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*Department of Hydrobiology, Institute of Ecology, Dziekanów Leśny near Warszawa

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

Anna HILLBRICHT-ILKOWSKA*, Andrzej PREJS**
and Teresa WĘGLEŃSKA*

EXPERIMENTALLY INCREASED FISH STOCK IN THE POND TYPE LAKE WARNIAK VIII. APPROXIMATE ASSESSMENT OF THE UTILIZATION BY FISH OF THE BIOMASS AND PRODUCTION OF ZOOPLANKTON***

(Ekol. Pol. 21: 553–562). The utilization by older age-groups of fish (tench, carp, crucian carp and bream) of the biomass and production of zooplankton in the years 1967–1969, was assessed. The increase of the predation rate of fish and the increase of the consumed biomass were observed in big crustacean species (*Daphnia cucullata*, *Eudiaptomus graciloides* and *Diaphanosoma brachyurum*), the biomass and production of which decreased in successive years.

I. INTRODUCTION

In the years 1967–1969 carp and bream were introduced (Zawisza and Ciepielewski 1973) into lake Warniak (surface 38.4 ha, mean depth 1.5 m, eutrophic, natural pond type lake, considerably overgrown). The aim of the experiment was to estimate the possible changes in the lake biocenosis due to the artificially increased fish stock and the changes in the trophic relations

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between the autochthonous and introduced fish. The three years of complex studies allowed to state, among others, great changes in the numbers and biomass of benthic fauna (Kajak and Dusoge 1973), fauna associated with macrophytes (Pieczyński 1973), zooplankton (Hillbricht-Ilkowska and Węgleńska 1973), and also directional changes in primary production and composition of phytoplankton (Spodniewska and Hillbricht-Ilkowska 1973). The character of these changes proves in general the increasing pressure of fish as predators on its prey communities (benthos, fauna associated with macrophytes, partly zooplankton) and also the strong pressure of fish on the habitat (e.g., by digging the bottom and destroying the vegetation), the physical and chemical changes of which are responsible for the changes in the biocenosis (zooplankton, primary production, phytoplankton). The parallel studies on the food composition, feeding intensity and distribution of the feeding grounds of introduced fish (carp and bream) and autochthonous fish (the dominant ones like crucian carp and tench) showed directional changes in the food composition and the feeding intensity of older age-groups of fish (Prejs 1973). In the course of years the food composition of fish feeding mainly on animal food (carp, tench) was becoming similar, among others, the zooplankton contribution in their food (especially of the *Cladocera*) increased. Also the individual food ration decreased and more frequently used were the feeding grounds in the central, deeper parts of the lake (Prejs 1973). In the case of carp, its increments decreased also in the successive years of life in the lake (Zawisza nad Ciepielewski 1973).

An approximate estimation of biomass (in kg) in lake Warniak of the fish analysed here is the following (acc. to the data in the paper by Zawisza and Ciepielewski 1973):

	1967	1968	1969
crucian carp	250	250	250
carp	1 100	1 500	2 500
tench	2 500	2 500	2 500
bream	300	300	300

The aim of this paper is to assess the utilization of biomass and production of plankton crustaceans by the older age-groups of carp, tench, crucian carp and bream. This assessment is based on the index of the predation pressure of the examined fish community, such as the ratio of the biomass of the given food component consumed by fish to its biomass (or production) in the habitat.

II. METHODS, MATERIAL, ASSUMPTIONS

It has been found that the plankton crustaceans are a significant component of the animal food of the examined fish (Prejs 1973). Their contribution is on the average 66% in crucian carp, 11% in carp, 6% in bream and 4% in tench, with a tendency to increase (especially in tench and carp) in the successive years of the experiment. In the total amount of zooplankton consumed by fish, besides the species exclusively connected with the littoral zone overgrown with emergent vegetation (such as *Alona* sp., *Alonella* sp., *Eurycercus* sp.), the contribution of species occurring in the entire lake (in the open water and littoral zones) has been considerable. They can be called "pelagic". They are: *Eudiaptomus graciloides* Lilljeborg, *Daphnia cucullata* Sars, *Diaphanosoma brachyurum* Liévin, *Ceriodaphnia quadrangula* Sars and *Bosmina longirostris* O. F. Müller. The contribution of these five species in the food of the mentioned fish is the smallest – 14% (in tench in 1968) and the greatest – 86% (in bream in 1969) (Tab. I). Also, there is a slight increase of the contribution of this "pelagic" component in the food of carp in the successive years of studies (Tab. I).

Average contribution (in %) of "pelagic" crustaceans
in zooplankton food of fish in lake Warniak
in successive years

Tab. I

Species	Contribution (%) in years		
	1967	1968	1969
Crucian carp	63	54	51
Carp	33	42	47
Tench	38	14	34
Bream	81	67	86

The contribution of the "pelagic" crustaceans in the plankton food of fish show that this kind of food resources is rather intensively utilized, and as in the case of carp this utilization increases in the course of years. Therefore, it seems that the assessment of food utilization, although concerning the "pelagic" crustaceans only¹, may provide general information on the utilization by the examined fish of the entire food resources such as the

¹Because of the lack of data on the biomass and production, omitted are the typical littoral crustaceans (e.g. *Eurycercus* sp., *Alona* sp.) and also plankton rotifers as they are insignificant in the feeding of older age-groups of fish.

zooplankton in lake Warniak. However, it should be remembered, that this concerns only some consumers of zooplankton namely the older age-groups of introduced fish and some autochthonous ones (the fry is not taken into account).

Here the index of utilization of the biomass and production of different crustacean species is calculated as a ratio of the biomass of given species consumed by the analysed age-groups of fish to the biomass (production) of this species in the habitat, in a unit of time. Of course, this index informs only approximately about the efficiency of the utilization of biomass and production of zooplankton by fish.

The first parameter of the index has been calculated taking into account: a) the reconstructed weight of the crustaceans found in the alimentary canals of fish, b) the rate of food passage through the alimentary canals of a fish at a given temperature, c) the biomass of fish in the lake. As a result an approximate biomass of the given species consumed by the examined fish during six months in each year was obtained by summing the "consumed" biomass calculated separately for each, successive month.

The second parameter of the index — the mean biomass for the vegetation period and the total biomass production of crustaceans — was calculated separately for each species and stage, using the already described methods (Hillbricht-Ilkowska and Węgleńska 1973) on the basis of the samples taken once a week from 2–3 sites in 1967 and 1968, and once a month in 1969². It is assumed that the obtained biomass and production values are the average values for the whole lake.

III. RESULTS

The results are presented in tables II–IV. In successive years the index of biomass or production utilization by fish (or of both indices) of *D. cucullata*, *D. brachyurum* and *E. graciloides* (Tab. IV) increases. This means that the predation pressure of examined fish on the big zooplankton components (the range of size of adult forms 0.9–2.0 mm) increases. In case of *D. cucullata* and *E. graciloides* the total biomass consumed by fish also increases (Tab. III). Simultaneously the biomass and production of these three species (with the exception of the production of *E. graciloides*) significantly decreases in the successive years (Tab. II), although, as shown by Hillbricht-Ilkowska and Węgleńska (1973), their fecundity (egg-ratio) and individual size increases.

²Because of the low sampling frequency in 1969 only the biomass of zooplankton was estimated.

Average biomass and production of several species of plankton crustaceans
in lake Warniak in successive years

Data for period of 6 months, in kg for the entire lake

Tab. II

Species	Biomass			Production	
	1967	1968	1969	1967	1968
<i>Daphnia cucullata</i>	8.3	3.0	1.3	175.9	48.5
<i>Diaphanosoma brachyurum</i>	17.9	2.5	3.3	536.4	127.7
<i>Eudiaptomus graciloides</i>	20.3	15.3	4.0	390.7	585.5
<i>Bosmina longirostris</i>	20.4	50.9	61.8	212.5	1129.6
<i>Ceriodaphnia quadrangula</i>	5.2	13.3	13.8	57.8	654.3

Biomass of several species of plankton crustaceans consumed by fish
in lake Warniak in successive years

Data for period of 6 months, in kg for the entire lake

Tab. III

Species	1967	1968	1969
<i>Daphnia cucullata</i>	55	59	94
<i>Diaphanosoma brachyurum</i>	1.4	1.2	1.5
<i>Eudiaptomus graciloides</i>	15	23	42
<i>Bosmina longirostris</i>	95	32	42
<i>Ceriodaphnia quadrangula</i>	37	50	60

The index of utilization of biomass and production of several species
of plankton crustaceans by fish in lake Warniak in successive years

Tab. IV

Species	Biomass			Production	
	1967	1968	1969	1967	1968
<i>Daphnia cucullata</i>	6.60	19.60	72.30	0.31	1.22
<i>Diaphanosoma brachyurum</i>	0.08	0.48	0.45	<0.01	<0.01
<i>Eudiaptomus graciloides</i>	0.75	1.50	10.50	0.04	0.04
<i>Bosmina longirostris</i>	4.75	0.62	0.68	0.45	0.03
<i>Ceriodaphnia quadrangula</i>	7.10	3.80	4.30	0.64	0.08

Therefore it can be assumed that these species preferred by fish, because of their rather big size³, and despite their decreasing accessibility in the

³The size of individuals found in the alimentary canals is 1.5–2.0 mm for *D. cucullata*, 0.9–1.2 mm for *D. brachyurum*, 1.5–1.8 mm for *E. graciloides* (Prejs 1973).

course of years (less dense population – lower production), are constantly more consumed. This is probably caused by greater penetration by fish of the open water in central part of lake and an increasing fish stock due to the successive introductions of carp and bream.

When comparing these species, it seems that the predation pressure is the strongest on the *D. cucullata* population (Tab. IV). The total biomass of this species consumed by fish during 6 months is the greatest (55–94 kg) (Tab. III), which at small biomass in the lake (even in 1967) and the smallest production among the three compared species (Tab. II) gives very high indices of the utilization by fish (Tab. IV). In 1968 and 1969 the biomass of this species consumed by fish is several tens greater than its average biomass in habitat and the production utilization in 1968 is presumably 100% as the index of utilization is the highest of all analysed cases (1.22) (Tab. IV). *D. cucullata* is a species occurring during the entire vegetation period (May–September) and is constantly recorded in the alimentary canals of fish.

D. brachyurum seems to be relatively the least (the smallest indices) used as food by the examined fish (Tab. IV). This species occurs mainly in summer and only then it is recorded in the alimentary canals of the four examined fish species. The index of utilization of *D. brachyurum* biomass, despite its increase in the three years of studies, does not exceed 50%. The production of this species (index of utilization <1%) is probably very little used by fish. The total biomass of this species consumed by fish is very low and rather equal during the successive years (Tab. III). Despite the relatively small predation pressure of examined fish the biomass and production of this species in the lake decreases significantly in the course of years (Tab. II).

E. graciloides is one of the constant food components of the examined fish community. The biomass consumed by fish increases in the successive years (Tab. III). In 1969 it exceeds ten-fold the average biomass in the habitat (Tab. IV). But the index of production utilization is small (about 4%) and similar in both years (1967 and 1968), which is probably due to the significant increase of production of this species in 1968. As a result of this the increase of the consumption rate of fish (increase of consumed biomass) does not change the average index of production utilization of this species.

Two other species out of the examined crustaceans, *B. longirostris* and *C. quadrangula*, found in the alimentary canals of the examined fish, display a significant increase of the biomass and production in the successive years (Tab. II). The availability of these species as food is smaller than of the others because of their smaller size (0.3–0.5 mm). Nevertheless the total biomass of these species consumed by fish is quite considerable and is close to *D. cucullata*, and even, as in the case of *C. quadrangula* shows

a considerable increase in 1968 and 1969 as compared with 1967 (Tab. III). However, as a result of the increase of biomass and production of these species in 1968 and 1969 (Tab. II) their utilization by fish gradually decreases, and in 1968 only about 10% of their production is probably consumed by fish (Tab. IV).

IV. CONCLUSIONS AND DISCUSSION

The comparison of the biomass and production of 5 crustacean species in lake Warniak with their biomass consumed by the community of older age-groups of fish in the successive years shows that:

1) The consumption of big species (*E. graciloides* and *D. cucullata*), the biomass and production of which, or only the biomass, decrease in the habitat, is the greatest and increases in the successive years; the total mass of consumed food and the indices of predation pressure increase in general;

2) Consumption of *D. brachyurum*, a species of smaller size, the biomass and production of which also decrease from year to year, is not great, although increases in the successive years;

3) The consumption of two very abundant but small species (*B. longirostris* and *C. quadrangula*), the biomass and production of which markedly increase in the lake in the successive years, decreases, despite that sometimes (as in *C. quadrangula*) the total mass consumed by fish increases.

These results seem to point to the changes in the character of food utilization by the ichthyofauna of lake Warniak – increased and changed by the introduction of carp and bream. The utilization of food resources (zooplankton) of the central less overgrown parts of the lake increases in the successive years. As a result of this the contribution of zooplankton in the food of fish, and especially of the “pelagic” species increases. This concerns especially the introduced carp. Carp prefer rather big species such as *E. graciloides* and *D. cucullata*. And therefore, in the successive years, the consumed biomass of these species increases, while parallel their biomass decreases, and sometimes the production also. It can be assumed that these species, due to the greater concentration of fish in the less overgrown central part of the lake, are more easily “found” and consumed. It is quite possible that the factor which makes the zooplankton more available to fish is its uneven horizontal distribution. Grygierek (1965) and Hillbricht-Ilkowska (1966) showed that as the zooplankton abundance decreases in ponds the clumpy character of its horizontal distribution increases.

The greater activity of fish in the central part of the lake probably affects also the feeding upon smaller species, as can be seen on the example of *C.*

quadrangula. The consumed mass of this species increases in the successive years although it does not make any proportional change of the index of predation pressure because simultaneously the biomass and production of this species increase strongly, probably due to the changes in the habitat transformed by fish. It is possible that the increase of the mass of *C. quadrangula* consumed by fish is a result of sufficient availability of this species, i.e. its great abundance in the habitat and relatively big size (0.4–0.5 mm). The individuals of this species, although smaller than the mentioned big species, can be caught by fish in place of the latter.

In the case of small species, such as *B. longirostris* and *C. quadrangula*, the mass consumed by the predators does not form an essential part of their production, and the production changes are probably the result of general changes in the habitat transformed by a large fish stock (Hillbricht-Ilkowska and Węgleńska 1973). But in case of other species the increase of their mass consumed by predators sometimes forms an essential part of their production, like for *D. cucullata*. However, it is difficult to decide whether the consumption by fish is the only reason why these species disappear in the course of years. The fish consumption is probably the only reason why *D. cucullata* is disappearing. This species is one of the biggest zooplankton species in lake Warniak and its indices of predation pressure are the highest (up to 100% of production). Whereas, in the case of *E. graciloides* this index is rather low (4%), and very low in the case of *D. brachyurum* (<1%), and these species are visibly disappearing during the 3 years' period. It is possible that the fact that these two species are disappearing is not only a reaction to the increasing consumption rate by fish, but also to the increasing abundance of small, quickly reproducing cladocerans, and also rotifers (Hillbricht-Ilkowska and Węgleńska 1973).

Looking for the reasons why the big crustacean species are disappearing the possible changes in the food composition of the fry of autochthonous species can not be excluded. The zooplankton which is the main component of the food of fry becomes more utilized by the older fish – especially carp. It can be assumed that the intense consumption by older fish of *D. cucullata* (the biggest species) and *E. graciloides* (second in size) in the central part of the lake caused that the fry penetrating this part of the lake (e.g. perch fry – Wawrzyniak unpublished) began to feed to a greater extent on smaller species, such as e.g. *D. brachyurum*. This species, because of its size can be probably less consumed by older fish. Wawrzyniak (unpublished) says that *D. brachyurum* is the essential food component of perch fry, attracted by the spot – the eye of *Diaphanosoma* individuals. In such situation the possible predation pressure of fry would concentrate only on one species – the change in food preference as a result of competition with older fish. It

is quite possible that this is why *D. brachyurum* is gradually disappearing in successive years, despite the fact that the predation pressure of older-groups of fish on this species is very small.

The regularity when together with the increase of the predation rate (increasing yield either for the predator or man) the efficiency of predation increases, i.e. the ratio of the yield to food production or biomass, has been frequently observed. This regularity has been observed in experiments on *Daphnia* (Slobodkin 1962) and a rotifer from the *Brachionus* genus (Hillbricht-Ilkowska and Pourriot 1970), and is often observed in the fishing practice. The consumption of zooplankton by carp several times exceeding the average biomass during the vegetation season and attaining 100% of production was observed by Grygierek (1962) in ponds.

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EKSPERYMENTALNE ZWIĘKSZENIE OBSADY RYB
W STAWOWYM JEZIORZE WARNIAK

VIII. PRZYBLIŻONA OCENA WYKORZYSTANIA PRZEZ RYBY
BIOMASY I PRODUKCJI ZOOPLANKTONU

Streszczenie

Oceniono stopień wykorzystania biomasy i produkcji skorupiaków planktonowych przez zespół starszych roczników ryb (lin, karp, karaś i leszcz) w latach 1967–1969. Ocenę tę oparto o wskaźnik presji drapieżniczej ryb, jakim może być stosunek biomasy danego gatunku, zjedzonej przez ryby, do biomasy (lub produkcji) tego gatunku w środowisku w jednostce czasu. Stwierdzono znaczny udział gatunków „pelagicznych” zooplanktonu (gatunków występujących w całym jeziorze, nie ograniczonych tylko do strefy przybrzeżnej) w pokarmie ryb, z tendencją wzrostu u karpia (tab. I). Wyjadanie największych gatunków skorupiaków planktonowych: *Daphnia cucullata* i *Eudiaptomus graciloides*, których biomasa i (częściowo) produkcja maleją w środowisku, jest najsilniejsze i wzrasta w kolejnych latach; wzrasta zarówno całkowita masa wyjedzonego pokarmu, jak i jeden lub oba wskaźniki presji drapieżniczej, szczególnie w przypadku *D. cucullata* (tab. II–IV). Wyjadanie *Diaphanosoma brachyurum*, nieco mniej liczniejszego gatunku i o mniejszych rozmiarach, którego biomasa i produkcja również maleją z roku na rok, jest niewielkie, choć też wzrasta w kolejnych latach (tab. II–IV). Presja drapieżnicza ryb na dwa drobne, ale bardzo liczne gatunki skorupiaków, *Bosmina longirostris* i *Ceriodaphnia quadrangula*, których biomasa i produkcja w kolejnych latach wzrastają, jest dość duża w 1967 r., potem maleje, mimo niekiedy (jak u *C. quadrangula*) wzrostu całkowitej masy wyjedzonej (tab. III).

Przyczyną opisywanych zjawisk wydaje się być wzrastająca w kolejnych latach penetracja przez ryby nie zarosniętej strefy centralnej jeziora przez zwiększającą się w wyniku introdukcji karpia i leszcza obsadę ryb.

AUTHORS' ADDRESS:

Dr Anna Hillbricht-Ilkowska,
Dr Teresa Węgleńska,
Instytut Ekologii PAN,
Dziekanów Leśny k. Warszawy,
05–150 Łomianki,
Poland.

Dr Andrzej Prejs,
Zakład Hydrobiologii
Instytutu Zoologicznego
Uniwersytetu Warszawskiego,
ul. Nowy Świat 67,
00–046 Warszawa,
Poland.