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FOOD, FEEDING HABITS AND RATE OF GASTRIC DIGESTION IN *NOEMACHEILUS TRIANGULARIS* DAY

by S. D. RITA KUMARI *and* N. BALAKRISHNAN NAIR, FNA
Department of Aquatic Biology & Fisheries,
University of Kerala, Trivandrum 695 007

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Food and feeding habits of *N. triangularis* indicate that the fish is an insectivore, its diet being composed chiefly of developmental stages of insects that fall within the ingestible size range of the species. Analysis of the gut contents of adult and young reveals no significant difference in food items consumed. Seasonal variation in the quantity of food eaten by males and females (separately) and by immature ones has been ascertained. It is found that female fish in general feeds more voraciously than males even though the seasonal variation in feeding activity shows similarity. The state of development of the gonad as well as the availability of food in the habitat account for the variation in feeding rate from time to time during the annual cycle. The rate of gastric digestion estimated under laboratory conditions is found to be rapid soon after feeding.

INTRODUCTION

Notwithstanding the importance of loaches as an interesting group of fishes, no earnest attempt has, hitherto, been made in India (except that of Jyoti & Malhotra, 1975) for an understanding of the kinds and amounts of food consumed, the way in which food habits are influenced by habitat, preferences, seasons, temperature, age and size, competitor species, food requirements, rate of gastric digestion, etc., that pave the way to the general conclusions that bear upon the biology of the loaches.

However, a few earlier investigators have given brief notes on food and feeding habits of certain cobitid fishes. Some of the earlier papers in which casual mention has been made on the food of the Indian loaches are those of Das (1935) and Bhimachar (1935). Menon and Chacko (1955), while investigating the food and feeding habits of freshwater fishes of Madras State, mentioned the different food items encountered in the stomach of *Lepidocephalus thermalis*. Chacko and Evangeline (1956) made a reference to the diet of *L. thermalis* in a survey of the Araniar valley. Later studies on Indian species include those of Das (1963), Rajan (1965), Malhotra (1967), Jyoti and Malhotra (1975).

Suyehiro (1942), Smyly (1955), Kubota (1960), Maitland (1965), Maksunov (1972) are the important contributors on food and feeding habits of loaches from other parts of the world. All the above-mentioned authors made only a qualitative study of the food except Smyly (1955) and Kubota (1960) who studied food in relation to different seasons and food intake at different stages of growth. This paucity of information on these groups prompted a detailed study of the food, feeding habits, and rate of gastric digestion in a hill-stream loach of Kerala *Noemacheilus triangularis* Day.

MATERIALS AND METHODS

Monthly random samples of *N. triangularis* were made from Kallar stream lying at the foot of Ponmudi Hills, Western Ghats. Soon after the fishes were netted out of water, they were killed and preserved in 5% formalin for later examination.

In the laboratory, they were wiped off moisture and each specimen was weighed and the data on size, sex and stage of sexual maturity were recorded for each fish. Then the stomach was dissected out. After noting the degree of fullness of the stomach — heavy, good, moderate, poor, empty — the weight of the stomach contents was determined. In evaluating the food of the stomach, the points method of Swynnerton and Worthington (1940), as modified by Hynes (1950), was employed.

The condition of feed in various months was calculated from the total number of fish that fall into different categories. Fish with heavy and good stomachs were categorized as actively fed, those with moderate stomachs as moderately fed and with poor as poorly fed.

The contents of the alimentary canal were examined by using a binocular microscope and the different food items were identified as far as possible up to the species level or up to the genus or family, depending upon the extent of digestion.

The gastro-somatic indices were determined separately for each sex and for immature fish, to study monthly fluctuations in the feeding rate. The gastro-somatic index (G.S.I.) was calculated as:

$$G.S.I. = \frac{Weight\ of\ stomach\ contents}{Weight\ of\ fish} \times 100$$

Guts of other fishes living together with these loaches in the same locality were also examined so as to study their relationship in the community. No attempt was made to estimate the abundance of constituent food organisms.

Serial slaughter method, that Windell (1966) recommended over other methods for following the progress of gastric digestion in fish, was used to measure quantitatively the rate of gastric digestion and evacuation in the loach. Healthy specimens of *N. triangularis* of uniform size were reared in separate 5 litre glass acquaria. They were fed to satiation, once daily, with live tubifex worms and the excess food was removed after 30 minutes. Only while feeding and cleaning the tanks, the fish were slightly disturbed. Temperature of the water remained at 27 ± 2°C and oxygen at nearly air saturation. The fish were thus held at least two weeks for acclimatization. By this time the fish were conditioned to feed as soon as food was offered. Following the acclimatization period, the fish were starved for a period of three days before experimental feeding, in order to completely emptying the stomach.

Each fish was then allowed to voluntarily consume a measured amount of tubifex worms. At intervals of 5 hours, each fish was removed and sacrificed immediately. The body cavity was opened and the alimentary canal removed. The stomach contents were squeezed into a watch glass. The remaining food in the stomach was also removed to the watch glass after opening the stomach. The weight of the food

removed from the stomach of each fish was noted. This serial slaughtering was continued until the stomach became completely empty.

RESULTS

(1) *Qualitative Analysis of the Stomach Contents*

An analysis of the stomach contents of *N. triangularis* reveals that aquatic larvae or nymphal stages of insects form the chief item of food of all length groups (Fig. 1). In almost all cases, these larvae and nymphs constituted the exclusive diet of the fish. Planarians were occasionally noticed in the diet. In rare instances water-mites constituted an insignificant percentage of the diet of the fish. In one instance, two small coleopteran adults were found along with other gut contents. Filamentous algae occurred at times mostly clinging to legs of insect nymphs. Pebbles could be found in fair proportions in most of the guts. Larval cases made of sand grains could be seen as such in several instances.

According to Price (1963) the food items composing the volume or frequency of 10% or more in the guts can be taken as significant food items. If the various food items are judged on this basis, the main food item of *N. triangularis* is found to be insect larvae and nymphs, even though it occasionally feeds on certain bottom invertebrates. Fig. 2 gives the composition of the food during the respective months of the year. The occurrence of other minor items noticed in the gut seems to be a matter of chance.

Among the developmental stages of insects, aquatic nymphs of ephemeropterans, plecopterans and larvae of coleopterans, trichopterans and dipterans were common. Among them, the following were identified up to the family or generic level.

Order : PLECOPTERA
Family : Perlidae
Genus : *Perla*

Order : EPHEMEROPTERA
Genus : *Potamanthus*

Order : COLEOPTERA
Family : Psephenidae
Family : Hydrophilidae
Genus : *Hydrobius*

Order : TRICHOPTERA
Family : Psychomyidae
Genus : *Psychomyia*

Order : DIPTERA
Family : Tabanidae
Genus : *Haematobota*

Family : Simulidae
Genus : *Simulium*

Family : Tipulidae
Family : Chironomidae
Genus : *Corynoneura*
,, : *Tanypus*

From the present observations, it would appear that the fish does not show any kind of selectivity among the insects available in its habitat. The relative importance of the various types of larval forms in the gut contents seemed to depend on the availability of the same in the environment. In no case, the fish was found to resort to feeding only on one type of insect larvae. From this, it seems that the fish does not have any preference for a particular food item, and the diet, therefore, seems to be dependent more on the availability of particular organisms than on any other factor.

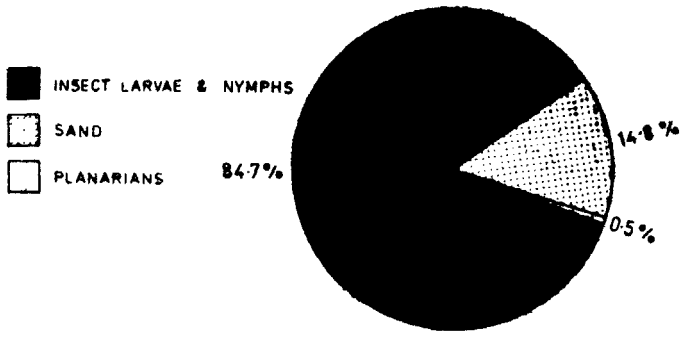

FIG. 1. Average annual feed of *N. triangularis.*

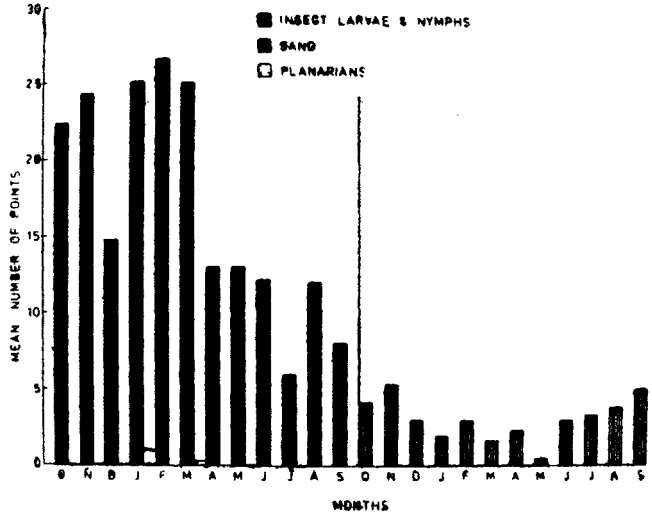

FIG. 2. Mean number of points of the gut contents of *N. triangularis* during different months.

Observations also show that there is no significant change in the diet of young and adult fishes.

(2) *Seasonal Variations in the Rate of Feeding*

Seasonal changes in the quantity of food eaten by mature (male and female separately) and immature fishes are shown in Figs. 3 and 4. It is seen that there are notable variations in the rate of feeding during the period of investigation. It is interesting to note that the female fishes feed more voraciously as compared to male fishes though the seasonal variation in feeding activity shows similarity.

Regarding the nature of feeding in females three modes are discernible, the first one in November, the second in April/May and the third in July/August. In April, the feeding reaches its maximum intensity. Then it gradually declines to reach a

low level in June. In the subsequent two months, moderate feeding occurs and feeding records its lowest value in September (Fig. 3).

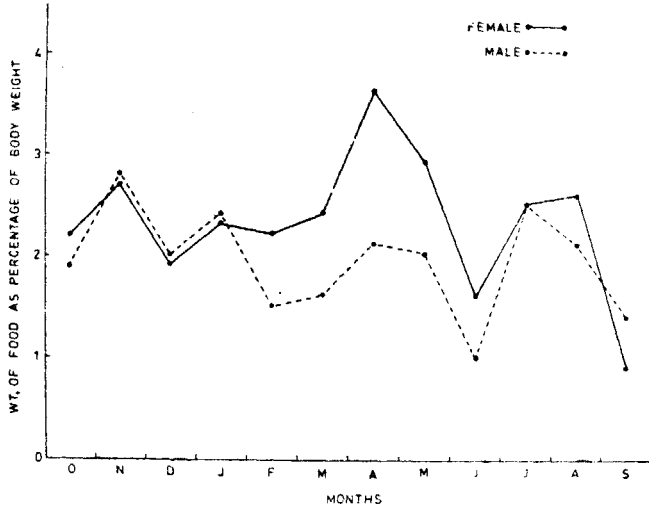

FIG. 3. Seasonal variation in quantity of food eaten by mature male and mature female *N. triangularis*.

The rate of feeding in immature fishes shows an altogether different trend. The data presented in Fig. 4 reveal that the feeding intensity widely fluctuates during the different months. The rate of feeding is low from October to January while February and March record high feeding activity. The period from April to June records intensive feeding activity and the period from July to September indicates a low rate of feeding.

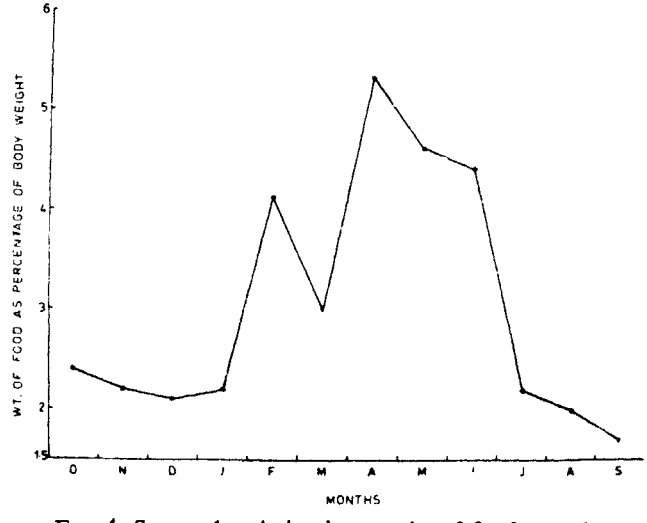

FIG. 4. Seasonal variation in quantity of food eaten by immature *N. triangularis*.

(3) *Condition of Feed*

The variations in the feeding intensity were further examined based on the relative fullness of the guts. Tables I and II present various categories of feed for mature and immature fishes separately for the period of investigation.

TABLE I

Condition of feed during the various months in mature fish of N. triangularis

Months	Number of fish	Rating		
		Poor	Moderate	Active
October	27	33·33	29·64	37·03
November	36	19·44	33·34	47·22
December	13	30·77	46·15	23·08
January	30	13·33	56·67	30·00
February	31	38·71	22·58	38·71
March	37	13·52	48·64	37·84
April	24	4·16	20·84	75·00
May	14	28·58	21·42	50·00
June	16	12·50	43·75	43·75
July	22	4·54	18·18	77·28
August	16	18·75	31·25	50·00
September	11	63·64	36·36	—

In October, some mature fish were found to feed actively and the trend showed further increase in November. In December and January most of the fish were in the category of moderate feeding. In February and March less number of fish fed actively. The percentage of fish that fed actively showed a steep rise in April and the trend was continued in May also. During June, most of the fish were either actively or moderately feeding but in July, actively fed fishes again increase steadily in number. Thereafter, the percentage of actively fed fishes decreased and in September most of the fish were poorly feeding.

For immature fish, a majority were either actively or moderately feeding throughout the year.

Feeding was minimal from January to March in mature fishes. This can be accounted to the presence of gravid females and ripe males in large numbers in the sample. It was observed that when the oocytes are fully mature and thus largest in size, the ovary in consequence becomes considerably large and dilated. It is probable that this increase in volume of the ovary exerts pressure on the alimentary canal, thereby preventing the passage of food through the alimentary

TABLE II

Condition of feed during the various months in immature fish of N. triangularis

Months	Number of fish	Rating		
		Poor	Moderate	Active
October	18	50·00	44·44	5·55
November	13	30·77	46·15	23·08
December	3	—	33·33	66·67
January	4	—	100·00	—
February	5	—	100·00	—
March	13	23·08	69·23	7·69
April	59	10·17	37·28	52·55
May	58	12·06	22·42	65·52
June	48	8·33	35·42	56·25
July	31	32·25	51·62	16·13
August	22	27·27	68·18	4·55
September	25	32·00	56·00	12·00

canal. This may result in the low rate of feeding. The slight increase in feeding intensity in March may be attributed to the high rate of feeding of spent individuals which is only 15%. During April-May the fish feeds voraciously. This intensive feeding coincides with the time after spawning (in late March and early May), when the largest number of spent ovaries are encountered in the sample. Similar explanation can be given to the high rate of feeding in July-August. This high rate of feeding is essential, not only for the recovery of the fish but also for the vitellogenic phases of the oocytes to provide raw materials for the conversion into yolk within the oocytes. Such reduced feeding during peak maturity followed by intensive feeding after spawning has been recorded for many other teleosts (Qayyum & Qasim 1964*a*, *b*, *c*). Another period of intense feeding was noticed during November after the spawning in late September or early October. Again a cessation of feeding activity is discernible during December. This slackening in feeding rate may be attributable to a possible decline in the availability of food or to a slackening in the general activity of the fish on account of the prevailing low temperature conditions in the habitat of the fish in the high ranges. In immature fish, too, there is a slight decrease in the rate of feeding during November to January. During the period April to June intensive feeding has been noticed in immature fish, and this may be a reflection of the abundant availability of the required type of food in its habitat.

It would appear from the above data that the state of development of the gonad as well as abundance of food in the habitat account for the variation in feeding rate from time to time during the annual cycle. The intensive feeding noticeable in both immature and mature fish from April to June furnishes corroborative evidence for the above-mentioned contention.

(4) *Feeding Habits*

From the observations it is clear that *N. triangularis* is essentially an insectivore preying mainly on aquatic larval or nymphal stages of insects. This monotype nature of stomach contents was observed in the great majority of cases. But in no instance, the entire stomach contained exclusively one particular item alone. This shows that the fish exhibits no special selectivity in feeding, the diet appears to be dependent on the availability of the food organisms.

It is evident from the nature of the stomach contents that the fish picks up the insects from the bottom or from the algal felt which cloths the rocks. Fish also seeks after the nymphs and larvae that hide beneath the stones. Each of these items of food appears to be individually selected. Location of such food is assisted by the sensory barbels. The ventrally placed mouth and the development of fleshy sensory lips naturally help the bottom feeding habit of the fish.

The fine sand grains invariably present in the stomach may be attributed either to accidental intake of the sand grains during feeding, or to swallowing of larvae contained within cases made up of sand grains. The presence of entire larval cases in the stomach suggests that the larvae together with their cases, are nipped off from the rock surface and swallowed by the fish. However, in *N. triangularis*, sand particles invariable occur in the gut and this gives room for doubts as to whether the ingestion of sand grains is accidental or part of its natural habit. Further observations are required for the elucidation of the nature and significance of these sand particles in the stomach.

(5) *Rate of Gastric Digestion*

The laboratory-acclimatized fishes voluntarily consumed 100 mg of tubifex worms. The amount of food recovered from the stomach of the fish at every 5 hr interval after the initial feeding is presented as the percentage of the total food consumed and is shown in Table III. The passage of chyme from the stomach to the intestine is dependent on the rate of digestion and hence the depletion rate of food from the stomach parallels digestion rate. On the basis of this, the rate of digestion in every 5 hr period was calculated and is presented in Table IV and Fig 5. The results show that the digestion rate is considerably higher during the first five hour interval.

But the rate gradually decreases as time passed on. Within a period of 25 hr the whole amount of food present in the stomach was seen to be completely evacuated.

TABLE III

Amount of food recovered and percentage of food digested in N. triangularis *of 550 ± 20 mg weight*

Hours after feeding	Weight of food presented (mg)	Weight of food recovered (mg)	Percentage of food digested
0	100	—	—
5	,,	25·0	75
10	,,	13·5	86·5
15	,,	10·7	89·3
20	,,	6·5	93·5
25	,,	0	100

TABLE IV

The rate of digestion in N. triangularis *of 500 ± 20 mg weight*

Sl. No.	Time (hr)	Rate of digestion %
1	0 — 5	75·0
2	5 — 10	11·5
3	10 — 15	2·8
4	15 — 20	4·2
5	20 — 25	6·5

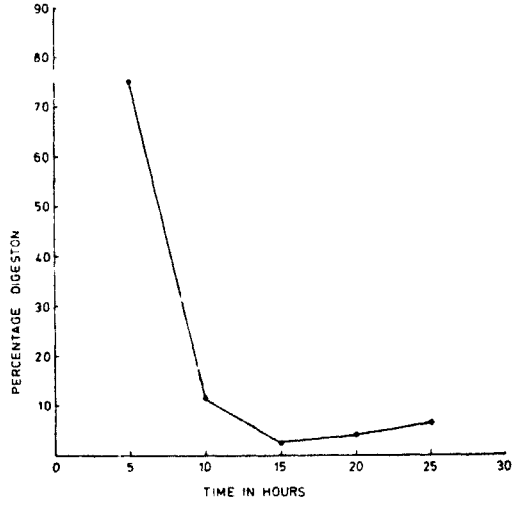

FIG. 5. The rate of digestion of food expressed as percentage.

Discussion

The foregoing analysis of food shows that *N. triangularis* is essentially an insectivore its diet consisting chiefly of developmental stages of aquatic insects. The observations of earlier workers on other species of *Noemacheilus* do not completely agree with those of the present study. Smyly (1955) in his elaborate study on the biology of the stone-loach *N. barbatula* from British Isles, states that the stomach contents of this fish included amphipods, several species of cladocerans, ostracods, copepods, annelids such as oligochaets, leeches, and molluscs besides the aquatic larval or nymphal stages of several insect groups. Maitland (1965) recorded in the gut contents of *N. barbatula*, *Lumbriculus* and *Gammarus*, along with the insect fauna, but the former two were never prominent. He further noted that molluscs were never eaten by the fish. The items of food of *N. kuschakewitschi* as recorded by Maksunov (1972) were Chironomidae. Ephemoroptera, Trichoptera and larvae of Simulida.

A few Indian investigators have also reported briefly on the food of certain species of *Noemacheilus*. Khanna and Pant (1964) who examined the gut contents of *N. rupicola* states that the fish is an insectivore feeding mainly on insects and crustaceans. Multicellular algae were also found in a few isolated cases, but do not form the regular food of the fish. Rajan (1965) in his report on food of some hill-stream fishes of South India noted that the stomach of *N. dayi* contained a variety of items as chironomid, dipteran and other insect larvae, dipteran and coleopteran adults, insect parts, copepods, cladocera, mites, eggs, higher plant matter and debris. He found the food of *N. beavani* to be chironomid larvae and debris, while that of *N. denisonii* as dipteran larvae. The food of *N. monilis* according to Rajan (1965) is mainly Ephemeroptera, Diptera, Coleoptera and hemipteran larvae.

Agrawal and Tyagi (1969) studied the food and feeding habits of two cobitid fishes—*N. botia* and *Botia lohachata*—and found them to be carnivorous, feeding on copepods and other small crustaceans as well as some insect larvae. Studies on *N. kashmirensis* reveal that this species feeds mostly on green vegetable matter, insects, their larvae and crustaceans ranking second in the dietary (Jyoti & Malhotra, 1975).

From the foregoing account of the food of the genus *Noemacheilus*, it seems that in all cases the fish feed on insect larvae. Variations in the insect fauna in the diet of different species may depend on the availability of the same in the habitat. Hora (1936) reported that insect fauna in the mountain streams depend primarily on the velocity of the current and the nature of the substratum. It is probable that the presence of various crustaceans in the diet also seems to depend on the availability of the same in the habitat.

Analysis of the bottom fauna and those entangled among the weeds indicate that the fish is actually feeding on these invertebrates The fish do not seem to restrict themselves only to some particular varieties. This is borne out by the fact that most of the items present in the habitat that fall within

the ingestible size range were represented in their guts as well. This would suggest that there is little selection on the part of the fish.

Kubota (1960) found the adult of *Misgurnus anguillicaudatus* essentially a herbivore and the young ones carnivorous. In the present study, no such change in food habits has been noticed.

The rare occurrence of filamentous algae as already noted in the stomach of *N. triangularis* represents the gut contents of the prey or that clinging to appendages of insect nymphs or that swept into the mouth during capture of the prey. Such material may be of nutritional significance to the fish. Though the algae as the gut contents of prey have a reduced calorie-per-gram value (Cummins & Wuycheck, 1970), they may well be assimilated with considerable efficiency by the fish since they form mechanically disrupted, partially digested, prepackaged food supply. The early stages of the majority of the insects are associated with organic accumulation (Cummins, 1972) hence of high caloric content and the intake of such animals alone as food by fishes is of high nutritive value for them.

Collections of invertebrate fauna, occurring in the Kallar area revealed the presence of aquatic larvae of insects dominating in quantity. A number of other species of fishes occurring in the locality were collected with a view to finding out the food items consumed by them. From such an examination it was gathered that both the mid-water and botton feeding fishes in the locality mainly consumed the various types of aquatic larvae which occurred there (Table V). Thus the statement that the material in the digestive tract of the fishes faithfully reflects the relative environmental densities of the food item in the locality (Cummins, 1972) holds good.

Qayyum and Qasim (1964a) recorded a cessation of feeding activity during winter months in *Ophiocephalus punctatus*. In the present observations also a low rate of feeding was found to occur during the colder months.

The relationship between feeding and breeding deserves mention. From December to March majority of mature *N. triangularis* examined were in stage IV (Rita & Nair, in press). Accordingly they partly abstain from active feeding. Subsequent to the peak spawning in late March and in early April, most of the fish (75%) feed actively. In May, though female fish (86%) were in ripe condition 50% feed actively. This can be accounted to the fact that in many of the fish the ova left in the ovary after the spawning in March-April are undergoing maturation. As in April, again percentage of actively feeding fish increases during July (77.28%) when immature, maturing and spent ovaries are abundant. This high value of actively feeding fish can be attributed to the increased feeding after the prolonged spawning during late May which apparently continues through June to end in late June.

Along with the prevalence of mature ovaries during September, the fish again abstains from feeding. During October-November feeding is resumed and the fish feeds either actively or moderately. Such a slackness in feeding prior to spawning associated with the development of the gonad has been the subject of discussions

TABLE V

Food categories identified from stomach of other fish species living together with N. triangularis

Food	Categories	*Puntius melanampyx*	*Puntius melanostigma*	*Mastacembalus armatus*	*Gara mullya*	*Laubuca laubuca*	*Tor khudree*	*Barilius gatensis*	*Bhavania australis*	*Rasbora rasbora*
Diatoms	Diatoms									
Algae	Filamentous algae	—	×	—	—	—	×	—	×	—
	Plant fragments									
Plants	Plant seeds	—	—	—	—	—	—	—	—	—
Worms	Annelids	—	—	—	—	—	—	—	—	—
	Cladocera									
Crustaceans	Ostracoda	—	—	—	—	—	—	—	—	—
	Nymphs									
Insects	Larvae	×	×	×	×	×	×	×	×	×
	Insect parts									
Molluscs	Molluscs	—	—	—	—	—	—	—	—	—
	Fish scales									
Fish	Fish eggs	×	—	—	—	—	×	—	—	—
	Fish remains									
Mud	Sand and mud particles	×	×	×	×	—	×	—	×	×

× = present

— = absent

from very early times. Miescher (1897) has shown that the salmon go practically without food as long as they are in fresh water. Todd (1915) associated the empty stomachs of *Pleuronectes platessa* with advent of spawning. Homans and Vladykov (1954) have observed that the haddock *Melanogrammus aegilifinus* ceases to take food during the spawning season, but feeds voraciously after termination of the spawning season, trying to regain the weight lost due to spawning. Karekar and Bal (1958) have correlated the feeding intensity with the maturity stages in *Polynemus indicus*. Latter Qayyum and Qasim (1964 a, b, c), Thomas (1969), Bhatt 1968, 1970), observed the same phenomenon in the fishes studied by them. A prespawning fasting has been recorded in *Botia birdi* by Malhotra (1967). He attributed this to the increase in the volume of ovary with higher stages of maturity which exerts great pressure on the alimentary canal pressing the latter against the body wall of the opposite side causing temporary collapse of the digestive tract, thereby preventing the passage of food through it. Later Jyoti and Malhotra (1975) found continuous voracious feeding even during spawning season in *N. kashmirensis*. The fish of the present study *N. triangularis* falls in the group of fishes where prespawning fasting or low rate of feeding has been reported and the explanation of Malhotra (1967) may well be the reason for this poor rate of feeding in *N. triangularis*.

The rate of digestion in *N. triangularis* differs from the usual pattern recorded for some other fishes. Windell (1966) found that fishes usually will hold their stomach contents for some time until a certain degree of liquifaction occurs. After this period, there will be a period of high digestive activity during which the major portion of the food material will be digested and evacuted. This will be followed by a very slow digestion rate during which time the small quantity of the food remaining in the stomach will be slowly digested. In the case of *N. triangularis*, as soon as the food was consumed, digestion started and about 75% of the food material in the stomach was digested and evacuated during the first 5 hr period. The remaining 25% food was found to be evacuated during the course of about 20 hr. This suggests that in this species the digestion rate is fast during the initial period but slows down as the stomach contents decrease.

Many reasons are put forward for explaining the difference in the digestion rate in fishes. Brett and Higgs (1970) state that factors like rate of secretion of enzyme, differences in substrate relation, enzyme saturation etc., will influence the rate of gastric digestion between species and between diets.

The size of a given food type has clearly been shown to have relatively little effect on the rate of gastric digestion (Hunt, 1960; Windell, 1966, Kitchell & Windell, 1968, and Magnuson, 1969). But the composition of the meal may affect the digestion rate (Brett & Higgs, 1970). High fat content of the food may slow down the digestive rate considerably (Windell, 1966). In the case of the food given for the present study viz. tubifex worms, even though fat content amounts to nearly 30% of dry weight, the digestion rate is faster. Hence as suggested by Brett and Higgs (1970) the rate of enzyme secretion may be the factor which promotes rapid digestion in this fish.

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