INSTITUTE OF ECOLOGY-POLISH ACADEMY OF SCIENCES

EKOLOGIA POLSKA

Vol. XXI Warszawa 1973 No. 30

Department of Hydrobiology, Institute of Zoology, University of Warsaw, Warszawa

Andrzej PREJS

EXPERIMENTALLY INCREASED FISH STOCK IN THE POND TYPE LAKE WARNIAK

IV. FEEDING OF INTRODUCED AND AUTOCHTHONOUS NON-PREDATORY FISH*

(Ekol. Pol. 21: 465–504). Carp, bream and tench feed mainly on bottom fauna and fauna associated with plants, crucian carp – on zooplankton, and roach prefer plant food (first of all the macrophytes). In the years of studies together with the increase of fish stock their grazing intensity decreased and their feeding habits changed. The fish mainly ate the bottom fauna and fauna associated with plants, to a lesser extent zooplankton and slightly plant communities. In the year with the most numerous fish stock the introduced species (carp and bream) ate about 60% of biomass of bottom fauna and fauna associated with plants, and about 30% of zooplankton biomass consumed by the whole community of non-predatory fish. Data on the differentiation of the distribution of basic feeding grounds of particular fish species, are presented.

I. INTRODUCTION

The research has been conducted within the experiment on the introduction of carp and bream into a shallow, eutrophic lake (Zawisza and Ciepielewski 1973). This aimed at studying the effect of the considerably increased and changed fish stock on the biocenosis of the water body, and on the other hand, the practical aspects of fishery management.

*Praca wykonana w ramach problemu węzłowego Nr 09.1.7.

k.cz.

The studies on the feeding of non-predatory fish were concerned with:

1) Food composition of introduced fish (especially of carp) and of dominant autochthonous non-predatory species (tench, crucian carp, roach);

2) Feeding intensity of examined species;

3) Analysis of food relations in the changed community of non-predatory fish due to the introduction of new species, changes of these relations as a result of the increasing in successive years fish stock, and the possible changes in the food resources.

II. AREA, MATERIAL AND METHODS

Lake Warniak in the complex of Masurian lakes is a eutrophic water body of natural pond type as understood by Stangenberg (1936), of a surface 38.4 ha, max. depth 3.7 m, mean depth 1.5 m and its bottom is covered with a thick layer of gyttja type sediments and is to a great extent overgrown.

The fish were caught during the vegetation seasons in monthly intervals using the electric shocker and seine net. The fry (Wawrzyniak – unpublished material)[1] and mature fish were examined. Among the latter the introduced fish were examined: two-year old carp (C_2), three-year old (C_3) and four-year old (C_4), bream above the age of three; and also autochthonous fish: tench and crucian carp above the age of two, and roach above the age of four.

The mature fish were immediately weighed, measured (longitudo corporis) and the alimentary tracts were preserved in separate containers in 75% ethanol and 40% formalin 25:1. Out of 1347 alimentary tracts 249 belonged to the carp, 624 to the tench, 368 to the crucian carp, 50 to the roach and 56 to the bream. Table I presents the numbers of alimentary tracts from particular months of the successive years of studies.

Each alimentary tract was divided into 3 equal parts, then weighed altogether and examined under the stereoscopic microscope with a measuring eyepiece. The animals or their remains were counted, measured, identified and their weight was reconstructed according to the indicators expressing the length-body weight relation (after Jablonskaja 1953, Morduchaj-Boltovskoj 1954, Starmach 1955, Boruckij 1958, Hillbricht-Ilkowska and Patalas 1967, Lebedeva and Kozlova 1969, Dusoge – unpublished material). Also, own indicators obtained from the material collected in lake Warniak were used. Because of the methodical difficulties the *Oligochaeta* weight was not reconstructed and only the information on their frequency of occurrence in food was available

[1]Wawrzyniak, U. – Food of crucian carp, tench, perch and roach fry in lake Warniak – M. Sc. thesis, 1970, Department of Hydrobiology, University of Warsaw.

Number of alimentary tracts of fish from lake Warniak in the years 1967–1969

Tab. I

Species	Year	Month								Total
		IV	V	VI	VII	VIII	IX	X	XI	
Carp	1967	12	17	10	11	10	18	12	–	90
	1968	8	37	9	8	8	10	15	15	110
	1969	–	12	6	6	7	8	10	–	49
Tench	1967	16	28	24	25	30	26	13	–	162
	1968	43	35	36	50	45	36	51	–	296
	1969	–	23	30	29	28	32	24	–	166
Crucian carp	1967	11	21	17	4	16	16	10	–	95
	1968	35	29	–	12	11	22	34	–	143
	1969	–	29	24	8	22	28	19	–	130
Bream	1967	–	–	4	8	11	–	5	–	28
	1968	–	–	–	–	4	–	–	10	14
	1969	–	–	–	–	6	–	8	–	14
Roach	1967	–	–	10	7	5	6	–	–	28
	1968	–	–	–	10	12	–	–	–	22

The share of plant parts and the approximate detritus content were calculated by conversing their volume into weight, assuming that 1 ml corresponds to 1 g fresh weight after Ball (1948), Hunt (1960) and Sandercock (1969).

The method of reconstructing the weight of specific animal organisms and calculating the volume into the weight of plant parts, does not take into consideration the approximately estimated detritus share together with other admixtures. Therefore, further in the paper, the term "total food" is used only for animal and plant food. The approximate percentage by weight of detritus ranged from 5 to 90% of the weight of intestine contents of carp, tench and bream, and 2 to 40% of the weight of intestine contents of crucian carp.

The alimentary tract contents were analysed with the help of the following indices:

a) index of consumption[2] – the proportion of the reconstructed weight of food components to the weight of fish. To avoid fractional numbers the obtained values were multiplied by 1000 (Bogorov 1934);

---

[2]In order to distinguish from the index of stomach fullness introduced by Blegvaad (1917) and express the proportion of the entire intestine content weight to the fish weight, the index of consumption is used here. A similar suggestion to make such a division can be found in Russian literature (Fortunatova 1964).

b) index of frequency of occurrence (Forbes 1880) – calculated as the per cent of intestines with the given food component in relation to all analysed alimentary tracts (without empty alimentary tracts);

c) index of food similarity (Šorygin 1952) – calculated on the basis of food composition of compared fish and the sum of the small or equal percentages by weight of the representants of the same systematic units in both comparisons. The values close to 100 prove the great similarity of compared feeding habits, whereas the values close to 0 prove their great divergence;

d) index of diurnal consumption – index of consumption intensity; the amount of food eaten by a fish in 24 hr. related to its weight. The amount of consumed animal food was calculated according to Bajkov (1935): $D = A \cdot \frac{24}{n}$, where A – weight of food found in alimentary tract (the reconstructed weight of food objects is used here), n – rate (in hours) of food passage through the intestines in a given temperature (further in the paper the term: passage rate is used).

III. FOOD COMPOSITION OF STUDIED FISH

1. Food of carp (*Cyprinus carpio* L.)

During the three years of studies it was found that the animal food (84% of food weight – Tab. II) dominated in the food of carp. Animal food was found in all filled intestines of examined carp. The remaining part (16%) was the plant food.

A. Animal food. Among 31 components of animal food the most significant as concerned the weight were: *Chironomidae*, *Trichoptera*, *Mollusca*, *Ephemeroptera*, *Cladocera* and *Odonata* – jointly 90% of reconstructed weight of all animal food (Tab. II).

a) *Chironomidae* (pupae and larvae). In the food of examined carp the *Chironomidae* pupae were more rarely found than the larvae. On the average they were 4% of the reconstructed *Chironomidae* weight. The significance of the pupae increased in May and June (8–12% of the weight of *Chironomidae*), and decreased visibly in other months (the minimum in October). Apart from the *Cladocera* the *Chironomidae* were the most abundant component of carp food. They were found in the intestines of 97% of examined fish, and their number in one alimentary tract reached 4450. The *Chironomidae* were on the average 30% of animal food.

b) *Trichoptera* (larvae). The share of caddis larvae in the food of animal origin was on the average 19%. They were found in the contents of intestines of 92% of examined carp. Among the *Trichoptera* larvae, quantitatively dominated

Share* (in % of food weight) and frequency of occurrence of particular components in the food of carp in lake Warniak (the average values for the years 1967–1969)

Tab. II

Share in the total food: animal food 84%, plant food 16%

Food components	% of food weight	Index of frequency of occurrence (%)
Animal food**		
Chironomidae (l, p)	30.0	97
Trichoptera (l)	19.0	92
Mollusca	17.0	65
Ephemeroptera (l)	10.0	87
Cladocera	8.0	84
Odonata (l)	6.0	57
Ostracoda		82
Copepoda		75
Diptera (a)		57
Heleidae (l)		52
Hydracarina		35
Lepidoptera (l)		25
Sialis lutaria L. *(l)*		16
Coleoptera (l, a)		16
Oribatei		16
*Diptera (l)****		14
Asellus aquaticus L.		10
Hirudinea	10.0 (Ostracoda – Pisces)	9
Rotatoria		9
Argyroneta aquatica Cl.		4
Chaoborus sp. *(l)*		4
Bryozoa (statoblasts)		2
Gammaridae		2
Nematoda (Dorylaimus sp.)		2
Corixidae		1
Formicidae		1
Turbellaria		1
Ova *Invertebrata*		15
Ova *Pisces*		4
Pisces		5
Oligochaeta		~75
Plant food		
Macrophytes	92.0	94
Seeds	6.0	7
Algae	2.0	90

*Without *Oligochaeta*.

***l* – larvae, *p* – pupae, *a* – adults.

***Without *Chironomidae* and *Heleidae*.

the representants of the *Hydroptilidae* family (*Oxyethira* sp., *Ithytrichia* sp., *Orthotrichia* sp.) and the *Leptoceridae*, and thus larvae of small body measurements not exceeding 5 mm (*Hydroptilidae*) and 9 mm (*Leptoceridae*). Also, frequently found were the caseless larvae from the *Polycentropidae* family (to the length of 15 mm) and the *Limnephilidae* family (to the length of 25 mm). Much more rarely were found 35 mm long larvae from the *Phryganeidae* family, and the larvae from the *Mollannidae* family (to the length of 17 mm) were sporadically found.

c) *Mollusca* (*Gastropoda* and *Lamellibranchiata*). The *Gastropoda* were found in the intestines of 54% of examined carp, the *Lamellibranchiata* in 39%. The *Mollusca* were 17% of the weight of animal food, but were a much rarer found food component (index of frequency of occurrence – 65%) than the less heavy (in the total share) *Ephemeroptera*, *Ostracoda* and *Copepoda*. Among the *Gastropoda* the most frequent were the representants of the *Lymnaeidae* family (*Radix* sp. and *Lymnaea* sp.), *Hydrobidae* (*Bithynia tentaculata* L.) and *Planorbidae*. Less seldom were found snails from the families *Viviparidae*, *Physidae* and *Valvatidae*. The majority of found snails were small individuals, not exceeding 5–8 mm. Less frequently were found individuals measuring 9–11 mm, and only sporadically 12–15 mm ones.

All found molluscs belong to the *Sphaeridae* family and their size did not exceed 7 mm.

d) *Ephemeroptera* (larvae). The larvae of mayflies were found in the food of 87% of examined carp. Their percentage by weight was on the average 10% of the reconstructed weight of animal food. About 90% of found larvae of mayflies belong to the *Caenis* genus. The other were the representants of species *Cloeon dipterum* (L.).

e) *Cladocera*. The cladocerans were a frequent and abundant food component of carp. They were found in 84% of examined alimentary tracts, and their number amounted to 27 000 individuals in one intestine. In respect of weight the cladocerans were on the average 8% of animal food. Among the found *Cladocera* the following dominated: *Alona* sp., *Alonella* sp., *Bosmina longirostris* (O.F. Müller) and *Ceriodaphnia quadrangula* (O.F. Müller). Also found were: *Daphnia longispina* (O.F. Müller), *D. cucullata* Sars., *Sida crystallina* (O.F. Müller), *Eurycercus lamellatus* (O.F. Müller), *Simocephalus vetulus* (O.F. Müller), *Acroperus harpe* Baird, *Chydorus sphaericus* (O.F. Müller), *Diaphanosoma brachyurum* (Liévin), *Graptoleberis testudinaria* (Fischer), *Camptocercus* sp. and *Polyphemus pediculus* (L.).

f) *Odonata* (larvae). The dragonflies were found in the food of 57 % of examined carp. Their percentage by weight was on the average 6% of the weight of animal food. About 80% of found dragonflies were species from the subfamily *Coenagrionidae* (*Zygoptera*). Other were representants of the subfamilies *Libellulinae* and *Cordulinae* from the suborder *Anisoptera*.

g) *Ostracoda*. The ostracods were the frequent and quite abundant food component of carp. They were found in the alimentary tracts of 82% of examined fish. The percentage by weight of *Ostracoda* was very small and ranged from 0.5 to 0.9% in spring and early summer to 3–4% in the second half of summer and in autumn.

h) *Copepoda*. The copepods were found in the food of 75% of examined carp. Among them identified were the representants of the suborders *Calanoida* (*Eudiaptomus graciloides* Lilljeborg) and *Cyclopoida* (*Mesocyclops leuckartii* (Claus) and *M. oithonoides* Sars.). Among the found copepods mature individuals and older copepodite stages dominated. The nauplii stages were sporadically found. The percentage by weight of the *Copepoda* was slight and never exceeded 3% of animal food.

i) *Diptera* (adults). They were found in intestines of 57% of examined carp. The *Chironomidae* dominated, and also the adults of *Culicidae* and *Heleidae* were found. Most frequently and abundantly (up to 70 individuals in one intestine) they were found in spring and early summer. The percentage by weight of the *Diptera* adults in the food of carp was small and did not exceed 1%.

j) *Heleidae* (larvae). They were found in the alimentary tracts of 52% of carp. The percentage by weight of the *Heleidae* in the animal food was usually below 2%.

k) *Hydracarina*. The water mites were a frequent (index of frequency of occurrence 35%), althought not very abundant, food component of carp, and their percentage by weight was very small. This group had been more thoroughly examined (Pieczyński and Prejs 1970, thus allowing to state that the qualitative composition of water mites was greatly differentiated in the alimentary tracts, and other species than in the habitat dominated. This was due to the predominance of small size of species in the alimentary tracts, whereas in the habitat the bigger forms dominated. Small water mites and pale coloured are probably accidentally caught by fish together with other representants of invertebrate fauna (basic food component). The big, brightly coloured species of water mites are avoided by fish.

l) *Lepidoptera* (larvae). Usually single larvae were found in the intestines of 25% of examined carp. The percentage by weight of the *Lepidoptera* did not generally exceed 2%. All found larvae belonged to the *Pyralidae* family.

m) *Sialis lutaria* (L.) (larvae). The *Sialis* larvae were found rarely, only in 16% of examined alimentary tracts. Their number reached usually several to several tens in one intestine (maximum 150 larvae 7–15 mm big). This explains the considerable share of *Sialis*, which in one instance (July 1967) was 16% of the weight of animal food.

n) *Coleoptera* (larvae and adults). Single beetles were found in 16% of examined intestines. Among them identified were the representants of the families *Chrysomelidae* (*Donacia* sp.), *Dytiscidae*, *Gyrrinidae*, *Haliplidae* and *Hydrophilidae*.

o) *Oribatei*. The representants of this *Acarina* group occurring on emergent vegetation were found in 16% of intestine contents.

p) *Diptera* (excl. *Chironomidae* and *Heleidae*) (larvae). Their larvae were found in 14% of intestines of examined carp. Among them identified were the representants of the families: *Cylindrotomidae*, *Liriopeidae*, *Stratiomyidae*, *Tabanidae* and *Tipulidae*.

r) Other invertebrates. The *Oligochaeta* were found in the intestine contents of 75% of examined carp. Other invertebrates were much more rarely found (index of frequency of occurrence below 15%) (Tab. II).

s) *Pisces*. Single fry individuals (most frequently tench and roach) 2–4 cm long were found in the intestines of 5% of carp in 1968, and 11% in 1969. In 1967 not one the C_2 individuals contained fry remains. In 1968 the fry was found in the food of carp (C_3) caught in July, August and September. The percentage by weight in the animal food material ranged in that time from 3 to 10%. In 1969, the fry remains were found in the intestines of fish (C_3 and C_4) caught in May, August and September, and their percentage by weight was approximate to that in 1968. Altogether the significance of fry as carp food was not great as they composed hardly 2% of the weight of animal food.

B. Plant food. The main component of plant food were fragments of macrophytes found in the intestines of 94% of examined carp, which were 15% of the weight of total food (92% of plant food weight).

The found macrophyte fragments belonged usually to: *Ceratophyllum* sp., *Elodea canadensis* and *Chara* sp., less frequently found were the remains of *Myriophyllum* sp. and *Potamogeton* sp. Sporadically recorded were young and thin leaves of *Stratiotes aloides* L. However, it is worth pointing out that some fish consumed in great abundance some fragments of submerged macrophytes. These were usually the oogonia of *Charales* and drupels of *Potamogeton* sp. and *Ceratophyllum* sp., found several times in number of 2000 and 3000 in one intestine. Also, in the food of examined carp, several to several tens of spicules of *Potamogeton* sp. and *Myriophyllum* sp. were sometimes recorded. Also the presence in the carp intestines of a varying number (50–2500) of seeds of aquatic plants (*Potamogeton* sp., *Glyceria aquatica* L. and other unidentified ones) was recorded as well as the floating seeds of black alder (*Alnus glutinosa* (L.)) growing close to the water body, and pine (*Pinus* sp.) seeds. The seeds were found in the alimentary tracts of 7% of examined carp and their percentage in the total food weight was estimated as 1.2% (in plant food about 8% of weight).

The algae were found in the intestines of 90% of examined carp and their percentage by weight was 0.3% of food. In 90% of examined intestines unicellular diatoms were found; filamentous algae were much more rarely found – only in 16% of intestines.

Therefore, the feeding of adult carp is in general the same as of the adult carp in breeding ponds of central and eastern Europe (Lapinskaite 1961, Maksimova 1961, Assman 1962, Borodič 1965, Szumiec 1966, Moskalenko 1968, Pekař and Krupauer 1968, Niculescu-Duvaz 1970). The differences between the results of this research and the data of cited authors are basically in the percentage in the food of carp of some groups of bottom fauna and fauna associated with plants. Usually this is connected with a greater share (than in carp examined here) of the *Chironomidae* larvae, of the order 50–70%. The *Cladocera*, which in the discussed material are a quite important food component of adult carp, may be in some situations the dominant element (Assman 1962, Borodič 1965).

In the successive years of studies some changes were observed in the feeding character of carp. The share of food of plant origin was in all instances the lowest in spring (April-May) and ranged then from 4 to 15% of the total food weight. The greatest share of plant food was recorded in September (23–31% of total food weight). In the successive years of studies the average share of plant food in total food weight was: 16% in 1967, 13% in 1968 and 24% in 1969. The changes in the share of dominant components of animal food during the respective vegetation seasons were very small (Fig. 1). The *Chironomidae* were the dominant component of carp food in the prevailing part of the studies. In single instances the position of the first dominant was occupied by the *Trichoptera* larvae (April 1968 and August 1969), *Ephemeroptera* (June 1968 and June 1969) and *Mollusca* (September 1968). The average feeding habits changed in the successive years of studies (Fig. 2). The share of the dominant *Chironomidae* in carp food during the entire period of studies decreased from 37% in 1967 to 22% of animal food weight in 1969; the *Mollusca* which in 1967 were 17% of the animal food weight, decreased their share to 8% in 1969. And the share of *Trichoptera*, *Ephemeroptera* and *Cladocera* was higher in 1969 than in 1967.

2. Food of tench (*Tinca tinca* (L.))

The dominant role in the feeding of tench had the animal food, which was 89% of the total food weight (Tab. III). This food was found in all filled intestines of examined tench. Food of plant origin was found in 89% of examined alimentary tracts of tench. It was 11% of the total food weight (Tab. III).

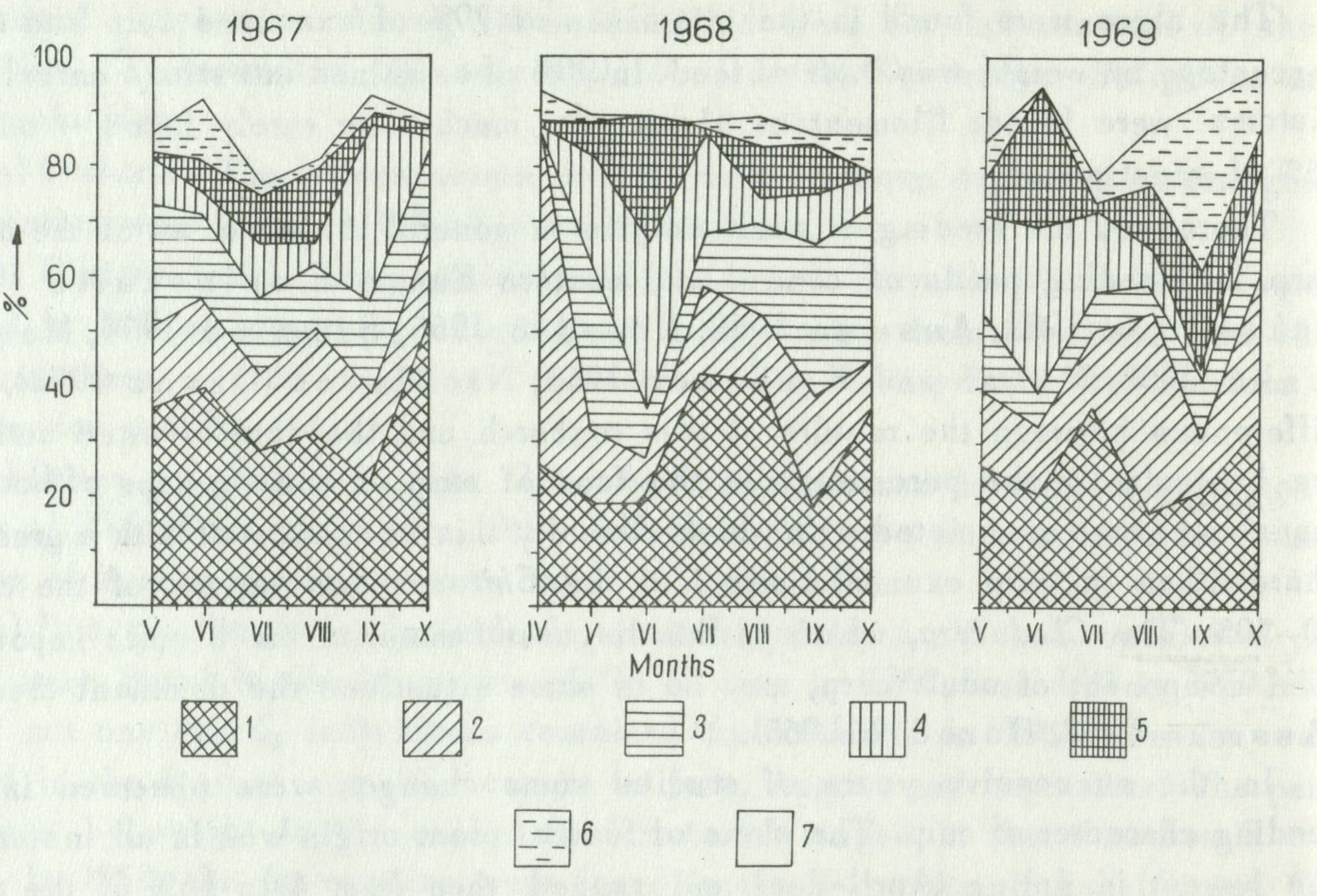

Fig. 1. Changes of the share (in % of weight) of the dominant animal food components of carp in successive years of studies

1 – Chironomidae, 2 – Trichoptera, 3 – Mollusca, 4 – Ephemeroptera, 5 – Cladocera, 6 – Odonata, 7 – others

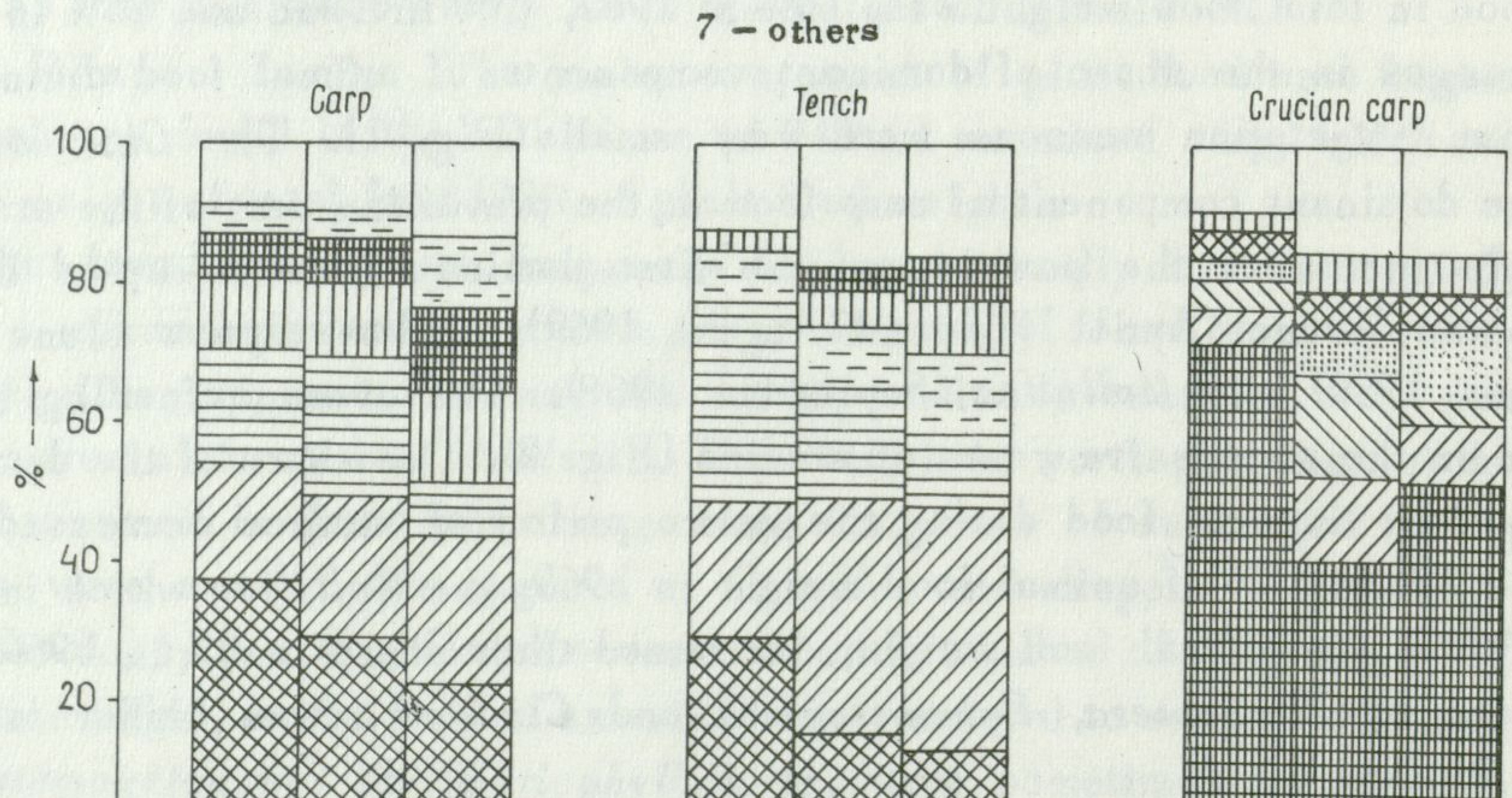

Fig. 2. Comparison of the animal food composition (in % of weight) of carp, tench and crucian carp in successive years of studies

1 – Chironomidae, 2 – Trichoptera, 3 – Mollusca, 4 – Ephemeroptera, 5 – Cladocera, 6 – Odonata, 7 – Copepoda, 8 – Ostracoda, 9 – others

Share* (in % of food weight) and frequency of occurrence of particular component in the food of tench in lake Warniak (the average values for the years 1967–1969)

Share in the total food: animal food 89%, plant food 11%

Tab. III

Food components	% of food weight	Index of frequency of occurrence (%)
Animal food**		
Trichoptera (*l*)	27.0	89
Chironomidae (l, p)	21.0	94
Mollusca	18.0	64
Odonata (*l*)	10.0	50
Ephemeroptera (l)	5.0	75
Ostracoda	19.0	71
Cladocera		62
Copepoda		62
Heleidae		46
Diptera (*a*)		25
Hydracarina		18
Lepidoptera (*l*)		17
Sialis lutaria L.		8
Rotatoria		7
Coleoptera (*l*, *a*)		6
Asellus aquaticus L.		5
Diptera (*l*) ***		4
Oribatei		4
Hirudinea		4
Argyroneta aquatica Cl.		4
Bryozoa (*statoblasts*)		1
Corixidae		1
Nematoda (*Dorylaimus* sp.)		1
Chaoborus sp.		1
Turbellaria		1
Ova *Invertebrata*		9
Ova *Pisces*		3
Pisces		2
Oligochaeta		~70
Plant food		
Macrophytes	96.5	90
Algae	3.5	91
Seeds	0.5	1

*Without *Oligochaeta*.

***l* – larvae, *p* – pupae, *a* – adults.

***Without *Chironomidae* and *Heleidae*.

A. Animal food. Among 29 components of animal food the greatest significance as regards the weight had: *Trichoptera*, *Chironomidae*, *Mollusca*, *Odonata* and *Ephemeroptera* – 81% of animal food weight (Tab. III).

a) *Trichoptera* (larvae). The share of caddis larvae in animal food was on the average 27%. They were found in 89% of examined tench intestines. Among the *Trichoptera* larvae species from the family *Hydroptilidae* (*Oxyethira* sp., *Ithytrichia* sp., *Orthotrichia* sp.) and *Leptoceridae* dominated quantitatively. Frequently found were the larvae from the family *Limnephilidae* and caseless larvae from the *Polycentropidae* family. More rarely were found the larvae from the *Phryganeidae* family and sporadically – the larvae from the *Mollannidae* family.

b) *Chironomidae* (larvae and pupae). The *Chironomidae* were the most frequent and abundant component of tench food. They were found in the intestines of 94% of examined fish, and their number in one alimentary tract reached 1250. On the whole the larvae and pupae of the *Chironomidae* were on the average 21% of the animal food weight.

The *Chironomidae* pupae were much more rarely found in tench food than the larvae. They were on the average about 5% of the reconstructed weight of the *Chironomidae*. The significance of the pupae increased in May and June (19% of the *Chironomidae* weight), and decreased definitely in other months (down to 0 in October).

c) *Mollusca* (*Gastropoda* and *Lamellibranchiata*). The snails were found in 50% of tench, the mussels were more rarely found (41% of tench). The molluscs were 18% of the animal food weight. Among *Gastropoda* the most frequently found were the representants of the families: *Lymnaeidae* (*Radix* sp. and *Lymnaea* sp.), *Hydrobidae* (*Bithynia tentaculata*) and *Planorbidae*. More rarely found were the snails from the families *Viviparidae*, *Physidae* and *Valvatidae*. All found mussels belong to the *Spheridae* family.

d) *Odonata* (larvae). The larvae of dragon-flies were found in the intestine contents of 46% of tench. Their percentage by weight was on the average 10% of the animal food weight. More than 75% of dragon-flies were species from the subfamily *Coenagrionidae* (*Zygoptera*). Other were from the subfamilies *Libellulinae* and *Cordulinae* from the suborder *Anisoptera*.

e) *Ephemeroptera* (larvae). The larvae of mayflies were found in 75% of alimentary tracts of tench. They were 5% of the animal food weight. About 90% of mayflies belong to the *Caenis* genus. Other were the representants of species *Cloeon dipterum* (L.).

f) *Ostracoda*. The ostracods were a frequent and relatively abundant food component of tench. They were found in the alimentary tracts of 71% of examined fish. The percentage by weight of the *Ostracoda* was rather small and ranged from 0.3 to 2.5% of animal food.

g) *Cladocera*. The cladocerans were found in 62% of alimentary tracts of examined tench. The average percentage by weight of the *Cladocera* in three years of studies was about 2,5%, ranging from 0.9 (1967) to 6.5% (1969) of the animal food weight. The following dominated: *Alona* sp., *Alonella* sp., *Ceriodaphnia quadrangula* (O.F. Müller), *Daphnia cucullata* Sars., *Simocephalus vetulus* (O.F. Müller). And also: *Sida crystallina* (O.F. Müller), *Graptoleberis testudinaria* (Fischer), *Bosmina longirostris* (O.F. Müller), *Acroperus harpe* Baird and *Eurycercus lamellatus* (O.F. Müller).

h) *Copepoda*. The copepods were found in the intestines of 62% of examined tench. Their percentage by weight in the food was small and did not exceed 1%. The found *Copepoda* (almost exclusively mature individuals and older copepodite stages) belonged to the orders: *Calanoida* (*Eudiaptomus graciloides* Lilljeborg) and *Cyclopoida* (*Mesocyclops leuckartii* Claus and *M. oithonoides* Sars.).

i) *Heleidae* (larvae). They were a relatively frequent (index of frequency of occurrence 46%), although not very abundant food component of tench. Their share in animal food was usually lower than 1.5% of weight.

j) *Diptera* (adults). They were found in 25% of examined tench intestines. *Chironomidae* dominated, but also *Culicidae* and *Heleidae* were found.

k) Other invertebrates. *Oligochaeta* were found in the contents of about 70% of intestines. Other invertebrates were less frequently found (index of frequency of occurrence below 20%) (Tab. III).

l) *Pisces*. The fry and spawn were found in the intestines of examined tench very rarely (index of frequency of occurrence 2%). But on the whole in one alimentary tract one fry specimen (usually tench or roach) was found, and only in one instance in the intestine of tench weighing 660 g, and 32 cm long, 5 specimens of tench fry, about 3 cm long, were found.

B. Plant food. The food of plant origin was about 11% of the total food (Tab. III). The main component of plant food were the fragments of macrophytes found in the intestines of 90% of examined tench. The macrophyte fragments belonged to plants of the following genera: *Ceratophyllum*, *Potamogeton*, *Chara*, *Myriophyllum* and *Elodea*. The algae were found in the alimentary tracts of 91% of examined tench. These were first of all the unicellular diatoms; the filamentous algae were not found so much. The seeds of aquatic plants (most frequently *Potamogeton* sp.) were found sporadically and in small numbers.

The authors of very few papers on the feeding of tench in natural water bodies (Schiemenz 1907, Starmach 1951, Pliszka 1953a, 1956, Skóra 1964, Spataru and Negrea 1969) emphasize the dominant role of *Trichoptera*, *Mollusca* and *Chironomidae*, and the quite considerable sometimes percentage of plant food (mainly macrophytes), and the small utilization of zooplankton food.

Similarly as in the instance of carp the share of plant food in tench food was the smallest in spring, and the highest in the second half of the summer and in autumn. In successive years of studies the percentage of plant food in the entire food material was: 10% in 1967 and 1968, and 12% in 1969.

In 1967, during particular months, *Chironomidae* and *Mollusca* dominated interchangeably in the tench food, and *Trichoptera* were on the third place. In 1968 and 1969, almost during the entire vegetation season (apart from September 1968), the *Trichoptera* larvae dominated in the tench food. The second and third place in 1968 belonged interchangeably to *Chironomidae* and *Mollusca*, and in 1969 – to *Chironomidae*, *Odonata* and *Cladocera*. Furthermore, similarly as in carp food, systematic changes were observed in the average feeding habits in successive years (Fig. 2). The percentage of the *Chironomidae*, dominant in the tench food in 1967 (29% of the animal food weight), decreased to 12% of food weight in 1969. Also the percentage of the *Mollusca* decreased from 28% in 1967 to 10% of the animal food weight in 1969. But the share of *Trichoptera*, *Cladocera*, *Odonata* and *Ephemeroptera* increased in the successive years of studies.

3. Food of crucian carp (*Carassius carassius* L.)

The animal food had the greatest significance in the feeding of crucian carp during the three years of studies and it was 94% of the total food weight (Tab. IV). The animal food was found in all filled intestines of examined crucian carp. The food of plant origin was found in 79% of analysed alimentary tracts of crucian carp. It was altogether 6% of the food weight (Tab. IV).

A. Animal food. Among 23 components of animal food the most important were *Cladocera*. Also, *Trichoptera*, *Ostracoda*, *Chironomidae* and *Ephemeroptera* were important components of the food of crucian carp. These groups were 91% of the reconstructed weight of animal food (Tab. IV).

a) *Cladocera*. The cladocerans were the most numerous (up to 40 000 individuals in one alimentary tract) and the most frequent (index of frequency of occurrence 98%) component of crucian carp food, and their percentage in the animal food weight reached 60%. Among cladocerans the following dominated: *Bosmina longirostris* (O.F. Müller), *Alona* sp. and *Alonella* sp. And also found were: *Daphnia longispina* (O.F. Müller), *D. cucullata* (O.F. Müller), *Ceriodaphnia quadrangula* (O.F. Müller), *Sida crystallina* (O.F. Müller), *Simocephalus vetulus* (O.F. Müller), *Eurycercus lamellatus* (O.F. Müller), *Chydorus sphaericus* (O.F. Müller), *Acroperus harpe* Baird, *Graptoleberis testudinaria* (Fischer), *Camptocercus* sp., *Polyphemus pediculus* (L.), *Pleuroxus* sp. and *Diaphanosoma brachyurum* (Liévin).

Share* (in % of food weight) and frequency of occurrence of particular components in the food of crucian carp in lake Warniak (the average values for the years 1967–1969)

Share in the total food: animal food 94%, plant food 6%

Tab. IV

Food components	% of food weight	Index of frequency of occurrence (%)
Animal food**		
Cladocera	60.0	98
Trichoptera (*l*)	8.0	68
Ostracoda	7.0	78
Copepoda	6.0	86
Chironomidae (*l, p*)	6.0	73
Ephemeroptera (*l*)	4.0	59
Hydracarina		57
Heleidae (*l*)		23
Oribatei		19
Diptera		19
Rotatoria		15
Lepidoptera (*l*)		12
Mollusca		9
Odonata (l)		6
Coleoptera (*l, a*)	9.0	5
Argyroneta aquatica Cl.		1
Asellus aquaticus L.		1
Corixidae		1
Diptera (*l*)***		1
Formicidae		1
Sialis lutaria L.		1
Ova *Invertebrata*		7
Ova *Pisces*		2
Oligochaeta		~20
Plant food		
Macrophytes	91.0	75
Algae	7.0	79
Seeds	2.0	1

*Without *Oligochaeta*.

***l* – larvae, *p* – pupae, *a* – adults.

***Without *Chironomidae* and *Heleidae*.

b) *Trichoptera* (larvae). The caddis larvae were found in the intestine contents of 68% of examined crucian carp. They were on the average 8% of the food weight. Among the found larvae the species from the *Hydroptilidae* family (*Oxyethira* sp., *Ithytrichia* sp., *Orthotrichia* sp.) were the most abundant. Also, larvae from the *Limnephilidae* family and caseless larvae from the *Polycentropidae* family were found.

c) *Ostracoda*. The ostracods were a frequent and abundant food component of crucian carp. They were found in the alimentary tracts of 78% of examined fish. Their percentage by weight was a relatively high one and was on the average 7% of animal food.

d) *Copepoda*. The copepods were the second most frequently found food component of crucian carp after the cladocerans (index of frequency of occurrence 86%), and their number reached 21 000 in one alimentary tract. The copepods were on the average 6% of the animal food weight, the majority of them were mature individuals and older copepodite stages and belonged to the suborders *Calanoida* (*Eudiaptomus graciloides* Lilljeborg) and *Cyclopoida* (*Mesocyclops leuckartii* and *M. oithonoides* Sars.).

e) *Chironomidae* (larvae). They were a frequent (index of frequency of occurrence 73%), but not very abundant food component of crucian carp. The percentage by weight of the *Chironomidae* was on the average 6%.

f) *Ephemeroptera* (larvae). The larvae of mayflies were found in 59% of alimentary tracts of crucian carp. The mayflies were 4% of the animal food weight. The great majority were the larvae of the *Caenis* genus. The representants of species *Cloeon dipterum* (L.) were sporadically observed.

g) *Hydracarina*. The water mites were found quite frequently – in 57% of examined crucian carp intestines. The percentage of the *Hydracarina* in animal food was usually lower than 2% of the weight, but in some instances (April, May and July 1968) they were about 10% of the animal food weight.

h) *Heleidae* (larvae). Found in the alimentary tracts of 23% of examined crucian carp, but their percentage by weight did not exceed on the average 1% of animal food.

i) Other invertebrates. *Oligochaeta* were found in 20% of examined intestines, other invertebrates were rarer (index of frequency of occurrence below 20%) (Tab. IV).

B. Plant food. The food of plant origin was altogether 6% of the total food weight (Tab. IV). The main component of plant food were the fragments of macrophytes found in the intestines of 75% of examined crucian carp and 91% of the plant food weight. The fragments of macrophytes belonged to plants of the following genera: *Chara*, *Elodea*, *Ceratophyllum* and *Potamogeton*. The algae were found in the alimentary tracts of 79% of examined crucian carp; their percentage by weight – 7% of plant food. Furthermore, in the intestines of 1% of examined crucian carp there were pine (*Pinus* sp.) seeds and floating seeds of black alder (*Alnus glutinosa* (L.)).

A similar image of the feeding habits of a mature crucian carp was obtained by Uspenskaja (1953) in Zarosloe Lake with similar conditions to those in lake Warniak, and by Koyama, Miyajima and Okubo (1968) and Spataru and Negrea (1969) in pond culture. Uspenskaja (1953), in her studies on carp food in 5 natural water bodies with different morphometric and trophic conditions, observed a great differentiation in the feeding character of this fish. She says that the crucian carp displays a high food plasticity due to which it can eat various kinds of animal food such as *Cladocera*, insect larvae and *Mollusca*. Karzinkin (1955) says that the crucian carp uses animal food consumed the least by other fish species.

The share of plant components in the food of crucian carp was the smallest in April (about 1% of food weight) in all instances and the greatest in August and September (to 11% of food weight). In the successive years of studies the percentage of plant food in total food weight was: 4% in 1967, 5% in 1968 and 7% in 1969.

The changes in the share of dominant components of animal food during the consecutive vegetation seasons were not great. During the entire period of investigations *Cladocera* dominated in the food of crucian carp, and the second and third place were interchangeably occupied by *Trichoptera*, *Ostracoda* and *Copepoda*. Regular changes were not observed in the average feeding habits during the successive years (Fig. 2). The only group, systematically increasing its significance in the food of crucian carp were the *Copepoda*, the percentage of which increased in 1969 to 11% as compared with the 3% in 1967.

4. Food of bream (*Abramis brama* (L.))

Animal food was 93% of food weight (Tab. V) in the food of bream during the period of investigations. It was found in all filled intestines of bream. The food of plant origin was found in 65% of analysed alimentary tracts and was altogether 7% of food weight (Tab. V).

A. Animal food. A marked dominance of the *Chironomidae* larvae was observed in the animal food. They were the most numerous and frequent (index of frequency of occurrence 96%) food component, and were 68% of this food weight (Tab. V). The *Trichoptera* larvae were found in 85% of the examined intestines and were 10% of the animal food weight. Among the caddis larvae identified were the representants of the families: *Hydroptilidae*, *Leptoceridae*, *Limnephilidae*, *Polycentropidae* and *Phryganeidae*. Quite frequently were found the larvae of *Ephemeroptera* (almost exclusively *Caenis* sp.), *Mollusca* (*Gastro-*

Share* (in % of food weight) and frequency of occurrence of particular components in the food of bream in lake Warniak (the average values for the years 1967–1969)

Share in the total food: animal food 93%, plant food 7%

Tab. V

Food components	% of food weight	Index of frequency of occurrence (%)
Animal food**		
Chironomidae (l, p)	68.0	96
Trichoptera (l)	10.0	85
Ephemeroptera (l)	6.0	70
Mollusca	5.0	58
Cladocera	5.0	59
Odonata (l)	3.0	41
Ostracoda	3.0 (jointly for *Ostracoda* – *Rotatoria*)	68
Copepoda		56
Heleidae (l)		22
Lepidoptera (l)		11
Chaoborus sp. *(l)*		9
Sialis lutaria L. *(l)*		5
Hirudinea		3
Hydracarina		3
Diptera (a)		2
Rotatoria		2
Oligochaeta		~65
Plant food		
Macrophytes	96.0	65
Algae	4.0	73

*Without *Oligochaeta*.

***l* – larvae, *p* – pupae, *a* – adults.

poda and *Lamellibranchiata*) and *Cladocera*. The representants of these groups were respectively 6, 5 and 5% of the animal food weight. The *Odonata* larvae (*Zygoptera* and *Anisoptera*) were found in the intestine contents of 41% of bream (3% of the animal food weight). Also, in the contents of examined alimentary tracts *Ostracoda* and *Copepoda* were frequently found, whereas the larvae of *Chaoborus* sp., *Heleidae* and *Lepidoptera* were less frequent, and *Sialis lutaria* larvae, *Hydracarina* and adult *Diptera* were sporadically found.

B. Plant food. The main component of plant food (7.0% of the total food) were the fragments of macrophytes found in 65% of examined intestines (Tab. V). The macrophyte fragments belonged to plants from *Ceratophyllum* and *Potamogeton* genera. The algae were found in the alimentary tracts of 73% of examined bream, and their percentage by weight was 4% of plant food.

This characteristic of the feeding habits of a mature bream is similar to the one found in literature. Laskar (1941), Pankratova (1948), Pliszka and Dziekońska (1953), Budzyńska et al. (1956), Kogan (1963) also found that the *Chironomidae* larvae were the dominant food component of bream (usually about 50–70% of food material).

5. Food of roach (*Rutilus rutilus* (L.))

During the entire period of studies it was observed that the plants forming about 99% of food weight were the most important in the feeding of roach. Plant food was found in all filled intestines of roach (Tab. VI). The main component of plant food were the macrophytes – about 95% of food weight. Among them the most frequently found were those belonging to plants of *Potamogeton* and *Elodea* genus. Less frequent were fragments of *Ceratophyllum* sp., *Charales*, *Lemna* sp., *Myriophyllum*, and sporadically found were – *Stratiotes aloides* L. and *Fontinalis* sp. The algae (mainly diatoms and filamentous blue-green and green algae) were found in the intestines of 96% of examined roach (4% of food weight).

Animal forms were on the average about 1% of food weight (Tab. VI). Among them *Chironomidae* and *Trichoptera* were the most frequently found ones. Also the representants of the following systematic groups were found: *Cladocera*, *Ephemeroptera*, *Copepoda*, *Lepidoptera*, *Ostracoda*, *Mollusca*, *Diptera* (larvae and adults), *Odonata* and *Hydracarina*.

The marked predominance of plant components in the food of adult roach was also found by: Dobers (1922), Hartley (1947), Pliszka and Dziekońska (1953), Karzinkin (1955), Hruška (1956), Paschalski (1958), Stangenberg (1958), Bogatova (1963), Wiktorowa (1964). In the food of roach studied by Hartley (1947), Spanovskaja (1948), Jelinowski (1950), Ivanova (1953), Pliszka (1953a), Ziteneva (1967) the animal components were the most frequent dominants. These were usually the *Mollusca* (*Dreissena polymorpha* Pallas, *Bithynia* sp., *Valvata* sp., *Viviparus* sp.) and the larvae of *Chironomidae*, *Trichoptera* and *Cladocera*. However, the food of plant origin was frequently observed, and in some instances (Jelinowski 1950, Pliszka 1953a, Budzyńska et al. 1956, Stangenberg 1958) its share was quite considerable. Želtenkova (1949) says that the roach displays a great food plasticity and therefore can use in each water body the food used

Share* (in % of food weight) and frequency of occurrence of particular components in the food of roach in lake Warniak

Tab. VI

Food components	% of food weight	Index of frequency of occurrence (%)
*Chironomidae (l, p)***	1.0	30
Trichoptera (l)		25
Cladocera		18
Ephemeroptera (l)		14
Copepoda		14
Lepidoptera (l)		11
Ostracoda		10
Mollusca		8
*Diptera (l)****		5
Diptera (a)		5
Odonata		2
Hydracarina		2
Oligochaeta		~20
Macrophytes	95.0	100
Algae	4.0	96

*Without *Oligochaeta*.
**l – larvae, p – pupae, a – adults.
***Without *Chironomidae*.

the least by other fish. And this is why the macrophytes and algae are frequently the typical food of freshwater roach, and of brackish water roach – the *Mollusca*.

IV. THE FEEDING INTENSITY

The feeding intensity, i.e., the amount of food consumed by the examined fish during a determined period of time, was assumed after Bajkov (1935) – information about the passage rate and the amount of food in the intestine allow to calculate approximately the amount of food consumed in 24 hr. On the basis of the studies on the feeding of *Coregonous clupeaformis* Bajkov (1935) presented a formula allowing to calculate the approximate diurnal food ration: $D = A\,\frac{24}{n}$, where D – mean daily amount of food consumed by a fish, A –

weight of food found in the intestine[3], n – passage rate (in hours) in the given temperature.

According to Bajkov's formula, we assumed here, a constant, equally intensive feeding and equal passage rate during the 24 hr.

The literature data (among others Wunder 1927, 1932, Contag 1931, Dobben 1937, Klust 1940, Špet 1953, Karzinkin 1955, Cihař 1957 and Niculescu-Duvaz 1970) and own observations allow to reach the conclusion that in the feeding of carp, tench and crucian carp the diurnal rhythm is rather poorly indicated, and its essential feature is a slight connection with the changes in light during the day-night cycle. The data on bream are even more controversial. In this instance, we should rather agree with the opinions of Vorobev (1938) and Kogan (1963, 1969), who pointed out the obvious connection between the feeding intensity of bream and the light conditions. The bream, which is a lake-river fish with a highly developed food selectivity (Karzinkin 1955), may have a more strongly indicated rhythm connected with the diurnal changes in light.

Therefore, the amount of food found in the intestines of carp, tench and crucian carp was treated as a representative one for 24 hr. For bream the average values of intestine fullness during the day have been assumed as 25–27% higher than the average diurnal fullness (after Kogan 1969). As the basic material here has been collected during the day, therefore, in the instance of bream a correction of Bajkov's formula has been made; and the formula used to calculate the feeding intensity of bream is the following: $D = 0.75\ A\ \frac{24}{n}$

Still, the lack of sufficient amount of data on the passage rate in the cyprynid fish is a serious difficulty in using Bajkov's formula. Furthermore, the majority of data are obtained in laboratory or semi-laboratory conditions, thus limiting the possibility of using them for natural conditions.

An attempt has been made in this research to determine the rate of food passage through the intestine of carp in conditions close to natural ones. The basic assumption of the experiment (conducted in the ponds of the Department of Pond Management, Inland Fisheries Institute at Żabieniec) was feeding the carp with small amounts of artificial food (protein granules) in order to "mark" the moment the food began to pass through the intestine. Six carp of an average weight 150 g were placed in small parts of pond fenced with plexiglass plates but with free access to the bottom, thus allowing them to use natural food resources. For few days the fish were getting used to the new food placed in the fenced area in special vessels, but everyday the vessels were taken out after a shorter time. On the fifth (last) day of the experiment the carp had the

[3]Here – reconstructed weight of food objects.

granules available for 15 min. Four hours after the removal of vessels with the granules the fish were caught, their intestines prepared and then analysed in the laboratory. The position of artificial food among the natural one (the *Chironomidae* larvae, *Cladocera*, *Copepoda*, filamentous algae and single specimens of diatoms) was relatively precisely determined. This allowed to determine approximately the passage rate. At the temperature of water 19°C the food material passed through the intestine in the mean time 7.5 hr (the time ranged from about 6 hr. 30 min. to about 8 hr. 30 min.). This result and the data of other authors for carp (Klust 1940, Assman 1962, Krajuchin 1963), *Missgurnus fossilis* (Scheuring 1928), caspian roach (Bokova 1938, 1940), roach (Karzinkin 1935), are shown in the diagram (Fig. 3). This

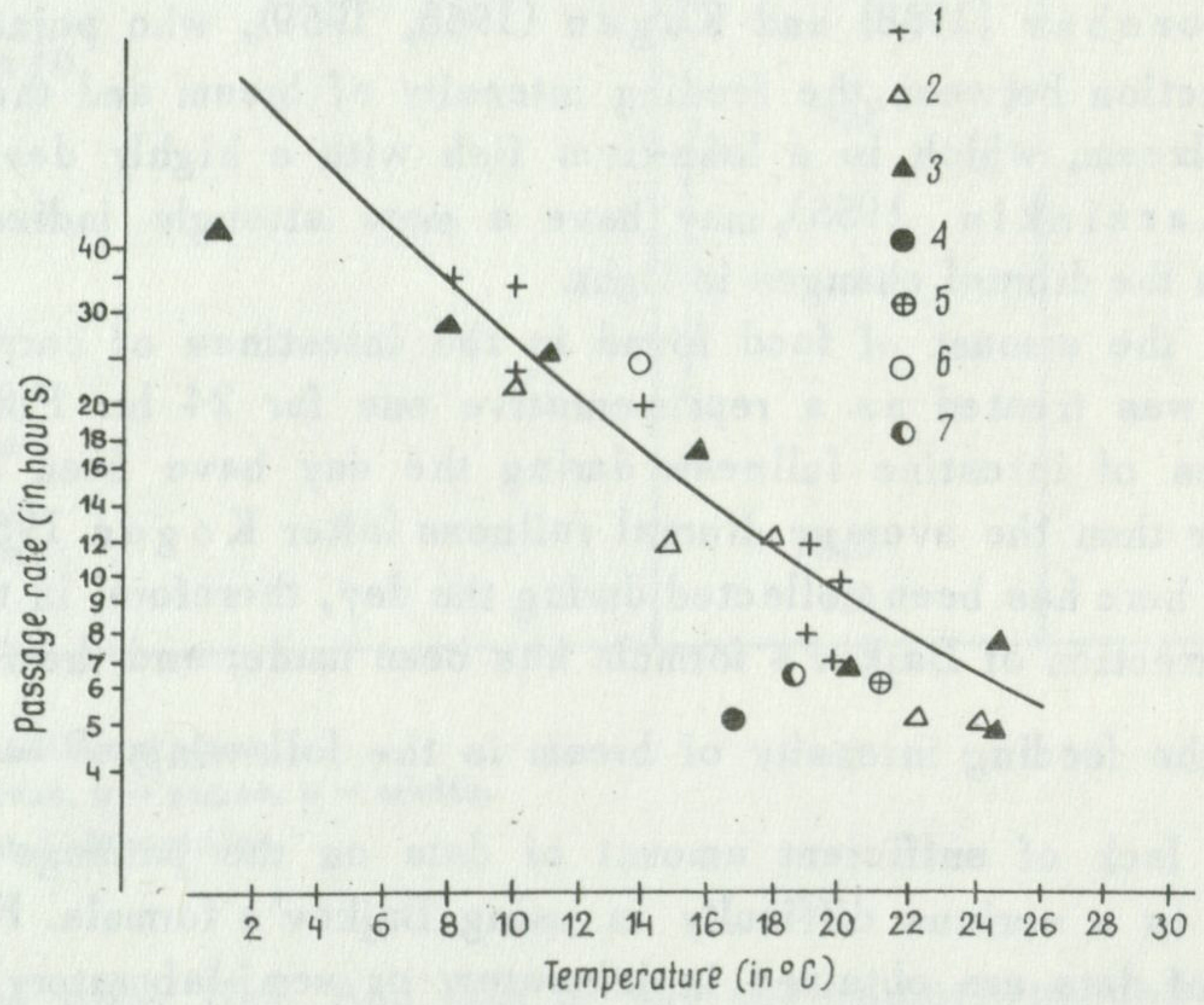

Fig. 3. The digestibility rate of non-predatory fish at different temperatures determined by the passage rate

Results of experiments of different authors against the Krogh's curve: *1* – *Missgurnus fossilis* (Scheuring 1928), *2* – caspian roach (Bokova 1938, 1940), *3* – small roach (Karzinkin 1935), *4* – carp (Klust 1940), *5* – carp (Assman 1962), *6* – carp (Krajuchin 1963), *7* – carp (own data)

diagram is partly based on the diagram of the dependence: passage rate – water temperature (Backiel and Horoszewicz 1970). Furthermore the Krogh's curve was plotted on the diagram, which even with so scarce data presents well the general relation of the passage rate in the intestines of cyprynid fish and the temperature of the habitat. This was sufficient to accept the numbers characterizing the passage rate in examined fish species in different thermal conditions (water temperature in lake Warniak measured in the days of fish catches – Tab. VII).

Temperature of water surface (12 a.m.) in lake Warniak on the dates of fish catches in successive vegetation seasons (1967–1969)

Tab. VII

Month	Temperature (in °C)		
	1967	1968	1969
IV	12	16	–
V	20	15	17
VI	24	26	19
VII	25	24	22
VIII	21	23	24
IX	19	20	19
X	9	9	14
XI	–	4	–

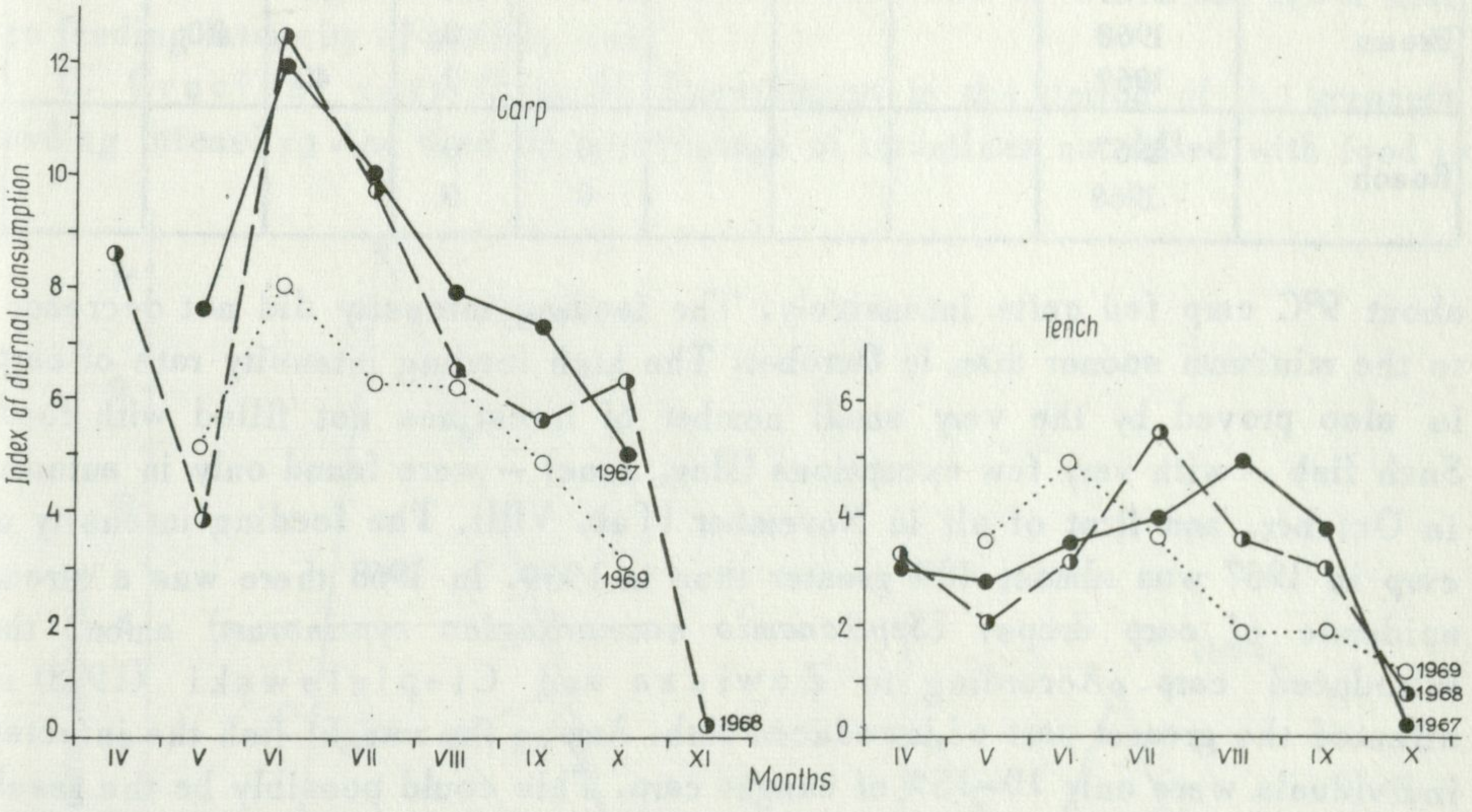

Fig. 4. Dynamics of the feeding intensity of carp and tench in lake Warniak in 1967–1969

The feeding intensity of examined fish species expressed by the amount of animal food consumed by a fish in 24 hr. is:

A. Carp (Fig. 4). During the three years of studies the first half of the summer (June-July) was the period of the greatest feeding intensity. Afterwards, despite the favourable thermal conditions (Tab. VII) the amount of food consumed in 24 hr. gradually decreased. But still in October at water temperature

Percentage of fish with empty alimentary tracts

Tab. VIII

Species	Year	% of intestines without food							
		Month							
		IV	V	VI	VII	VIII	IX	X	XI
Carp	1967		0	0	0	0	0	12	
	1968	0	5	10	0	0	0	21	70
	1969		8	0	0	0	0	10	
Tench	1967	12	10	12	11	20	38	46	
	1968	1	20	19	22	15	30	33	
	1969		30	25	10	25	32	40	
Crucian carp	1967	9	20	6	0	12	12	50	
	1968	3	3		0	10	20	30	
	1969		0	8	0	9	10	45	
Bream	1967			0	0	0	30		
	1968					0		80	
	1969					0	40		
Roach	1967				0	0	0		
	1968				0	0			

about 9°C carp fed quite intensively. The feeding intensity did not decrease to the minimum sooner than in October. The high feeding intensity rate of carp is also proved by the very small number of intestines not filled with food. Such fish – with very few exceptions (May, June) – were found only in autumn, in October, and first of all in November (Tab. VIII). The feeding intensity of carp in 1967 was almost 40% greater than in 1969. In 1968 there was a strong epidemic of carp dropsy (*Septicaemia haemorhagica cyprinorum*) among the introduced carp. According to Zawisza and Ciepielewski (1973) it affected the greater part of introduced fish. Among the caught fish the infected individuals were only 10–15% of caught carp. This could possibly be the result of the selectivity of catching devices. The active, feeding or searching for food fish were more likely within the range of the seine net or electric shocker than the sick individuals hiding in the vegetation. The results of catches affected of course the estimation of the feeding intensity of carp in 1968. This intensity was only slightly lower than in 1967. However, taking into consideration that in the intestines of infected individuals there was about three times less food than in healthy fish and assuming the information about the carp dropsy epidemic (Zawisza and Ciepielewski 1973), it can be said that the average feeding intensity of carp in 1968 was about three times lower than in 1967.

B. Tench (Fig. 4). The average feeding intensity of tench was more than twice smaller than that of carp. The course of the dynamics of the feeding intensity of tench varied in different years of studies. In 1967 a slow increase of the amount of consumed food was observed from April till August, which was the peak month. Afterwards the feeding intensity decreased till the October minimum. In the next years (and especially in 1969) much greater fluctuations of the feeding intensity were observed. The more visible than in 1967 peaks fell in July (1968) and June (1969). In other months the amount of consumed food was rather smaller. A characteristic phenomenon for the entire period of studies was the high percentage of tench, in the intestines of which no food was found (Tab. VIII). In 1968 the feeding intensity remained on the same level as in 1967, and in 1969 it decreased 12% as compared with 1967.

In spring 1967, part of the examined tench was infected with the fluke *Asymphlodora tincae* (Modeer). And as in the instance of carp infected by *Septicaemia* the feeding intensity of sick tench was three to four times lower than the feeding intensity of healthy fish.

C. Crucian carp (Fig. 5). June-August is the period of the greatest feeding intensity. And then the percentage of intestines not filled with food is

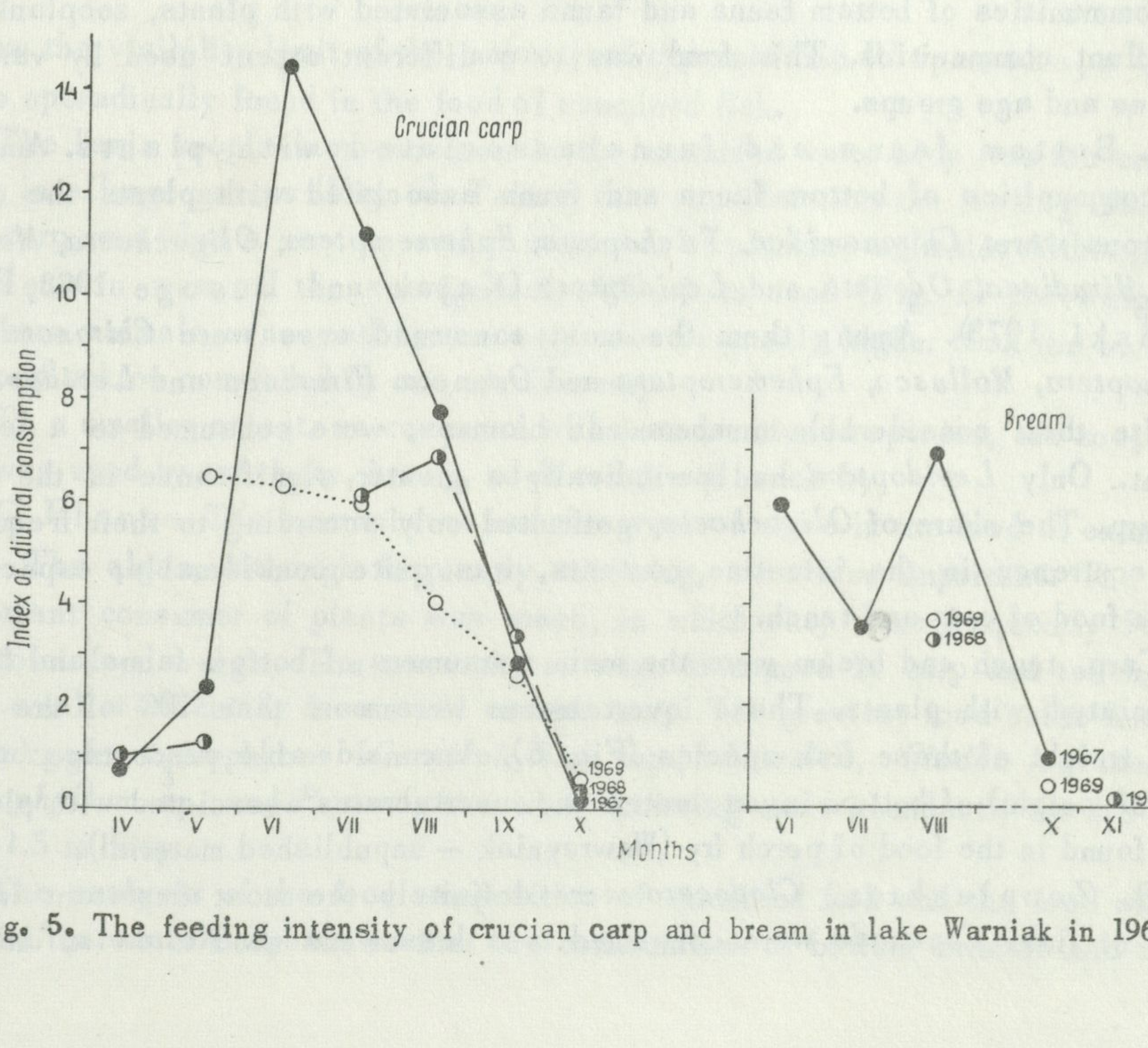

Fig. 5. The feeding intensity of crucian carp and bream in lake Warniak in 1967–1969

the lowest. In autumn, and usually in spring the feeding intensity of crucian carp was low, and in autumn (October) there was the greatest number of crucian carp with intestines void of food (Tab. VIII). The feeding intensity of crucian carp was the greatest in 1967. In 1968 and 1969 it decreased almost 50% as compared with 1967. However, it should be added that the estimates for 1968 may be incomplete because of the lack of crucian carp in the catches in June, the month which in 1967 was the period of the most intensive feeding.

D. Bream (Fig. 5). In summer 1967 the feeding intensity of bream was smaller than that of carp, but 25% greater than that of tench. In the period June--August 1967 and in August 1968 and 1969 all the examined intestines were filled with food (Tab. VIII). The feeding intensity of bream decreased to the minimum in October and November. 80% of the intestines examined in October 1967 were void of food (Tab. VIII), and 70% in November 1968.

V. FEEDING OF FISH AND FOOD RESOURCES IN THE LAKE

1. Utilization of food resources

The basic food resources for the examined non-predatory fish and fry were the communities of bottom fauna and fauna associated with plants, zooplankton and plant communities. This food was to a different extent used by various species and age groups.

A. Bottom fauna and fauna associated with plants. Among the communities of bottom fauna and fauna associated with plants the most numerous were: *Chironomidae, Trichoptera, Ephemeroptera, Oligochaeta, Mollusca, Hirudinea, Odonata* and *Lepidoptera* (Kajak and Dusoge 1973, Pieczyński 1973). Among them the most consumed ones were *Chironomidae, Trichoptera, Mollusca, Ephemeroptera* and *Odonata. Hirudinea* and *Lepidoptera*, despite their considerable numbers and biomass, were consumed to a lesser extent. Only *Lepidoptera* had periodically a greater significance in the food of carp. The share of *Oligochaeta*, estimated only according to their frequency of occurrence in the intestine contents, was quite considerable, especially in the food of carp and tench.

Carp, tench and bream were the main consumers of bottom fauna and fauna associated with plants. These invertebrates were more than 70% of the total food weight of these fish species (Fig. 6). A considerable percentage (above 65% of weight) of bottom invertebrates and invertebrates associated with plants was found in the food of perch fry (Wawrzyniak – unpublished material).

B. Zooplankton. *Cladocera* were definitely the most important in the food of fish. *Copepoda* were consumed to a lesser extent. *Rotatoria*, animals

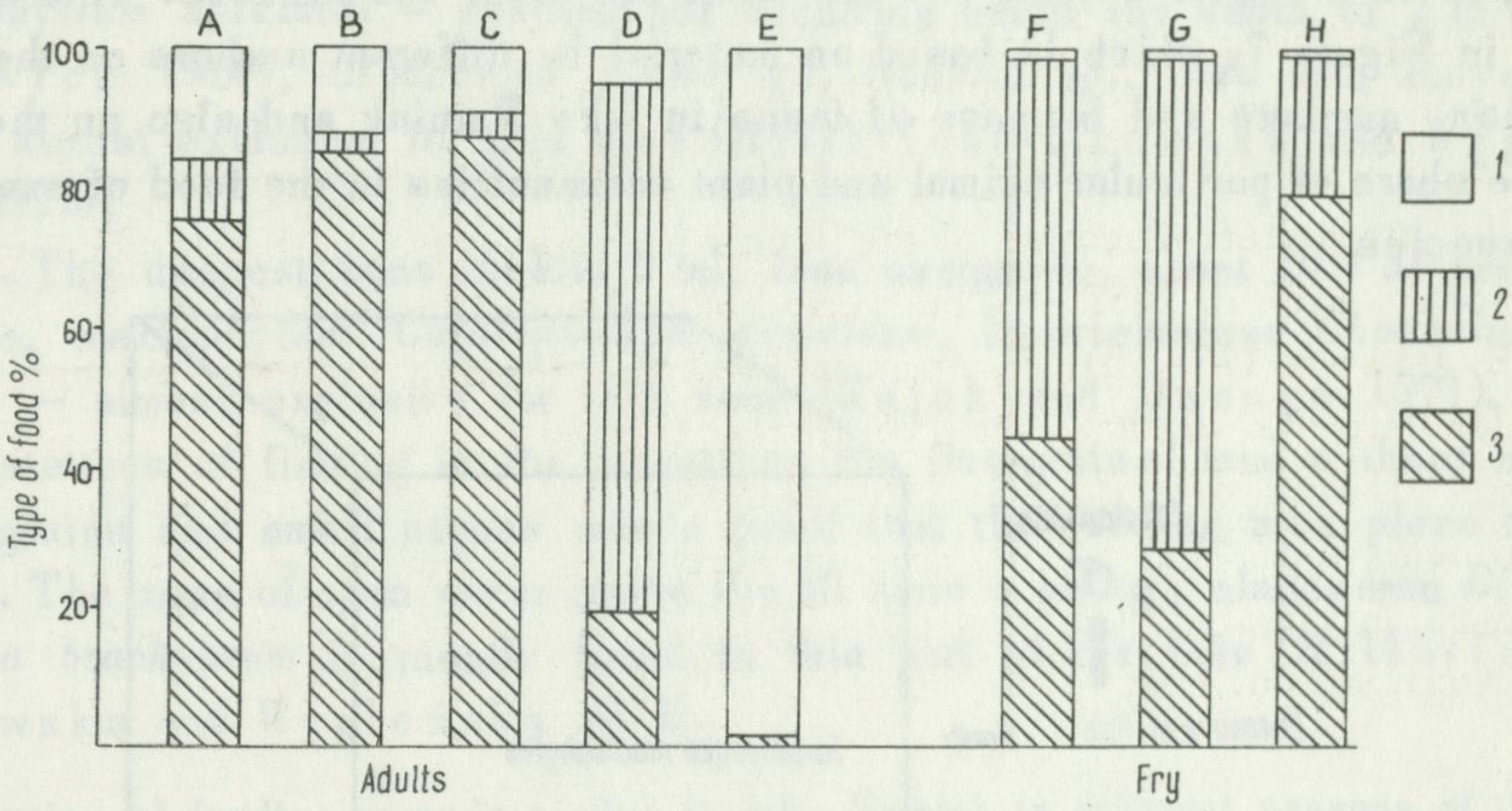

Fig. 6. Share (in % of weight) of benthos, fauna associated with plants, zooplankton and plants in the food of adult non-predatory fish and fry in lake Warniak (data on fry acc. to the unpublished material by Wawrzyniak)
1 – plants, *2* – zooplankton, *3* – benthos and fauna associated with plants; *A* – carp, *B* – tench, *C* – bream, *D* – crucian carp, *E* – roach, *F* – tench fry, *G* – crucian carp fry, *H* – perch fry

below the visibility limit of the majority of cyprynid fish (Uspenskaja 1953), were sporadically found in the food of examined fish.

The basic zooplankton consumer in the examined water body was the crucian carp in all age groups (Fig. 6). Taking into consideration the feeding intensity the carp was also a very important consumer of plankton animals. Although the zooplankton was on the average only 9% of its food (Fig. 6) the weight of plankton animals consumed by one carp was frequently higher than the biomass of zooplankton consumed by one crucian carp.

To a smaller extent, as compared with both mentioned species, the zooplankton was used by tench fry, bream, adult tench and perch fry.

C. Plants. The macrophytes had the greatest share in the food of examined fish. The algae, although frequently occurring, were less important. The most important consumer of plants was roach, in which they were frequently 99% of the total food weight. The macrophytes were also used by carp and tench, and to a smaller extent by bream and crucian carp. The greatest food value had the submerged macrophytes (*Ceratophyllum* sp., *Charales*, *Elodea canadensis*, *Myriophyllum* sp. and *Potamogeton* sp.) occurring most abundantly in the zone 0.5–1.5 m deep.

The analysis of the food composition of examined fish and the food resources of the water body shows that the communities of bottom animals and those associated with plants were consumed the most, whereas the zooplankton communities to a lesser extent, and the least the plant communities. This can be seen in Figure 7, which is based on material by different authors on the composition, numbers and biomass of fauna in lake Warniak and also on the data on the share of particular animal and plant communities in the food of examined fish species.

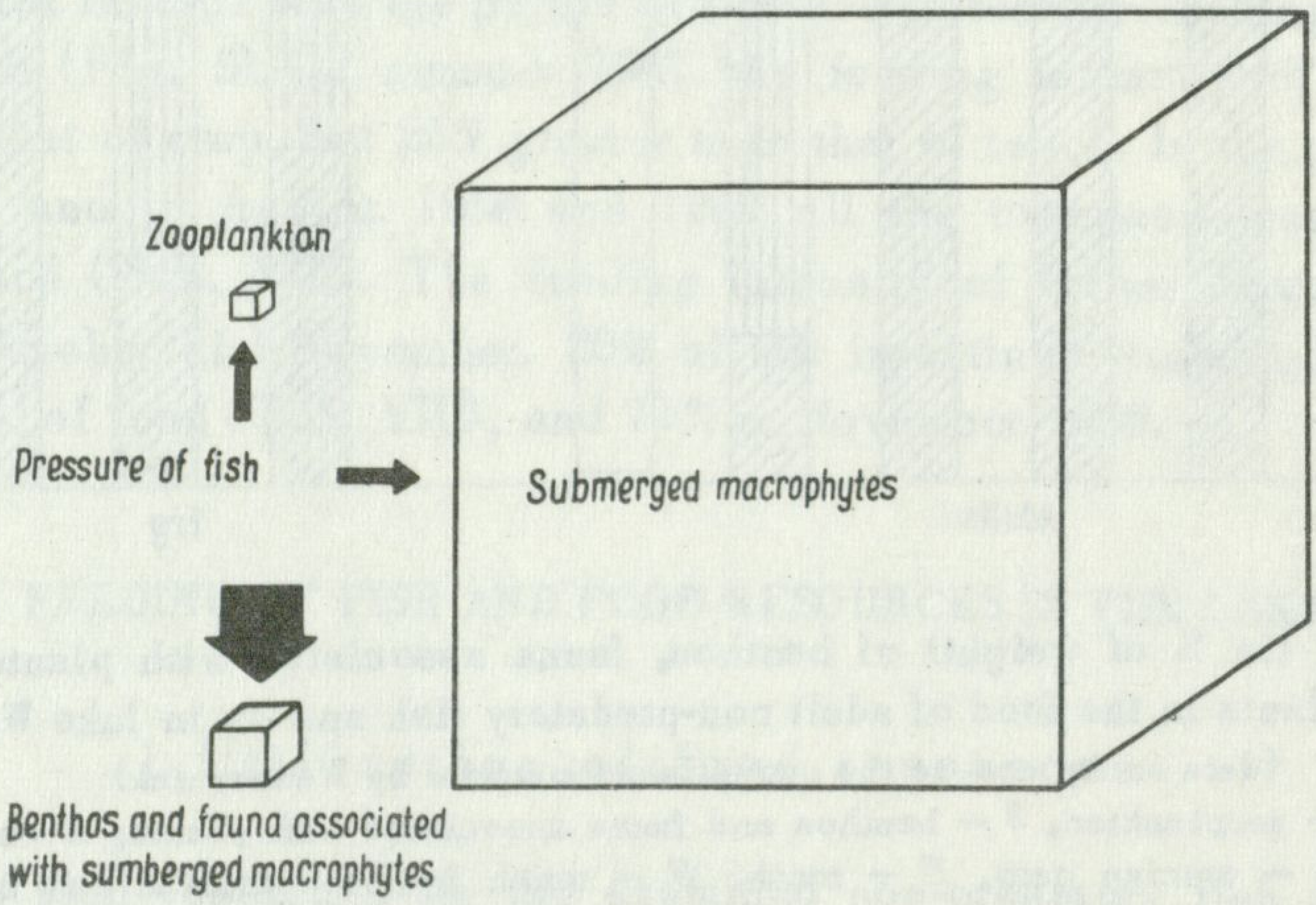

Fig. 7. The diagram illustrating the pressure of adult non-predatory fish on different communities of organisms in lake Warniak (see explanations in the paper)

Also, the consumption rate of particular species of examined fish and approximate data of Zawisza and Ciepielewski (1973) on the abundance of adult non-predatory fish in lake Warniak, allowed to calculate that in 1969 the introduced species (carp and bream) consumed about 60% of the biomass of benthos and fauna associated with plants consumed by the whole community of adult non-predatory fish. The zooplankton was less affected by the introduced fish, as they consumed only about 30% of biomass of zooplankton consumed by the whole community.

2. Distribution of feeding grounds of particular fish species

In order to illstrate the distribution of feeding fish several food objects consumed by the fish were chosen as good indikators of their feeding grounds:

I. Eulittoral zone, about 11% of the lake surface, *Diptera* larvae from the families: *Cylindrotomidae*, *Liriopeidae*, *Stratiomyidae*, *Tabanidae* and *Tipulidae*. Pieczyńska (1972, 1973) found hat thes larvae were occurring only in this zone;

II. The zone strongly overgrown with submerged vegetation (to the depth of 2 m), about 70% of the lake surface, macrophytes: *Elodea canadensis* and *Myriophyllum spicatum* – species not occurring below the depth of 2 m (Bernatowicz 1969), *Cladocera*: *Alona* sp., *Alonella* sp., *Sida* sp., *Eurycercus* sp. – almost exclusive for this zone (Hillbricht-Ilkowska and Węgleńska 1973);

III. The deepest zone (below 2 m), less overgrown, about 10% of the lake surface, macrophytes: *Ceratophyllum demersum*, invertebrates: *Chaoborus* sp. larvae – almost exclusive for this zone (Kajak and Dusoge 1973). Also the instances of finding in the intestines the fine-grained mud without bigger sand grains and small stones was a proof that the feeding took place there;

IV. The zone of open water above the III zone – pelagic cladoceran *Diaphanosoma brachyurum* frequently found in this part of the lake (Hillbricht-Ilkowska and Węgleńska 1973).

Distribution of feeding grounds of fish in lake Warniak in different seasons of the year

A – spring, *B* – summer, *C* – autumn

I – eulittoral, *II* – the zone to the depth of 2 m, strongly overgrown with submerged vegetation, *III* – the zone below the depth of 2 m, less overgrown, *IV* – the zone of "open water" above zone *III*

+ – basic feeding grounds, o – secondary feeding grounds

Tab. IX

Lake zone	Carp			Tench			Bream			Crucian carp			Roach			Fry* Crucian carp, tench and roach			Fry* Perch		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
I	o		o	o		o				o		o	o		o		o	o		o	o
II	+	+	+	+	+	+	o	o	o	+	+	+	+	+	+		+	+		+	+
III	o	o	o		o		+	+	+												
IV		o					o	o	o		o									o	o

*Data obtained in the catches with the electric shocker and from the unpublished material of Wawrzyniak.

Analysing the occurrence of indicatory organisms in the food of examined fish, and taking into account the places of the most frequent catching of particular species, and on the basis of literature data (Laskar 1941, Pliszka 1953a, 1953b, Uspenskaja 1953), the following picture of fish feeding during the vegetation season has been obtained (Tab. IX):

Zone *I* – penetrated in spring and autumn by carp, tench, crucian carp and rarely by roach. In summer it is not easily accessible for fish due to the very low water level, exuberant growth of submerged vegetation and frequent oxygen deficits (P i e c z y ń s k a 1973);

Zone *II* – during the entire vegetation season carp, tench, crucian carp, roach and fry feed here. Bream feeds here less frequently;

Zone *III* – basic feeding ground of bream. Carp and tench feed here mainly in summer; in spring and autumn they do not penetrate this zone so much;

Zone *IV* – the least frequented one by fish. Periodically feed here: bream, carp, crucian carp and older stages of perch fry.

VI. RECAPITULATION

The material presented here and the data from the paper by Wawrzyniak (unpublished material) on the food of fry in lake Warniak allow to distinguish among the introduced and autochthonous non-predatory fish and fry two groups with different feeding habits:

1. Fish preferring animal food;

A. Fish feeding mainly on bottom fauna and fauna associated with plants – carp, tench, bream, perch fry;

B. Fish feeding mainly on zooplankton – crucian carp and crucian carp and tench fry;

2. Fish preferring plant food – older roach age groups.

The share of particular animal and plant components in the food of adult fish and fry is presented in Figure 8.

Table X compares the indices of food similarity of fish feeding mainly on animal food. The greatest food similarity (index of similarity 81) had the carp and tench. These species mainly fed on *Chironomidae*, *Trichoptera* and *Mollusca*, which were about 50% of the total food weight. A great similarity in the food of carp and tench (index of food similarity about 90) bred in the same ponds was observed also by P e k a ř and K r u p a u e r (1968). Smaller values of the index of food similarity pointing to a smaller food similarity were obtained by comparing the feeding habits of carp and bream, and tench and bream. This is due to the greater utilization by bream of the *Chironomidae* larvae (about 60% of food weight) and poor feeding on the *Mollusca* and *Trichoptera* larvae. The relations between fish feeding mainly on bottom fauna and fauna associated with plants and fish, in the food of which plankton animals dominate, are first of all visible in zooplankton utilization by the former and of the *Trichoptera* associated with plants by the latter. The relations between the fish feeding mainly on animal food and the older roach age groups feeding almost exclusively on plant food, are not great. Thus, judging by the fact that the weight ratio of animal components to macrophyte fragments in roach food is similar to the analogous one in the habitat (P i e c z y ń s k i 1973), this fish does not prefer animal forms. These food relations between particular fish species underwent some changes during the successive years of studies.

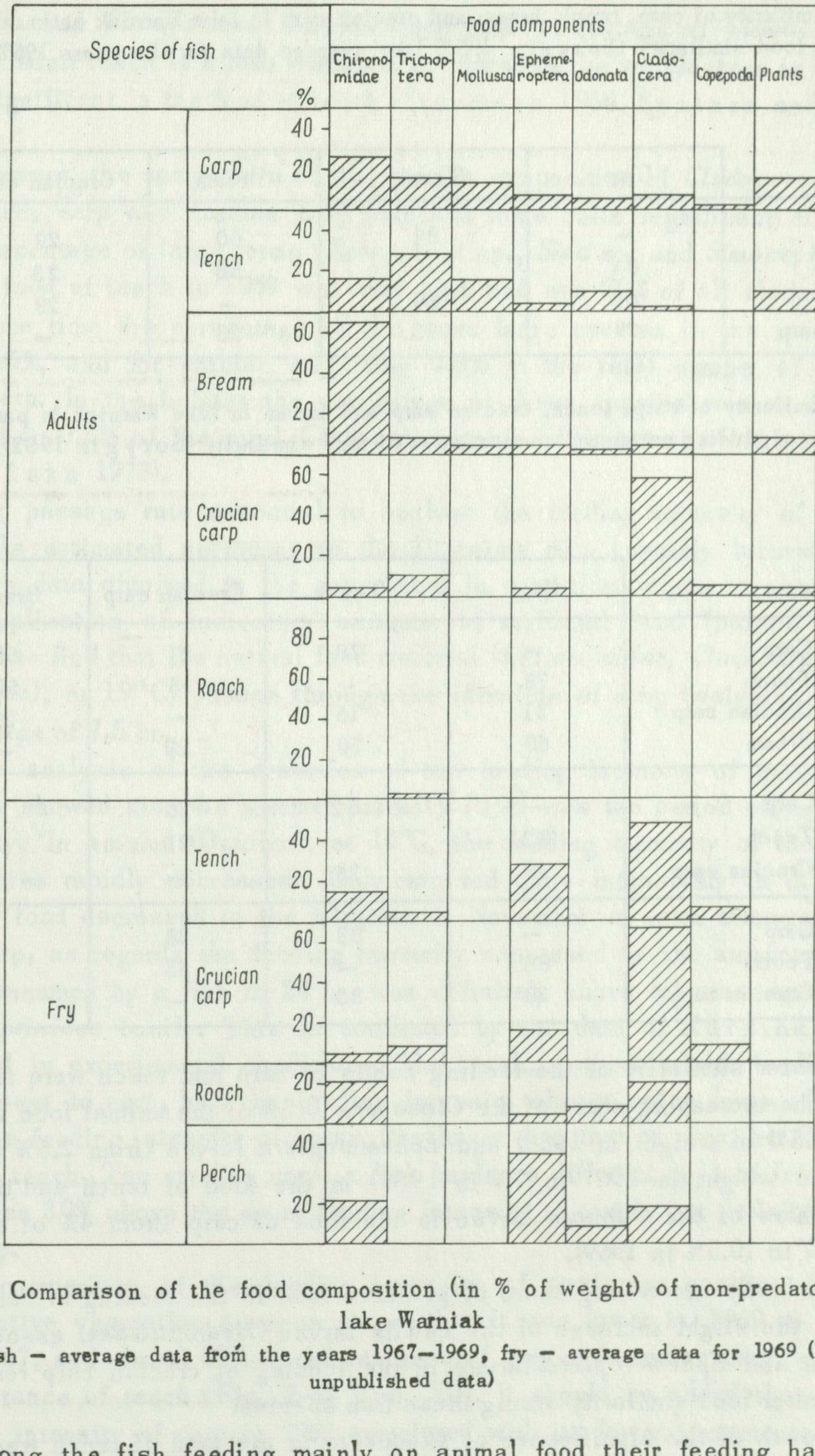

Fig. 8. Comparison of the food composition (in % of weight) of non-predatory fish in lake Warniak

Adult fish – average data from the years 1967–1969, fry – average data for 1969 (Wawrzyniak unpublished data)

Among the fish feeding mainly on animal food their feeding habits were becoming more similar in the course of years, and thus the values of the indices of food similarity were increasing (Tab. XI).

The food similarity of carp, tench, bream and crucian carp in lake Warniak estimated acc. to index of food similarity (Šorygin 1952) (the average data for the years 1967–1969)

Tab. X

	Carp	Tench	Bream	Crucian carp
Carp	–	81	60	29
Tench	81	–	50	23
Bream	60	50	–	28
Crucian carp	29	23	28	–

The food similarity of carp, tench, crucian carp and bream in lake Warniak in particular years of studies estimated acc. to index of food similarity (Šorygin 1952)

Tab. XI

		Carp	Tench	Crucian carp	Bream
1967	Carp	–	78	21	60
	Tench	78	–	15	50
	Crucian carp	21	15	–	29
	Bream	60	50	29	–
1968	Carp	–	82	28	
	Tench	82	–	25	
	Crucian carp	28	25	–	
1969	Carp	–	88	38	
	Tench	88	–	33	
	Crucian carp	38	33	–	

The greater similarity of the feeding habits of carp and tench were first of all due to the increasing share of the *Cladocera* (0.5% of the animal food weight in 1967, 6.5% of weight in 1969) and *Ephemeroptera* larvae (from 2.5% of the animal food weight in 1967 to 7% in 1969) in the food of tench and the increasing share of the *Odonata* larvae in the food of carp (from 4% of animal food in 1967 to 10.5% in 1969).

The gradually increasing share of plankton food in the feeding of carp and tench, and the slight increase of the caddis larvae (*Hydroptilidae*) associated with plants and *Ephemeroptera* larvae in the feeding of crucian carp resulted in even greater food similarity among these fish species.

The growth of the significance of *Cladocera* in the food of tench was very characteristic in 1969, especially in the period July-September, when the cladocerans were about 15% of the animal food weight, and were next to *Tri-*

choptera and *Chironomidae* larvae. Such high percentage of *Cladocera* in the food of adult tench is a rare instance. In literature the zooplankton is mentioned as insignificant in the food of tench (Starmach 1955, Spataru and Negrea 1969).

However, the comparison of the species composition of *Cladocera* consumed by tench, carp and crucian carp points to some quite significant differences. The percentage of large forms (*Eurycercus* sp., *Sida* sp. and *Simocephalus* sp.) in the food of tench in 1969 was very high and was 20% of all cladocerans. In the same time the percentage of the same large species in the food of carp was 5.5%, and for crucian carp only 0.8% of the total number of consumed *Cladocera*. In the habitat the percentage of these species was on the whole lower than 0.5% of the total *Cladocera* number (Hillbricht-Ilkowska and Węglеńska 1973).

The passage rate essential to analyse the feeding intensity of examined fish was estimated according to the literature data (usually laboratory data) and own data obtained in the experiment in conditions close to natural ones. The application of indicatory amounts of artificial food (protein granules) allowed to find that the natural food material (*Chironomidae, Cladocera, Copepoda*, algae), at 19°C, passes through the intestine of carp (weighing 150 g) at an average of 7.5 hr.

The analysis of the dynamics of the feeding intensity of examined fish species showed that the summer (usually June) was the period of the greatest intensity. In autumn (October), at 10°C, the feeding intensity of the majority of species rapidly decreased. Only carp fed quite intensively in that period, and its food decreased to the minimum in November at water temperature 4°C. The carp, as regards the feeding intensity expressed by the amount of animal food consumed by a fish in 24 hr, was definitely above all other species from the *Cyprinidae* family. This is confirmed by the data of Karzinkin (1955) obtained in experimental conditions. The tench, a species with feeding habits the closest to carp, had the feeding intensity almost twice lower. In summer 1967 the feeding intensity of bream was lower than that of carp, but 25% higher than of tench. The crucian carp, a fish having a different type of feeding, was more than 30% above the mean feeding intensity of tench, but definitely behind the carp.

A comparison of the feeding intensity of particular species during the consecutive vegetation seasons shows that it was lower in 1969 as compared with 1967, and almost 50% in the instance of carp and crucian carp, and 12% in the instance of tench (Fig. 7–8, Tab. XII). It should be added that the lower feeding intensity of carp in 1969 correlated with its lower increments as found by Zawisza and Ciepielewski (1973).

The infection of carp (*Septicaemia*) and tench (*Asymphlodora tinca*

Average daily index of consumption* of fish in lake Warniak for the period of intensive feeding in successive years

Tab. XII

Months	Fish species	1967	1968	1969
V-X	Carp	8.4	7.5	5.7
V-IX	Tench	3.7	3.4	3.1
VI-VIII	Crucian carp	11.2	6.5	5.5

*The relation of the weight of reconstructed food to the weight of fish × 1000.

affected the feeding intensity. The amount of food consumed by infected fish was three times smaller than by healthy fish.

It has been shown that during the studies the communities of bottom fauna and fauna associated with plants were consumed the most by fish, the zooplankton community – to a lesser extent and the plant communities were consumed the least (Fig. 7). In the last year of the experiment (1969) the introduced species (carp and bream) consumed about 60% of the biomass of benthos and fauna associated with plants and about 30% of zooplankton biomass consumed by the whole community of non-predatory fish.

Furthermore, data on the differentiation of feeding grounds of adult non--predatory fish were obtained (Tab. IX). In spring, the entire lake surface was penetrated, but some differentiation in the distribution of fish was observed. The basic feeding grounds of carp, tench, crucian carp and roach were the strongly overgrown with submerged vegetation parts of the water body (to the depth below 2 m). These fish, to a smaller extent, penetrated also the eulittoral zone and the deepest zone (below 2 m). The basic feeding ground of bream was the deepest zone. The bream penetrated also the zone strongly overgrown with emergent vegetation, but did not feed in the eulittoral. From July to August the eulittoral (11% of lake surface) was hardly accessible and practically unfrequented by the examined species because of the low water level, exuberant vegetation growth and frequent oxygen deficits (Pieczyńska 1973). At that time the distribution of feeding grounds was similar to the spring one with the difference that carp and tench more frequently than in spring used the deepest parts of the lake. In autumn the examined species penetrated again the whole lake surface. The distribution of feeding grounds was similar as in spring.

Comparing the food resources in the lake in 1967 and 1969 it can be said that the changes were frequently unfavourable for the increasing in successive years fish stock. An example may be the decrease of average benthos biomass in June-July, the period of the highest feeding intensity, from 9.2 g per m² in

1967 to 5.4 g per m^2 in 1969 (Kajak and Dusoge 1973). An essential fact is also the maximal in these three years decrease of water level in summer 1969, and thus the smallest lake surface accessible for the feeding fish.

All this could result in periodical competition between particular fish species. Assuming that such a situation existed it should be pointed out that it is very difficult to determine the factor conditioning this. For example, it can not be stated beyond any doubt whether the food or only the food was the reason. It is known, among others, from the papers by Lack (1945) and Pliszka (1953b) that in more thorough analyses of food composition of animals, which use the same kind of food, their food similarity may be somewhat apparent. Furthermore, Hartley (1947), Starret (1950) and Pliszka (1953b) pronounce the opinion that the fact that different species require the same food does not necessarily mean that there is a competition. Also the possibility of space competition among the examined species, which is observed by Larkin (1956) as opposed to food competition, can not be excluded. Such competition may weaken the feeding intensity even at great food abundance. The possibilities of such competition are confirmed by ethological studies (among others Newman 1956), and the observed by Bennett (1952) lower production of one species in the presence of another potential competitor, may be partly due to this. Ivlev (1955) says that food competition may arise or become more intense either in worse food conditions or in greater fish density. The effect of the interaction of co-feeding species may in such situations be the decrease of the absolute value of food or its qualitative changes.

Altogether, it seems that there are reasons form connecting the changes in feeding and fish increments (Zawisza and Ciepielewski 1973) in the examined period with the changes in flora and invertebrate fauna communities (Spodniewska and Hillbricht-Ilkowska 1973, Hillbricht-Ilkowska and Węgleńska 1973, Kajak and Dusoge 1973), and with the changes in the community of autochthonous and introduced non-predatory fish of lake Warniak.

REFERENCES

1. Assman, A. V. 1962 — Vyedanie estestvennych kormov karpami pri različnom kormovom režime i različnoj plotnosti posadki — Trudy Inst. Morf. Živ. 42: 62–119.
2. Backiel, T., Horoszewicz, L. 1970 — Temperatura a ryby — Olsztyn, Żabieniec, 25 pp.
3. Bajkov, A. D. 1935 — How to estimate the daily food consumption of fish under natural conditions — Trans. Amer. Fish. Soc. 65: 288–289.

4. Ball, L. C. 1948 – Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake – Tech. Bull. Mich. St. Coll. agr. exp. Stat. 206: 1–59.

5. Bennett, G. W. 1952 – Pond management in Illinois – J. Wildlife Mgmt, 16: 249–253.

6. Bernatowicz, S. 1969 – Macrophytes in the lake Warniak and their chemical composition – Ekol. Pol. A, 17: 447–467.

7. Blegvaad, H. 1917 – On the food of fish in the Danish waters within the Skaw – Rep. Danish biol. Stat. 24: 19–72.

8. Bogatova, J. B. 1963 – O piščevych otnošenijach u ozernych ryb – Vopr. Ichtiol. 3: 336–345.

9. Bogorov, V. 1934 – Issledovanie pitanija planktonojadnych ryb – Bjull. vsesojuzn. nauč.-issled. Inst. morsk. rybn. Choz. Okeanogr. 1: 21–43.

10. Bokova, E. N. 1938 – Sutočnoe potreblenie i skorost perevarivanija korma vobloj – Rybn. Choz. 6: 86–99.

11. Bokova, E. N. 1940 – Potreblenie i usvoenie korma vobloj – Trudy vsesojuzn. nauč.-issled. Inst. morsk. rybn. Choz. Okeanogr. 11: 5–24.

12. Borodič, N. D. 1965 – Vlijanie godovikov i dvuchletkov karpa na donnoe naselenie rybovodnych prudov – Vestn. Čsl. zool. Spol. 29: 40–55.

13. Boruckij, E. V. 1958 – K metodike opredelenija razmerno-vesovoj charakteristiki bezpozvonočnych organizmov služaščich piščej ryb – Vopr. Ichtiol. 11: 181–187.

14. Budzyńska, H., Romaniszyn, W., Romański, I., Rubisz, A., Stangenberg, K. 1956 – The growth and the summer food of the economically most important fishes of the Gopło lake – Zool. Pol. 7: 63–120.

15. Cihař, J. 1957 – Potravni biologie karasa obecného (*Carassius carassius* (L.) *morpha humilis* Haeckel 1840) – Vestn. Čsl. zool. Spol. 21: 311–325.

16. Contag, E. 1931 – Der Einfluss verschiedener Besatzstärken auf die natürliche Ernährung zweisömmeriger Karpfen und auf die Zusammensetzung der Tierwelt ablassbarer Teiche – Z. Fischerei, 19: 569–595.

17. Dobben van, W. 1937 – Über den Kiefermechanismus der Knochenfischer – Arch. Neerl. Zool. 2: 1–12.

18. Dobers, E. 1922 – Nahrungsuntersuchungen bei Wildfischen – Z. Fischerei, 21: 164–167.

19. Forbes, S. A. 1880 – The food of fishes *Acanthopteri* – Bull. Illinois State Lab. nat. Hist. 3: 71–89.

20. Fortunatova, K. R. 1964 – Ob indeksach pitanija ryb – Vopr. Ichtiol. 4: 188–190.

21. Hartley, P. T. H. 1947 – The natural history of some British freshwater fishes – Proc. zool. Soc. Lond. 117: 129–206.

22. Hillbricht-Ilkowska, A., Patalas, K. 1967 – Metody oceny produkcji i biomasy oraz niektóre problemy metodyki ilościowej zooplanktonu – Ekol. Pol. B, 13: 139–172.

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

24. Hruška, V. 1956 – Přispevek k potravni biologii plotice v tuni Poltrubé – Univ. Carolina, Biolog. 2: 161–207.

25. Hunt, B. P. 1960 – Digestion rate and food consumption of Florida gar, warmouth and largemouth bass – Trans. Amer. Fish. Soc. 89: 206–211.

26. Ivanova, L. D. 1953 – Biologičeskie osobennosti plotvy kak komponenta ozernoj ichtiofauny – Vopr. Ichtiol. 1: 82–93.

27. Ivlev, V. S. 1955 – Eksperimentalnaja ekologija pitanija ryb – Moskva, 252 pp.

28. Jablonskaja, E. A. 1953 – Bentos nerestogo-vyrastnogo chozjajstva Azovo-Dolgij – Trudy vsesojuzn. nauč.-issled. Inst. morsk. rybn. Choz. Okeanogr. 24: 71–101.

29. Jelinowski, B. 1950 – Pokarm płoci (*Rutilus rutilus* L.) z jeziora Charzykowo (Jezioro Charzykowo) – Warszawa, 185–209.

30. Kajak, Z., Dusoge, K. 1973 – Experimentally increased fish stock in the pond type lake Warniak. IX. Numbers and biomass of bottom fauna – Ekol. Pol. 21:563–573.

31. Karzinkin, G. S. 1935 – Prodolžitelnost prochoždenija pišči i usvoenie ee malkami *Esox lucius* L. – Trudy limnol. Stanc. Kosino, 20: 81–92.

32. Karzinkin, G. S. 1955 – Podstawy biologicznej wydajności zbiorników wodnych – Warszawa, 386 pp.

33. Klust, G. 1940 – Über Entwicklung, Bau und Funktion des Darmes beim Karpfen – Int. Rev. Hydrobiol. 39: 488–498.

34. Kogan, A. V. 1963 – O sutočnom racione i ritme pitanija lešča *Abramis brama* (L.) Cimljanskogo vodochranilišča – Vopr. Ichtiol. 3: 317–325.

35. Kogan, A. V. 1969 – O sutočnom racione i indekse napolnenija kišečnika u ryb – Vopr. Ichtiol. 9: 956–958.

36. Koyama, H., Miyajima, T., Okubo, H. 1968 – Studies on increasing fish production by fertilization in farm ponds. Observations of stomach contents of fish – Bull. Frenshwat. Fish. Res. Lab. 2: 95–101.

37. Krajuchin, E. V. 1963 – Fiziologija piščevarenija presnovodnych ryb – Moskva, 139 pp.

38. Lack, D. 1945 – Ecology of closely related species with special reference to cormorant (*Phalacrocorax carbo*) and shag (*P. aristotelis*) – J. Anim. Ecol. 14: 12–16.

39. Lapinskaite, Ja. S. 1961 – Donnaja fauna prudov „Rita Ausma", ee dinamika i rol v pitanii karpa – Avtoref. Vilnjus, 19 pp.

40. Larkin, P. A. 1956 – Interspecific competition and population control in freshwater fish – J. Fish. Res. Bd Can. 13: 327–342.

41. Laskar, K. 1941 – Die Ernährung des Brassers – Fisch. Ztg. 51/52: 339–344.

42. Lebedeva, L. I., Kozlova, E. I. 1969 – Razmerno-vesovaja charakteristika živych i fiksirovannych formalinom presnovodnych *Cladocera* – Gidrobiol. Ž. 5: 73–79.

43. Maksimova, L. P. 1961 – Pitanie i stepen ispolzovanija estestvennych i isskustvennych kormov gibridami karpa s amurskim sazanom – Izv. Gos. nauč.-issled. Inst. ozern. rečn. rybn. Choz. 51: 65–95.

44. Morduchaj-Boltovskoj, F. D. 1954 – Materjaly po srednemu vesu vodnych bespozvonočnych bassejna Dona – Trudy probl. Sovešč. ZIN, 2: 223–241.

45. Moskalenko, M. 1968 – Plotnost posadki i estestvennych kormov – Rybovod. Rybolov. 2: 13–14.

46. Newman, M. A. 1956 – Social behaviour and interspecific competition in two trout species – Physiol. Zool. 29: 64–81.

47. Niculescu-Duvaz, M. 1970 – Ecologia alimentatiei naturale si suplimentare la crapul cultura – Bull. Inst. Cerc. pisc. 29: 29–56.

48. Pankratova, V. Ja. 1948 – Materialy po pitaniju volžskich ryb – Trudy zool. Inst. Akad. Nauk SSSR, 8: 601–620.

49. Paschalski, J. 1958 – Żywienie się płoci (*Rutilus rutilus* L.) oraz świnki (*Chondrostoma nasus* L.) w Rożnowskim zbiorniku zaporowym – Pol. Arch. Hydrobiol. 45: 55–64.

50. Pekař, C., Krupauer, V. 1968 – Potravni vztahy dvouletych karpu a linu v kombinovane obsadce – Pr. VURH, Vodňany, 8: 29–54.

51. Pieczyńska, E. 1972 – Ecology of the eulittoral zone of lakes – Ekol. Pol. 20: 637–732.

52. Pieczyńska, E. 1973 – 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.

53. Pieczyński, E. 1973 – Experimentally increased fish stock in the pond type lake Warniak. XII. Numbers and biomass of the fauna associated with macrophytes Ekol. Pol. 21: 583–593.

54. Pieczyński, E., Prejs, A. 1970 – The share of water mites (*Hydracarina*) in the food of three species of fish in lake Warniak – Ekol. Pol. 18: 445–452.

55. Pliszka, F. 1953a – Dynamika stosunków pokarmowych ryb jeziora Harsz – Pol. Arch. Hydrobiol. 1: 271–300.

56. Pliszka, F. 1953b – Zmienność charakteru żywienia się ryb jako czynnik stabilizujący zespoły ichtiofauny – Pol. Arch. Hydrobiol. 1: 301–315.

57. Pliszka, F. 1956 – Znaczenie organizmów wodnych jako pokarmu ryb w świetle badań polskich – Pol. Arch. Hydrobiol. 3: 428–458.

58. Pliszka, F., Dziekońska, J. 1953 – Analiza stosunków pokarmowych ryb w jeziorze Tajty jako podstawa do jego zagospodarowania – Roczn. Nauk roln. D, 67: 187–208.

59. Sandercock, F. D. 1969 – Bioenergetics of the rainbow trout (*Salmo gairdneri*) and the kokanee (*Oncorhynchus nerka*) populations of Marion lake, British Columbia – Ph. D. Thesis, 165 pp.

60. Scheuring, L. 1928 – Beziehungen zwischen Temperatur und Verdauungsgeschwindigkeit bei Fischen – Z. Fischerei, 26: 183–215.

61. Schiemenz, P. 1907 – Betrachtungen über die natüraliche Ernährung unserer Teichfische – Dtsch. Fischereiztg, 30: 261–348.

62. Skóra, S. 1964 – Charakterystyka lina (*Tinca tinca* L.) ze Zbiornika Goczałkowickiego – Acta Hydrobiol. 6: 97–118.

63. Spanovskaja, V. D. 1948 – Pitanie ryb Učinskogo vodochranilišča – Zool. Ž. 27: 39–49.

64. Spataru, P., Negrea, S. 1969 – Rolul Cladocerelor in hrana pestilor din complexul de Balti Crapina-Jijila (Zona inundabila a Dunarii) – Bull. Inst. Cerc. pisc. 28: 15–22.

65. Spodniewska, I., Hillbricht-Ilkowska, A. 1973 – Experimentally increased fish stock in the pond type lake Warniak. VI. Biomass and production of phytoplankton – Ekol. Pol. 21: 519–537.

66. Stangenberg, K. 1958 – Letni pokarm płoci (*Rutilus rutilus* L.) z jeziora a-mezotroficznego i dystroficznego – Pol. Arch. Hydrobiol. 4: 251–275.

67. Stangenberg, M. 1936 – Szkic limnologiczny na tle stosunków hydrochemicznych Pojezierza Suwalskiego – Rozpr. Spraw. Inst. Bad. Lasów Państw. A, 19: 7–85.

68. Starmach, K. 1951 – Chów linów w stawach – Warszawa, 82 pp.

69. Starmach, K. 1955 – Metody badań planktonu – Warszawa, 133 pp.

70. Starrett, W. C. 1950 – Food relationship of the minnows of the Des Moines River, Iowa – Ecology, 31: 216–233.

71. Šorygin, A. A. 1952 – Pitanie i piščevye vzaimootnošenija ryb Kaspijskogo morja – Moskva, 268 pp.

72. Špet, G. J. 1953 – Ekologija pitanija karpa v svjazi s rozrabotkoj racionalnych metodov kormlenija – Trudy nauč.-issled. Inst. prud. ozern. rečn. rybn. Choz. 9: 39–68.
73. Szumiec, J. 1966 – Udział pokarmu naturalnego przy żywieniu karpi – Acta Hydrobiol. 8: 199–253.
74. Uspenskaja, V. D. 1953 – Pitanie obyknovennogo karasja v uslovijach pojmennych ozer r. Kljazmy – Trudy vsesojuzn. gidrobiol. Obšč. 5: 347–364.
75. Vorobev, V. P. 1938 – Raspredelenie lešča v Azovskom more v svjazi s pitaniem – Trudy Azovsk. Černomorsk. nauč.-issled. Inst. morsk. rybn. Choz. Okeanogr. 2: 112–131.
76. Wiktorowa, K. 1964 – Związki między produkcją zooplanktonu a odżywianiem ryb planktonożernych – Morsk. Inst. ryb., Stud. Mat. A, 2: 1–100.
77. Wunder, W. 1927 – Sinnesphysiologische Untersuchungen über die Nahrungsaufnahme bei verschiedenen Knochenfischen – Z. vergl. Physiol. 6: 67–95.
78. Wunder, W. 1932 – Wie fangen planktonfressende Fische ihre Nahrungstiere – Z. vergl. Physiol. 17: 304–326.
79. Zawisza, J., Ciepielewski, W. 1973 – Experimentally increased fish stock in the pond type lake Warniak. II. Changes of the autochthonous ichtyofauna due to the introduction of carp (*Cyprinus carpio* L.) and bream (*Abramis brama* (L.)) – Ekol. Pol. 21: 423–444.
80. Żeltenkova, M. V. 1949 – Sostav pišči i rost nekotorych predstavitelej roda *Rutilus* – Zool. Ž. 28: 257–267.
81. Žiteneva, T. S. 1967 – Pitanie ryb v zone zatoplennych lesov Rybinskogo vodochranilišča – Vopr. Ichtiol. 7: 1100–1104.

EKSPERYMENTALNE ZWIĘKSZENIE OBSADY RYB W STAWOWYM JEZIORZE WARNIAK

IV. ODŻYWIANIE SIĘ INTRODUKOWANYCH I AUTOCHTONICZNYCH RYB NIEDRAPIEŻNYCH

Streszczenie

Pracę wykonano w ramach eksperymentu polegającego na introdukcji do płytkiego eutroficznego jeziora karpia i leszcza. Miał on na celu z jednej strony uchwycenie wpływu poważnie zwiększonej i zmienionej obsady ryb na biocenozę zbiornika, z drugiej zaś względy praktyczne związane z gospodarką rybacką.

Celem badań odżywiania się ryb niedrapieżnych było: 1) określenie składu pokarmu ryb introdukowanych (w szczególności karpia) i dominujących autochtonicznych gatunków niedrapieżnych (lin, karaś i płoć); 2) ocena intensywności żerowania badanych gatunków; 3) analiza stosunków pokarmowych wśród zmienionego przez introdukcję nowych gatunków zespołu ryb niedrapieżnych, zmian tych stosunków pod wpływem zwiększają-

cej się w kolejnych latach obsady ryb oraz ewentualnych zmian zasobności bazy pokarmowej.

Stwierdzono, że karp, leszcz i lin odżywiały się w głównej mierze fauną denną i fauną zasiedlającą makrofity, karaś — zooplanktonem, płoć natomiast zdecydowanie preferowała pokarm roślinny (fig. 6).

Największą zbieżnością pokarmu charakteryzowały się karp i lin. Pokarmem wykorzystywanym najsilniej przez te gatunki były *Chironomidae*, *Trichoptera* i *Mollusca*, stanowiące przez cały okres badań ok. 50% ciężaru pokarmu.

Czas pasażu niezbędny do analizy intensywności żerowania (wyrażonej ilością pokarmu spożytego przez rybę w ciągu doby) badanych ryb określano na podstawie danych piśmiennictwa (przeważnie dane laboratoryjne) i danych własnych uzyskanych w eksperymencie w warunkach bliskich naturalnym. Stosując wskaźnikowe ilości pokarmu sztucznego (granulat białkowy) ustalono, że porcja pokarmu naturalnego (*Chironomidae, Cladocera, Copepoda*, glony) w temperaturze 19°C przesuwała się przez jelito karpia (osobniki o ciężarze 150 g) w średnim czasie 7,5 godz.

Stwierdzono, że okresem najwyższej intensywności żerowania badanych gatunków ryb było lato (fig. 4—5). Jesienią (październik), przy temperaturze wody ok. 10°C, intensywność odżywiania się większości gatunków gwałtownie spadała. Stosunkowo intensywnie w tym okresie żerował tylko karp, u którego spadek ilości pokarmu do minimum obserwowano dopiero w listopadzie, przy temperaturze wody ok. 4°C. Karp pod względem intensywności żerowania przewyższał wszystkie współbytujące z nim gatunki.

Stosunki pokarmowe wśród przekształconego przez introdukcję nowych gatunków zespołu ryb ulegały zmianom w ciągu kolejnych lat badań (fig. 2). Polegały one zarówno na zmianach składu pokarmu, jak i intensywności odżywiania się. Zmiany składu pokarmu były najbardziej widoczne u karpia i lina. Obserwowano zmniejszanie się znaczenia grup dominujących w ich pokarmie w pierwszym roku eksperymentu (*Chironomidae, Mollusca*), wzrost udziału skorupiaków planktonowych oraz larw *Ephemeroptera* i *Odonata*. Równocześnie zmniejszała się intensywność żerowania poszczególnych gatunków. W 1969 r., ostatnim roku badań, była ona niższa w stosunku do 1967 r. w przypadku karpia i karasia o blisko 50%, w przypadku lina o 12%.

Ponadto stwierdzono wpływ zarażenia karpi (posocznica — *Septicaemia haemorhagica cyprinorum*) i linów (*Asymphlodora tincae*) na intensywność żerowania. Ilość pokarmu spożytego przez ryby zarażone była trzy do czterech razy mniejsza niż konsumowanego przez ryby zdrowe.

Wykazano, że w okresie badań najintensywniej wyżerane przez ryby były zespoły fauny dennej i fauny zasiedlającej makrofity, w mniejszym stopniu zespół zooplanktonu i w minimalnym zespoły roślinne. Obliczono, że w ostatnim roku eksperymentu (1969 r.) gatunki introdukowane (karp i leszcz) wyżerały ok. 60% biomasy bentosu i fauny zasiedlającej makrofity oraz ok. 30% biomasy zooplanktonu konsumowanych przez cały zespół ryb niedrapieżnych.

Opierając się na występowaniu w pokarmie ryb organizmów traktowanych jako wskaźnikowe dla określonych części jeziora uzyskano dane świadczące o zróżnicowaniu ich żerowisk (tab. IX). Podstawowymi żerowiskami karpia, lina, karasia i płoci były płytkie (do 2 m głębokości), silnie porośnięte roślinnością zanurzoną partie zbiornika. Ryby te penetrowały także, choć w mniejszym stopniu, strefę pobrzeża i strefę najgłębszą. Podstawowym miejscem żerowania leszcza była strefa najgłębsza (poniżej 2 m głębokości); gatunek ten penetrował także część zbiornika silnie porośniętą roślinnością zanurzoną, nie żerując jednak w pobrzeżu. W lecie, ze względu na niski stan wody i deficyty tlenu, pobrzeże było praktycznie niedostępne dla penetracji ryb.

AUTHOR'S ADDRESS:
Dr. Andrzej Prejs,
Zakład Hydrobiologii
Instytutu Zoologicznego
Uniwersytetu Warszawskiego,
ul. Nowy Świat 67,
00-046 Warszawa,
Poland.