *M. spicatum*, *Ceratophyllum demersum*, *Elodea canadensis* and *Potamogeton praelongus* and *P. lucens*. The material was sampled at 6 stations in Lake Piaseczno, and at 4 in Lake Głębokie (Table 2). Altogether 93 fauna taxons of different systematic rank were found. Several animal taxons showed distinct preference for particular elodeid groups, which was reflected mainly by their species composition and degree of species diversity (Table 3). Greater differences as regards fauna density and biomass were observed in relation to fresh plant weight (Figs. 3, 4). Their values were usually inversely proportional to plant biomass and to density and biomass of fauna as related to bottom surface. These relations are probably connected with the possibility of using food resources of a given habitat by invertebrates.

The higher trophy in Lake Głębokie was reflected by poorer and slightly different quantitative composition (Table 3), by smaller total species diversity (Table 4) and differently formed dominance structure (Fig. 2), higher density and biomass of fauna as related to fresh plant weight (Figs. 3, 4) and bottom surface than in Lake Piaseczno.

7. POLISH SUMMARY

Celem pracy była analiza jakościowych i ilościowych relacji między różnymi gatunkami elodeidów a zasiedlającą je makrofauną oraz zbadanie wpływu trofii zbiornika na te zależności. Badania przeprowadzono od stycznia 1983 r. do grudnia 1984 r. w eutroficznym Jeziorze Głębokim i mezotroficznym jeziorze Piaseczno (Pojezierze Łęczyńsko-Włodawskie), istotnie różniących się pod względem własności fizyko-chemicznych wody (tab. 1). Analizą objęto faunę zasiedlającą *Myriophyllum alternifolium* i *M. spicatum*, *Ceratophyllum demersum*, *Elodea canadensis* oraz *Potamogeton praelongus* i *P. lucens*. Materiał pobierano z sześciu stanowisk w jeziorze Piaseczno i z czterech w Jeziorze Głębokim (tab. 2). Ogółem w faunie stwierdzono 93 taksony różnej rangi systematycznej. Szereg taksonów zwierząt wyraźnie preferowało określone grupy elodeidów, co znalazło odbicie przede wszystkim w jej składzie gatunkowym i stopniu zróżnicowania gatunkowego (tab. 3). Większe różnice stwierdzono pod względem liczebności i biomasy fauny w odniesieniu do mokrej masy roślin (rys. 3, 4). Ich wartości kształtowały się na ogół odwrotnie proporcjonalnie do biomasy roślin oraz do liczebności i biomasy fauny w odniesieniu do powierzchni dna. Zależności te prawdopodobnie są ściśle związane z możliwością wykorzystania przez bezkręgowce zasobów pokarmowych danego siedliska.

Wyższa w Jeziorze Głębokim trofia znalazła odzwierciedlenie w uboższym i nieco innym składzie jakościowym (tab. 3), w mniejszym ogólnym zróżnicowaniu gatunkowym (tab. 4), w inaczej wykształconej strukturze dominacji (rys. 2) oraz większej liczebności i biomasie fauny w odniesieniu do mokrej masy roślin (rys. 3, 4) i powierzchni dna niż w jeziorze Piaseczno.

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