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Feeding of *Scardinius acarnanicus* Stephanidis, 1939 (Pisces: Cyprinidae) from Lakes Lysimachia and Trichonis, Greece

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The feeding of the endemic freshwater fish *Scardinius acarnanicus* Stephanidis, 1939 has been studied from the content of its intestine and from the results of feeding experiments in the laboratory. This species appears to be phytoplanktophagous when young, whereas as an adult, it becomes macrophytophagous. No difference was observed in the diet of males and females.

Key words: *Scardinius acarnanicus*; Greece, Lakes Lysimachia and Trichonis; feeding; phytoplankton; macrophytes.

I. INTRODUCTION

Many studies have been carried out on the feeding of various herbivorous freshwater fishes. Some of them (e.g. Avault, 1965; Pentelow & Stott, 1965; Dudgeon, 1983) were aimed at studying the biological reduction of the flora in eutrophic waters. Others (Bohl, 1980, 1982) have studied the feeding activity phases of these fishes, as well as the mechanisms of prey selection. There have also been papers (Prejs & Blaszczyk, 1977; Prejs, 1978; Hofer & Niederholzer, 1980; Prejs, 1984) calculating the daily quantity of food herbivorous fishes consume or studying the effectiveness of mechanical and enzymatic processing of the ingested plants. Other papers (e.g. Bubinas, 1974; Klimczyk-Janikowska, 1975; Popovska-Stankovic, 1977; Jankovic & Trivunac, 1978; Niederholzer & Hofer, 1980; Akitoye & Pugh-Tomas, 1981; Prejs, 1984) have reported the feeding habits of various herbivorous fishes of several lakes in relation to the season, the temperature and other factors involved in the lakes' environment. Hitherto, no paper has been devoted to the detailed qualitative analysis of the plant food such fishes select, except for the works of Penzes & Tölg (1966) and Jähnichen (1967), which, however, do not refer to species of the *Scardinius* group.

As far as the feeding of herbivorous freshwater fishes in Greece is concerned, only two papers are known (Iliadou & Ondrias, 1980; Daoulas & Economidis, 1984). In the first, there is a brief report on the feeding of *S. erythrophthalmus* (L.) (= *S. acarnanicus*) from Lakes Lysimachia and Trichonis. In the second, the feeding of *Rutilus rubilio* (Bonaparte) from Lake Trichonis was examined.

The present paper reports the first detailed study of food preference and the qualitative composition of the plants eaten by the endemic fish *S. acarnanicus* in Lakes Lysimachia and Trichonis.

The populations of this species are commercially important not only in the immediate vicinity of the two lakes and the Acheloos River system, but also in

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Central and West Macedonia (North Greece), where catches are sent to the local fish co-operatives. The annual production of this fish for the period 1975–1978 was as follows: 1975 (4546 kg); 1976 (5062 kg); 1977 (4822 kg); 1978 (3323 kg).

TAXONOMIC NOTE

The first report of the presence of this species in the system of the Aspropotamos (=Acheloos) River and the connected Lake Angelocastro (=Lysimachia) was made by Koller (1927) who classified it as the subspecies *Scardinius scardafa plotizza* Heckel. Stephanidis (1939) later named it *Scardinius scardafa plotizza* forma *acarnanicus*. According to him, this form is different from the subspecies recognized by Koller, the body is shallower, the eyes are smaller, the interorbital width is smaller, the snout is more acute and the number of lateral line scales and the number of anal fin rays are larger. The fins are dark and the iris is golden yellow. In the absence of further studies this taxon was referred to as *Scardinius erythrophthalmus scardafa* (Bonaparte, 1832) or *S. e. acarnarnanicus* Stephanidis, 1939 by Ondrias (1971) and Economidis (1972–1973). Recent research by A. Wheeler, P. Economidis and K. Iliadou (unpublished) into the systematic position of this form has shown that the form described by Stephanidis (1939) must be elevated to full species rank, as the endemic species *Scardinius acarnanicus*.

II. MATERIALS AND METHODS

STUDY AREA

Lakes Lysimachia and Trichonis are in the west-central part of Greece, in Etoloacarnania (Fig. 1). Both lakes belong to the Acheloos River system and have a higher water level than the system. The permanent drainage of Lake Trichonis is carried out at the western end through an artificial canal (3 km in length) which connects the lakes. The waters of Lake Lysimachia are carried to the Acheloos River through an artificial canal (7 km in length) at the western end of the lake. Other than the north-east part of Lake Trichonis both lakes have low and obscure shores because of the existence of luxuriant vegetation around them. This vegetation extends into the lakes and plays a significant role in the ecosystem, by enriching the water with oxygen and providing food and shelter for the reproduction of some fishes. Table I shows the physical features of Lakes Lysimachia and Trichonis.

SAMPLING

Three hundred and sixty individuals of *S. acarnanicus* were caught from Lakes Lysimachia and Trichonis, by means of seine, trammel and set gillnets, at monthly intervals from March 1977 till December 1979.

LABORATORY WORK

All specimens of *S. acarnanicus* were measured, weighed and used for the study of the biology of this species (Iliadou & Ondrias, 1980; Iliadou, 1981). As with other cyprinids, this species does not have a stomach, the z-shaped intestine was removed and preserved in 4% formaldehyde solution. The intestine content was used in qualitative analysis of the food. The method of analysing the qualitative food composition of young individuals differed from that applied to the analysis of the food of adults.

Qualitative composition of the food of the young fish was made by floating small particles (in total 189) from each part of the intestine in a drop of water on a microscope slide and examining them under ×40 magnification. For each ingredient in the contents of the intestines of young fish, the frequency of presence index and the index of predominance (Borutsky, 1974) were noted. The frequency of presence index is the percentage of the number of intestines containing a particular food ingredient out of the total number of the

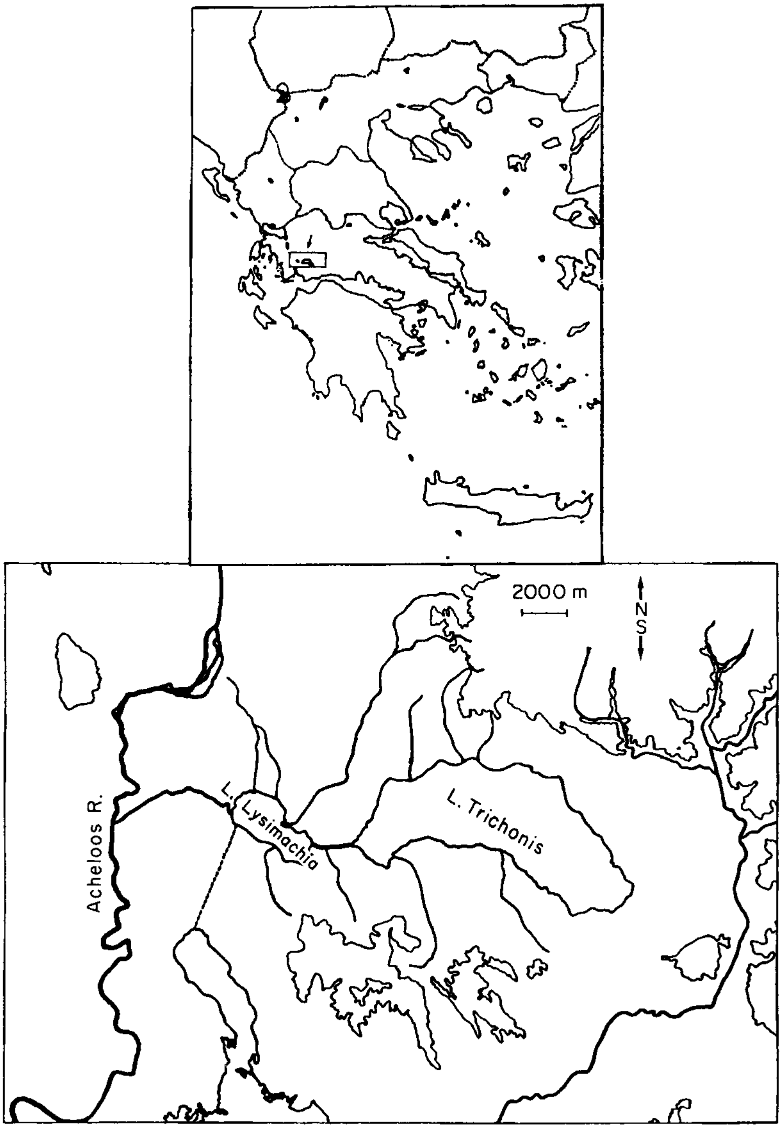

FIG. 1. Acheloos River and connecting Lakes Lysimachia and Trichonis.

TABLE I. Physical features of Lakes Lysimachia and Trichonis (Leontaris, 1968)

Lake	Surface (km^2)	Perimeter (km)	Length (km)	Width (km)	Maximum depth (m)	Altitude level (m)
Lysimachia	13·2	17	6	3	9	16
Trichonis	96·9	51	20	6·5	58	18

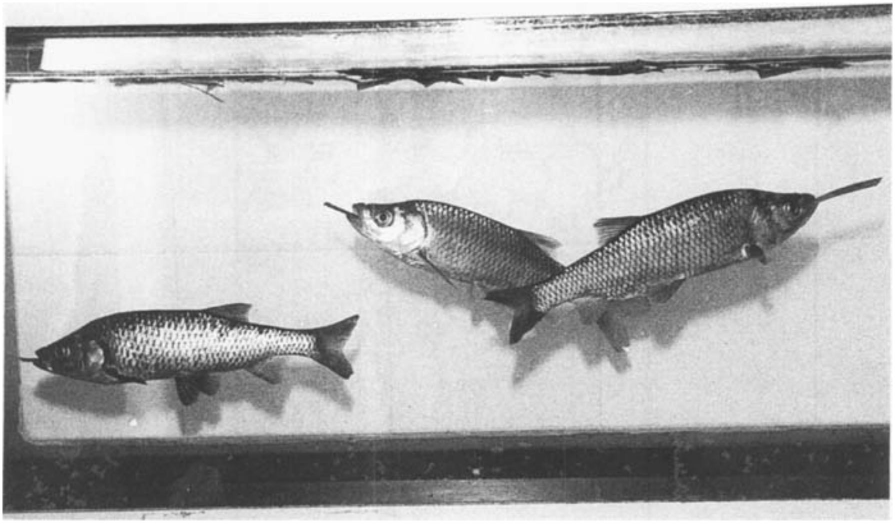

FIG. 2. Fish feeding.

intestines that contained food. The second index (of predominance) is the percentage of the number of intestines in which some particular food ingredient dominated over others out of the total number of the examined intestines containing food. To employ this index, the amount of each food ingredient found during the microscopic analysis was arbitrarily determined as either 'very many', 'many', 'numerous', 'few', 'some' and 'very few'. 'Very few' indicates a food ingredient that was represented at the most by one or two organisms.

To analyse the qualitative composition of the food of adults an attempt was made to identify the plants composing the food represented in their intestine. This was unsuccessful as the plants had been macerated by the pharyngeal teeth and in most cases identification was impossible. The only certain result was that the masticated food belonged to the higher aquatic vegetation of the lakes. For this reason, experimental feeding of the fish was carried out.

LABORATORY EXPERIMENTS

The experiments began in July 1979 and finished in January 1980. Seven adult individuals (3 male and 4 female) with a mean total length of 20 cm, were caught in fish traps as used by the local fishermen and transported alive to the laboratory. They were kept in four aquaria, two of 70 l and two of 40 l capacity. The aquariums were kept at room temperature, the monthly fluctuation of water temperature being: July 26–28° C; August 24–29° C; September 23–26° C; October 16–26° C; November 11–17° C; December 8–10° C and January 5–6° C. Prior to the plant food from the two lakes was given to the fishes, they were fasted until the intestine was emptied.

Qualitative study of the food

During this experiment the fishes took a total of 38 species of plants which represented both the higher aquatic vegetation of lakes and plants from the shore. The latter was used to establish if fishes prefer the plants during the flood period. The first attempt during which food was put at the bottom of the aquariums as entire plants, was unsuccessful; the fishes in spite of their hunger were indifferent. Another feeding method was then used, different parts of plants (leaves, stems, seeds) were distributed on the surface of water. This proved successful (Fig. 2). Some plant species were given repeatedly (two or three times) and at different intervals. Each species of plant was given to the fishes only after the intestine had been completely emptied from the remains of the previous feeding and after all excrement was removed from the water of the aquarium. The interval between two meals was 1 to 3 days depending on the plant species, water temperature and other factors. However, each plant species remained in the water for the same length of time.

Quantitative study of the food

Study of the quantity of food was also attempted (Borutsky, 1974). The plant material which was to be given to the fishes for food, as well as the uneaten material in the aquarium after the meal, were dried carefully and then weighed. The weight of the food which remained uneaten in the aquarium at the end of 24 h was subtracted from the quantity of food offered and represented the food intake in 24 h. Before weighing all collected excrement was dried on filter paper until the water had evaporated. The weight of the excrement subtracted from the weight of the consumed food gave the food quantity assimilated by the fishes. The percentage of food assimilated for each plant species was derived from the ratio of the food assimilated to the food intake. It was assumed that fishes of the same body length kept in groups of two or three in the same aquarium all fed at the same speed and had the same food intake.

It must be pointed out that the quantitative aspect of the experiment is relative, because the fishes had plenty of food in their aquariums while their limited mobility reduced their need for food. No consideration was given to the chemical composition or the percentage of the water present in the plants used either in the meals, in the remains of these plants or in the excrement.

III. RESULTS

Examination of the full length of intestine usually showed a green mass originating from plants. Further analysis of this mass revealed that the external structure and compositions of this mass differed greatly between young and adults.

YOUNG FISH

The content of the intestines was a thick pulp mainly of microscopic plant organisms representative of the phytoplankton abundant in the lakes. The results of this qualitative analysis are presented in Tables II and III. The fish are ordered according to their body length in five groups so as to establish possible variation in the qualitative composition of the food relative to body length.

In Tables II and III it appears that the planktonic microalgae classified as Chrysophyceae, Chlorophyceae, Cyanophyceae and Pyrrophyceae constitute the basic category of food for young *S. acarnanicus*. The tissues of macrophytes which appear in the gut constitute a minor food category. Tables II and III illustrate that as the body length of the young fish increases, the index of predominance of the various microalgae tends to move from the ‘ very many ’ to the ‘ very few ’ categories other than for the Pennatae where the index increases with length. The same observation can be made for the tissues of higher aquatic plants. In conclusion it can be said that, as the young fish grow, they gradually move from feeding on phytoplankton to feeding on higher aquatic plants. Therefore, *S. acarnanicus* appears to be phytoplanktophagous when young, whereas later, it is mainly macrophytophagous.

ADULT FISH

The intestines of the adults contained a mass of extremely small pieces of plants which were visible to the naked eye. These particles were masticated plant and

TABLE II. Frequency (%) of various kinds of food in the gut of young *Scardinius acarnanicus* grouped according to body length

Food	Body length (S.L.) of fish (cm)				
	4·0–6·0	6·1–8·0	8·1–10·0	10·1–12·0	12·1–14·0
Chrysophyceae:					
Pennatae	100	100	100	100	100
Chlorophyceae:					
Scenedesmus	100	75	100	100	100
Oedogonium	40	100	75	100	100
Cosmarium	40	50	75	50	100
Pediastrum	40	50	75	25	—
Cladophora	—	—	25	—	—
Chlamydomonas	—	—	—	25	—
Cyanophyceae:					
Oscillatoria	80	25	25	—	—
Merismopedia	60	50	75	50	25
Pyrrhophyceae:					
Peridinium	—	25	—	—	25
Ceratium	—	—	—	25	—
Tissues of higher plants	20	75	100	100	100

macroalgae remains, representative of the higher aquatic vegetation in the lakes. The results of the experimental feeding of *S. acarnanicus* are shown in Tables IV, V and VI. These tables contain all plant species which were given to fishes during the experiment. These plants are divided into three categories according to the degree of consumption. The first category includes plant species which were completely and regularly consumed (Table IV), the second of plant species with little or irregular consumption (Table V), and the third includes the plant species which were never eaten (Table VI). The plants which were used during the experiment belong to the following families, aquatic plants: Hydrocharitaceae; Haloragidaceae; Ceratophyllaceae; Potamogetonaceae; Najadaceae. Riparian plants: Onagraceae; Gramineae; Cyperaceae; Typhaceae; Alismataceae; Lythraceae. Terrestrial plants: Gramineae; Cyperaceae; Papilionaceae; Polygonaceae; Labiatae; Plantaginaceae; Verbenaceae; Juncaceae; Compositae; Scrophulariaceae; Onagraceae.

As is obvious from Tables IV–VI, all three categories of plants include aquatic, riparian and terrestrial plants. This means that although *S. acarnanicus* feeds on the higher aquatic plants, 29% of these are not eaten. In contrast, 78% of riparian and 64% of terrestrial plants may be eaten. During experimental feeding it was observed that the fishes preferred the herbaceous aquatic and shore vegetation and especially the new growth and tender parts of the plants. It was also noticed that the fishes did not eat the plants which were either spiny (*Picris* sp., *Cichorium* sp.) or pubescent (*Mentha pulegium, Mentha aquatica* and *Kickxia* sp., Table VI). The fishes tried the leaves of these plants but abandoned them immediately. It is noteworthy that the fishes did not attempt to eat the named woody plants (*Typha* sp., *Juncus heldreichianus* and *Juncus* sp., Table VI). The fishes merely approached

TABLE III. Predominance (%) of various kinds of food in the gut of young *Scardinius acarnanicus* grouped according to body length*

Food	Body length (S.L.) of ᶠsh (cm)																													
	4·0–6·0						6·1–8·0						8·1–10·0						10·1–12·0						12·1–14·0					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Chrysophyceae:																														
Pennatae	80	20	—	—	—	—	75	—	25	—	—	—	75	25	—	—	—	—	100	—	—	—	—	—	100	—	—	—	—	—
Chlorophyceae:																														
Scenedesmus	—	60	40	—	—	—	—	50	25	—	—	—	—	75	25	—	—	—	—	75	25	—	—	—	—	—	75	25	—	—
Oedogonium	—	—	—	20	20	—	—	—	25	50	25	—	—	—	50	25	—	—	—	25	75	—	—	—	—	—	75	25	—	—
Cosmarium	—	—	—	—	—	40	—	—	25	25	—	—	—	—	25	50	—	—	—	—	25	—	—	25	—	—	—	25	—	75
Pediastrum	—	—	—	—	—	40	—	—	—	—	—	50	—	—	—	—	—	75	—	—	—	25	—	—	—	—	—	—	—	—
Cladophora	—	—	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlamydomonas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—	—	—	—	—	—
Cyanophyceae:																														
Oscillatoria	—	—	80	—	—	—	—	—	25	—	—	—	—	—	—	—	25	—	—	—	—	—	—	—	—	—	—	—	—	—
Merismopedia	—	—	40	20	—	—	—	—	25	25	—	—	—	—	—	75	—	—	—	—	25	—	25	—	—	—	—	25	—	—
Pyrrhophyceae:																														
Peridinium	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25
Ceratium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—	—	—	—
Tissues of higher plants	—	—	—	20	—	—	—	—	25	50	—	—	—	50	50	—	—	—	—	75	25	—	—	—	—	100	—	—	—	—

*1, Very many; 2, many; 3, numerous; 4, few; 5, some; 6, very few.

TABLE IV. Plant taxa consumed regularly and completely by fishes

Family	Species	Plant category	Plant parts used	Assimilation (%)
Hydrocharitaceae	*Vallisneria spiralis*	Aquatic	Leaves	48
Haloragidaceae	*Myriophyllum spicatum*	Aquatic	Small fragments	37
Ceratophyllaceae	*Ceratophyllum demersum*	Aquatic	Small fragments	32
Potamogetonaceae	*Potamogeton fluitans*	Aquatic	Leaves	40
Onagraceae	*Ludwigia palustris*	Riparian	Leaves	42
Gramineae	*Phragmites* sp.	Riparian	Leaves	46
Gramineae	*Agropyron* sp.	Terrestrial	Leaves and stems	32
Gramineae	*Digitaria* sp.	Terrestrial	Leaves and stems	15
Gramineae	*Avena* sp.	Terrestrial	Seeds	57
Cyperaceae	*Cyperus* sp.	Riparian	Leaves	33
Cyperaceae	*Carex* sp.	Terrestrial	Leaves and stems	15
Papilionaceae	*Medicago* sp.	Terrestrial	Leaves and stems	55
Papilionaceae	*Trifolium repens*	Terrestrial	Leaves and stems	50
Polygonaceae	*Rumex* sp.	Terrestrial	Leaves	51
Polygonaceae	*Polygonum* sp.	Terrestrial	Leaves	16
Labiatae	*Lycopus europaeus*	Terrestrial	Leaves	21
Labiatae	*Stachys palustris*	Terrestrial	Leaves	30
Labiatae	*Scutellaria galericulata*	Terrestrial	Leaves	43

TABLE V. Plant taxa consumed irregularly and incompletely by fishes

Family	Species	Plant category	Plant parts used	Assimilation (%)
Potamogetonaceae	*Potamogeton* sp.	Aquatic	Leaves	60
Cyperaceae	*Cyperus* sp.2	Riparian	Leaves	37
Cyperaceae	*Cyperus* sp.3	Riparian	Leaves	29
Cyperaceae	*Scirpus* sp.	Riparian	Leaves	60
Lythraceae	*Lythrum salicaria*	Riparian	Leaves	59
Plantaginaceae	*Plantago* sp.	Terrestrial	Leaves	60
Labiatae	*Mentha microphylla*	Terrestrial	Leaves	30
Verbenaceae	*Lippia nodiflora*	Terrestrial	Leaves	49

them and then ignored them. A large number of seeds of *Avena* sp. were consumed although these seeds are very hard. The fishes ate them with such skill that finally there was nothing left except the skin of the seeds. The other favoured foods of the fishes consisted of the following plant taxa, *Vallisneria spiralis, Cyperus* sp., *Phragmites* sp., *Medicago* sp., *Trifolium repens, Rumex* sp., *Agropyron* sp., *Digitaria* sp. and *Carex* sp. (Table IV).

It is obvious from comparison of the plants in Tables IV and V that although the consumption of those in Table IV was regular and high, assimilation was no higher than those plants which had a lower degree of consumption. In fact, from Tables

TABLE VI. Plant taxa not consumed by fishes

Family	Species	Plant category	Plant parts used	Fishes behaviour
Najadaceae	*Najas marina*	Aquatic	Small fragments	Not approached
Potamogetonaceae	*Potamogeton lucens*	Aquatic	Leaves	Tasted and vomited
Typhaceae	*Typha* sp.	Riparian	Leaves	Approached, then ignored
Juncaceae	*Juncus heldreichianus*	Terrestrial	Leaves	Approached, then ignored
Juncaceae	*Juncus* sp.	Terrestrial	Leaves	Approached, then ignored
Compositae	*Picris* sp.	Terrestrial	Leaves	Tried, then abandoned
Compositae	*Cichorium* sp.	Terrestrial	Leaves	Tried, then abandoned
Alismataceae	*Alisma plantago-aquatica*	Riparian	Leaves	Tried, then abandoned
Onagraceae	*Epilobium* sp.	Terrestrial	Leaves	Tasted and vomited
Labiatae	*Mentha pulegium*	Terrestrial	Leaves	Tried, then abandoned
Labiatae	*Mentha aquatica*	Terrestrial	Leaves	Tried, then abandoned
Scrophulariaceae	*Kickxia* sp.	Terrestrial	Leaves	Tried, then abandoned

IV and V it appears that both the smallest and the largest percentage of assimilation which had been calculated for the first category of the plants, are lower than those of the second category respectively. The high assimilation of plants belonging to the second category may be the cause of the limited consumption of these plants.

It should be noted that no difference was observed in plant species preference between males and females. It was also found that the rate of food consumption by fishes was independent of season and water temperature.

IV. DISCUSSION

No previous papers detail qualitative analysis of the plant food of *S. erythrophthalmus*; comparing previous studies with the results of the present study (i.e. on the feeding of *S. acarnanicus*) provides some general conclusions.

Firstly, the feeding of these two species depends on the living conditions of each, i.e. season, temperature, water quality, geomorphology, geographical area and other factors involved in the lake environment, influence the food conditions and food supply. Under stable conditions with a rich food supply, the fish species appears to be stenophagous, i.e. it adapts to feeding on a few categories of food. Euryphagous fishes however feed on many categories of food under changing food conditions.

S. erythrophthalmus, in some European populations (Bubinas, 1974; Klimczyk-Janikowska, 1975; Bohl, 1980; Hofer & Niederholzer, 1980; Niederholzer & Hofer, 1980) has been characterized as euryphagous or omnivorous because it feeds on both plant and animal food, such as insects and their larvae. In the present study, *S. acarnanicus* appears to be stenophagous, because the intestines in all seasons over 3 years of sampling, were found to be full of a green mass originating from plants. This feeding behaviour of *S. acarnanicus* like that of *S. erythrophthalmus* (Niederholzer & Hofer, 1980) is independent of season and temperature.

Juveniles and young individuals of *S. erythrophthalmus* in some European populations (Bohl, 1980, 1982; Niederholzer & Hofer, 1980) feed on zooplankton, but in some other populations (Klimczyk-Janikowska, 1975) ingest phytoplankton. In the present study, *S. acarnanicus* was found to be phytoplanktophagous when young, and the species composition of its microalgae diet was similar to that reported for *S. erythrophthalmus* by Klimczyk-Janikowska (1975). Each of the two types of planktonophagy represents the type of plankton which is abundant in the particular lake and is the actual food supply there.

The same phenomenon was observed concerning the feeding on aquatic vegetation from the lakes. Both *S. erythrophthalmus* and *S. acarnanicus*, consume species of macrophytes which exist in the lake, occurring in sufficiently high densities and are both accessible and attractive to them. This is probably the reason for the difference in diet between the adults of *S. acarnanicus* and the adults in some European populations of *S. erythrophthalmus* (Klimczyk-Janikowska, 1975; Hofer & Niederholzer, 1980; Prejs, 1984). However, it is unlikely that either species causes direct damage to the vegetation when feeding on macrophytes, as they do not pull out whole plants. According to Prejs (1984), plucking of leaves, particularly the young upper ones with parts of the stems, may even stimulate the production of some macrophytes which will thus renew the loss due to grazing.

The macrophytes of Lakes Lysimachia and Trichonis constitute the basic food of *S. acarnanicus*. The intensity of food intake is much increased by frequent flooding in the area, the fishes then migrate to the shore zone of the lakes to graze on riparian and terrestrial plants, which are accessible to them due to the flooding. A similar phenomenon was reported by Dudgeon (1983) for the Plover Cove Reservoir of Hong Kong. Thus, the vegetation of Lakes Lysimachia and Trichonis, as a food source for *S. acarnanicus*, is of great significance.

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