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ON THE FEEDING OF *EUDIAPTOMUS GRACILIS* IN LAKE BALATON

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The way of feeding of *Eudiaptomus gracilis* is maxillary filtering (KAESTNER, 1959; MARSHALL and ORR, 1960). The size of food to be filtered depends on the barbs of filtering setae. GLIWICZ (1969 a, b), when investigating the gut content of *Eudiaptomus gracilis* and *E. graciloides*, found parts of algae (cells, colonies) of 4–6 μ. He established that *E. graciloides* mostly feeds on particles larger than 6 μ, thus, we may consider it to be a "macrofiltrator".

Investigations dealing with planktonic Crustacea (SEBESTYÉN, 1960; PONYI, 1968; PONYI, 1973) show that *Eudiaptomus gracilis* is the most important species of its kind in Lake Balaton. It has a wide ecological valency, accordingly it may be found in waters of the most diverse types. In Lake Balaton it is just as frequent in winter as in summer, consequently, it plays a decisive role in the plankton association. This fact requires a detailed investigation into the nutrition of the species. When perusing other studies too (FRYER, 1954; MALOVICKAJA and SOROKIN, 1961; SCHINDLER, 1971; KIBBY, 1971) we may suppose a certain degree of food selectivity of *Eudiaptomus gracilis*.

This study deals with the results on the selectivity and optimal food concentration of this species. The rate of incorporation which informs us more than the ingestion was determined by feeding of different species of algae.

Method

We received algae of pure cultures from KOL's and FELFÖLDY's collection of algae, Diatomea were made available for us by MARVAN (Brno) and HINDÁK (Bratislava). At a permanent exposure the algae were cultivated in Knopp-Pringsheim solution, in the apparatus described by MESZES and SIPOS (1968). After one week (Chlorophyta) and six-week (Diatomea) cultivations the algae were labelled with $Na^{14}CO_3$ and filtered through a membrane filter (pore size 0.2 μ). It was rinsed with filtered Balaton water until it became nonactive. Subsequently the membrane filter was washed into filtered (0.2 μ) Balaton water. To establish specific activity, the activity and organic carbon content of a unit of food suspension was determined before every experiment, showing a variability between 6000—16 000 dpm/ml.

The *Eudiaptomus* was collected in the open water in front of the Biological Research Institute. During summer, the acclimatization time was disregarded since the temperature of Lake Balaton was the same or nearly so as in the laboratory. Before the experiments in October and November, the *Eudiaptomus* was placed at the experimental temperature for 24—36 h in order to become acclimatized to experimental conditions.

The adult male and female specimens, without eggs, were selected under a microscope and placed into 100 ml Balaton water filtered through a membrane filter (pore size 0.2 μ), with the chosen species of alga in the required concentration.

The organic carbon content of 70—120 specimens of the population under examination was determined by wet combustion.

Afterwards we adapted SOROKIN's procedure (1968). The animals were fed on labelled algae for 2—4 h. Then they were rinsed through a net of coarse mesh several times to remove the nonconsumed labelled food. Then the crustaceans were transferred into Balaton water filtered with net No. 6 and enriched with nonlabelled algal food. The animals were left four hours to clear their gut of labelled food. After rinsing them through again, they were placed on a membrane filter and in Bray solution the activity of their bodies was measured with USB—2 liquid scintillation detector (Biuro Urzadzen Technici Jadrowej, Warsaw). Counting efficiency was determined by toluene-7-^{14}C internal standard (Isotope Institute, Budapest), the selfabsorption of the crustaceans was determined by adopting GUPTA's procedure (1966). When evaluating the results, we used SOROKIN's assimilation formula corrected for the selfabsorption. When testing the optimal concentration of food, selfabsorption was disregarded.

Results

The difference between the organic carbon content of *E. gracilis* in the summer (April—November) and winter period was conspicuous. In the summer it was 2.80 μg/ind. while in winter 4.35 μg/ind. on an average. The great difference may be explained by the different quantities of fat content in the bodies of the animals (FARKAS and HERODEK, 1960).

Combusting the dried animals with GUPTA's method and measuring the activity we found the self-absorption coefficient to be 1.38.

The activity of crustaceans, depending on quality and quantity of the food ingested the season of sampling, etc., was different. Disregarding the self-absorption it approximately varied between 200—20 000 dpm/ind/24 h.

The food selectivity of adult male and female specimens of *Eudiaptomus gracilis* was tested in nine species of algae, three of them belonging to Chrysophyta and six to Chlorophyta group. Five species inhabit Lake Balaton, although in low individual number (TAMÁS, 1959; 1963) *(Table 1)*.

The experiments were carried out between May and November. The quantities of food were various, they surpassed, however, the value of the "threshold concentration" *(Table 2)*.

The *Eudiaptomus* could always filter out the species of algal food, however, the rate of incorporation fluctuated *(Fig. 1)*. For example, the incorpo-

TABLE 1

Species and size of algal food

Alga species	Algal phyla	largest size (μ)*	Occurrence in Lake Balaton
Chlorella pyrenoidosa	Chlorophyta	3—5	—
Chlorella vulgaris		5—8	+
Chlorococcum infusionum		6—8	+
Keratococcus caudatus		16—21	—
Scenedesmus obtusiusculus		5—11	+
Stichococcus bacillaris		3—8	+
Botrydiopsis minor	Chrysophyta	18—21	—
Chlorocloster minimum		15—21	—
Nitzschia communis		12—19	+

* We should like to express our deep gratitude to Dr. GIZELLA TAMÁS for determining the size of algal cells.

TABLE 2

Circumstances of investigations on incorporation

Date of experiments	Temperature of Lake Balaton	Algal food	Food concentration mgC/l	Number of samples
29., 31., May 6. June 1972	18.5; 18.3 21.2	*Keratococcus c.*	1.72—7.05	34
11., 19., 22., June 1972	22.5; 22.2; 23.5	*Chlorella p.*	1.66—5.19	31
5. July 8. Aug. 1972	21.0; 22.5	*Scenedesmus o.*	1.61—5.29	21
22., 29., Aug. 1972	16.0; 18.5	*Botrydiopsis m.*	1.43—5.82	19
12., 27., Sept. 1972	16.8; 14.0	*Chlorocloster m.*	1.10—6.03	17
17., 23., Oct. 1972 2. May 1973	10.2; 8.8 17.2	*Chlorococcum i.*	1.00—4.20	16
24. Oct. 3. Nov. 1972	8.8; 10.2	*Stichococcus b.*	2.88—3.36	12
16. Nov. 1972	8.3	*Chlorella v.*	2.65	11
25., 27., July 1. Aug. 1973	21.5; 20.0 21.5	*Nitzschia c.*	0.47—1.4	10

ration of carbon of *Nitzschia* was 10-fold higher than that of the *Chlorella* or *Keratococcus*. The figure shows high SD values corresponding to the high concentration of food in which the experiments were carried out it does not occur in the waters or at least only very sporadically, consequently, *Eudiaptomus* has not yet accustomed to it in Lake Balaton.

To determine the optimal food concentration, the male and female specimens of *Eudiaptomus gracilis* were fed on the two best incorporated alga species (*Nitzschia communis* and *Scenedesmus obtusiusculus*). The experiments took place in June, July and August, 1973. It was found that the increase of incorporations of both of the two algae is linear up to the concentration of 0.3—0.4 mg C/l (*Figs 2, 3*). Exceeding this value the curves bend and nearly turn into horizontal. It means that with increasing food concentration the incorporation becomes almost standard. The optimal food concentration to *Eudiaptomus gracilis* for incorporation begins at 0.3—0.4 mg C/l. The variability of incorporation also begins at this concentration. When reflecting the rate of incorporation with a curve, we will find that at higher concentration it turns nearly into horizontal between 0.5 and 1.1 mg C/l.

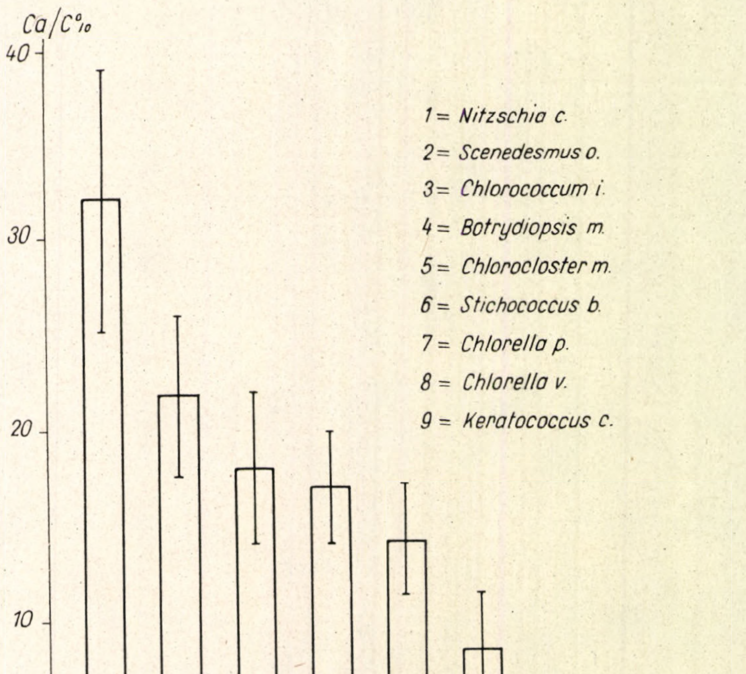

Fig. 1. The daily incorporation of *Eudiaptomus gracilis* when feeding on different species of algae

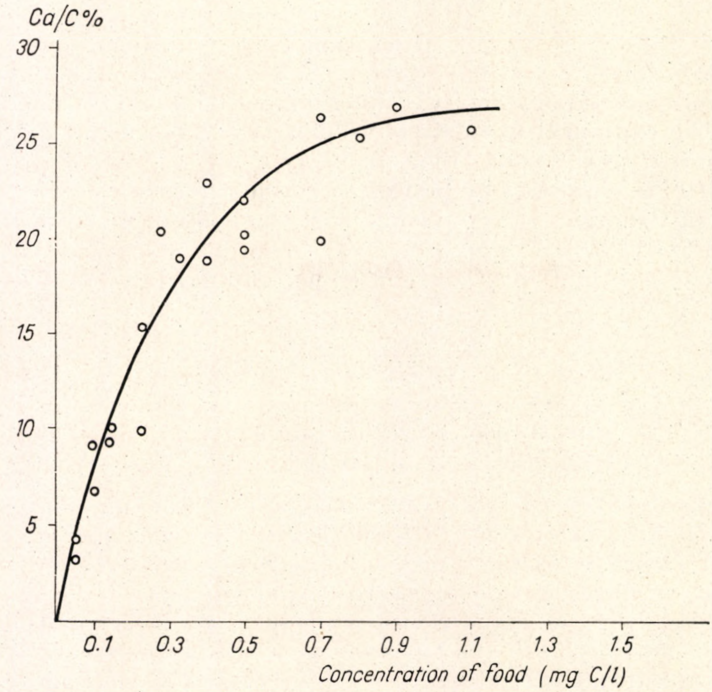

Fig. 2. The relation of food concentration to the incorporation when feeding on *Nitzschia*

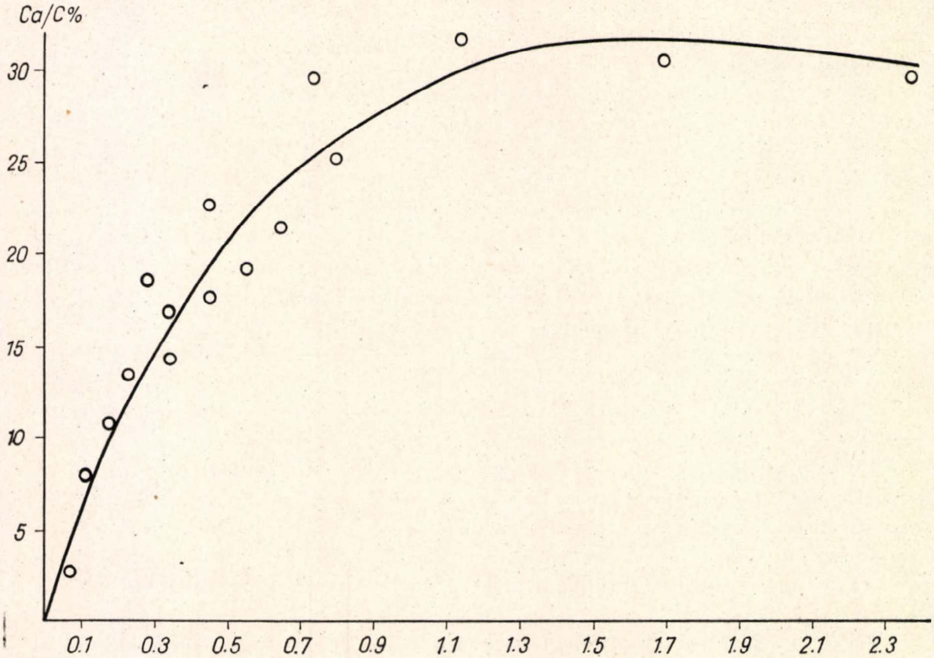

Fig. 3. The relation of food concentration to the incorporation when feeding on Scenedesmus

Discussion

The word "incorporation" (Ausnutzung, assimilation) is understood as follows: 1. The consumed quantity of food. 2. The quantity of food ingested and incorporated (NAUWERCK, 1963; p. 127).

The latter is expressed by SOROKIN's formula for assimilation according to the ratio of the organic carbon content in the body of the animal (Ca/C%) interpolated for 24 h.

$$Ca = \frac{r \cdot Cr \cdot 24 \cdot S}{t}$$

Where, r = activity of one crustacea (dpm),
Cr = reciprocal of the specific activity of the food,
S = self-absorption,
t = time of feeding on labelled food.

The results of incorporations obtained when using nine various species of algae for feeding show that *Eudiaptomus gracilis* consumes algal cells of 3—21 μ, but incorporates their carbon content to various extents. Between these values the incorporation seems to be independent of the size of algal cells. *Nitzschia* of 12—19 μ and *Scenedesmus* of 5—11 μ are incorporated the best, while *Chlorella* of 3—8 μ is but scarcely. Other authors obtained diverse results when feeding *Eudiaptomus gracilis* on *Chlorella*. Among them KIBBY (1971), when making experiments with *E. gracilis* originating from a reservoir in England, experienced that the speed of filtering and assimilation efficiency are much larger when *Chlorella* serves as food than e.g. *Scenedesmus* or *Nitzschia*. For feeding *E. gracilis* and *E. graciloides* originating from the reservoirs in the mid-northern part of the Soviet Union, MALOVICKAJA and SOROKIN (1961) used *Scenedesmus, Aphanizomenon, Melosira* and *Asterionella*. Their results show that *Scenedesmus,* followed by two Diatomea, was incorporated to the largest extent. In BOGATOVA's experiments (1965) *E. gracilis* fed on the species of *Chlorella, Scenedesmus, Crucigenia,* etc. in naturally occurring phytoplankton. Its food selectivety varied between 4—20 μ. NAUWERCK (1963) fed the two species of Crustacea on *Chlorella* (pyrenoida typ). The two *Eudiaptomus* did not feed on algal cells at all, since their size exceeded the lower limit of the filtering ability of crustaceans (STORCH and PFISTERER, 1925; cit. ap. NAUWERCK, 1963). MCQUEEN (1970) reports that *Diaptomus oregonensis* can filter out and consume *Chlorella pyrenoidosa* and even smaller algal cells. He states that 490 μ^3 is the limit of the cell volume over which the feeding rate decreases.

Thus, data on the incorporation of *Chlorella* smaller than 10 μ are rather contradictory. Regarding that the size of algae varies depending on the circumstances of cultivation, their age, etc., perhaps it may be explained by the authors' using *Chlorella* types of different sizes. In our cultivation the algal cells of about 5 μ could have dominated thus, we measured a low incorporation rate.

To know the incorporation rate alone is not enough for a final answer to the feeding rate. Since the animal may feed on a great quantity of food incorporating only a small amount and the best part of it passes through its gut nondigested.

The incorporation rate can be modified, apart from the size of algal cells, by the thickness of their cell-wall, structure and, last but not least, the chemical compound of the cells. SCHINDLER (1971) observed that *Eudiaptomus gracilis* assimilates the testaceous *Cryptomans* to a larger extent and more efficiently than it does *Asterionella*. Our data also prove that Diatomea with its thick testacea is incorporated to a higher degree. Two reasons are offered: 1. especially in the case of heterotrophic algae, the cell-wall porous since it is full of pores and slits through which the gastric juices of the animal pass to the plasm of the algal cell. The cell-wall of other algae is usually intact, nonporous; 2. methodological insufficiency. When determining the specific activity of algae, the activity implies only the organic carbon content. The carbon content of a cell-wall containing cellulose is higher, its specific activity is lower. At the same time, the share of carbon content of the cell-wall passes through the gut nondigested. Due to SOROKIN's index the incorporation rate is calculated higher than it is in fact. On the other hand, because of the SiO_2 content of the Diatomidae cell-wall, specific activity is higher. In this case the plasm of known activity gets into the gut of the animal as a digestable food.

Experiments were carried out to determine the role of ash content of the food in influencing the incorporation rate. CONOVER (1966), related to *Calanus*, proved that the algal food containing less ash are assimilated to a higher extent than those rich in ash. As for *Eudiaptomus gracilis*, no connection between the percentage of assimilation and the ash content of food is proved (KIBBY, 1971).

In addition to the difference in alga species the quantity of the offered food is also a significant factor as far as crustacean feeding is concerned (CONOVER, 1966; RICHMAN, 1966; MARSHALL and ORR, 1960; etc.). MALOVICKAJA and SOROKIN (1961), who were the first to investigate the food incorporation of *Eudiaptomus gracilis* in various concentration of algae, found that the feeding with normal intensity takes place between the concentration of 1 g algal biomass/m^3 and 4.84 g/m^3. Increasing the concentration consumption is unaffected practically. It means that the incorporation increases linearly with a food concentration of 0.1 mg C/l, then the curve bend and at 0.48 mg C/l nearly runs into horizontal. In the Ribinszky Reservoir, where the crustaceans were collected, the mean biomass of the phytoplankton was 0.2 mg C/l rising up to 0.4—0.5 mg C/l in the summer. That is, the lower limit of optimal food concentration was smaller in the experimental environment than in nature.

At that part of Lake Balaton wherefrom the crustaceans originated, nearly at the same time when the samples were taken, the biomass of algae was 0.2 mg C/l (HERODEK and TAMÁS, 1973), while, related to the best incorporated species of alga, the series of experiments repeated several times showed the lower limit of optimal food concentration to begin at 0.27 mg C/l, that is, three-times higher than the data mentioned above. The rate of incorporation, apart from one experiment, always attains a standard at higher concentration than it was found by MALOVICKAJA and SOROKIN (1961). Our results are supported by the observation at other sites of higher trophyty of the lake where the average algal biomass is 0.8 mg C/l in July and August. The number of eggs of *Eudiaptomus gracilis* is significantly higher than in the open water in front of the Biological Research Institute (average biomass in the summer 0.2 mg C/l (HERODEK and TAMÁS, 1974) where the animals were collected.

Summary

The authors investigated the incorporation of *Eudiaptomus gracilis* collected in Lake Balaton. For feeding nine alga species obtained from pure cultures, labelled with $Na^{14}CO_3$ were used. The activity incorporated was measured with liquid scintillation detector and the results were calculated by adapting SOROKIN's assimilation index.

It was established that *Eudiaptomus gracilis* incorporated *Nitzschia communis*, belonging to Diatomea, to the largest (33%), while *Keratococcus caudatus* and the *Chlorella* species to the lowest extent (3—4%).

The optimal concentration of algae incorporated by *Eudiaptomus gracilis* begins at 0.3—0.4 mg C/l and the rate of incorporation becomes standard between 0.5 and 1.1 mg C/l.

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A BALATONI *EUDIAPTOMUS GRACILIS* TÁPLÁLKOZÁSÁRÓL

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Összefoglalás

A szerzők a Balatonból származó *Eudiaptomus gracilis* táplálékértékesítését vizsgálták. Táplálékként 9 tiszta tenyészetből származó algafajt használtak, melyeket $Na^{14}CO_3$-al jelöltek. A beépített aktivitást folyadékszcintillációs készülékkel mérték, és eredményeiket a SOROKIN-féle (1968) asszimilációs index segítségével értékelték.

Megállapították, hogy az *Eudiaptomus gracilis* a 9 algafaj közül legnagyobb mértékben a Diatomea-khoz tartozó *Nitzschia communis*-t értékesítette (33%), legkisebb mértékben pedig a *Keratococcus caudatus* ill. a *Chlorella* fajokat (3—4%).

Az optimális algakoncentráció az *Eudiaptomus* táplálékértékesítésére vonatkozóan 0,3—0,4 mgC/l-nél kezdődik, és az értékesítés standardizálódása 0,5—1,1 mgC/l között található.