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Studies on the Biology of Young Grey Mullet *(Mugil cephalus)* Digestion

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Abstract

The effect of body size and salinity on the rate of digestion of young grey mullet, *Mugil cephalus* L., was studied using the "sacrifice" method. The rate of digestion was found to be salinity-dependent, being slower at lower salinities than at higher salinities. This is correlated to higher food intake at the lower salinities. Rate of digestion was also found to be dependent on body size, increasing with increasing body weight.

Introduction

The digestive physiology of teleost fish has been reviewed by Bernard (1952), Barrington (1957) and Kapoor *et al.* (1975). It is generally accepted that physiological processes of digestion are dependent on a number of environmental and endogenous factors and also on the quality and quantity of food ingested. Although studies on aspects of food and feeding on certain mugilids, and *Mugil cephalus* L. in particular, have been carried out (Luther, 1962; Suzuki, 1965; Odum, 1968, 1970; De Silva and Wijeyaratne, 1976), there is no information available on any aspect of digestion of this euryhaline species. This paper is the fourth of a series of detailed investigations into the biology of young grey mullet and feasibility of its culture in the coastal estuarine waters of Sri Lanka (see De Silva and Perera, 1976; De Silva and Wijeyaratne, 1976; Perera and De Silva, in preparation), and here results on gastric digestion are presented.

Materials and Methods

Mugil cephalus L., ranging in total length from 10 to 50 mm, were collected from the shallow areas of a coastal lagoon, the Negombo Lagoon (7°10' N; 79°50' E), using a cast net of 1 cm stretched mesh. Laboratory experiments were carried out at the Fisheries Research Station situated close to the mouth of the lagoon. The fish were grouped according to size, and kept in glass aquaria until the start of the experiments (see Perera, 1976).

Experiments were performed with groups of fish at salinities of <1, 10, 20 and 30‰. All experiments were carried out in 5 l capacity glass aquaria provided with constant aeration and maintained at 27.0°C ± 1.0 C°. Before experimentation, fish were acclimatized to the respective salinities for 1 week and fed regularly with a mixture of rice bran and fish meal (3:1). A 3-day starvation period was enforced prior to the start of the experiments to ensure removal of any food in the alimentary canal (Hunt, 1960).

In the present experiments, the "sacrifice" method of Maynard and Loosli (1962) was adopted. Groups of young mullet were allowed to feed voluntarily on meal presented in excess for a period of 30 min; the remaining food was then removed. With smaller size groups, feeding was completed in 15 min while the largest size groups took 30 min. After completion of feeding, groups of fish (minimum of 3) were randomly selected at intervals of 30 min, except for the smallest size group (Table 1), killed by immersion in MS 222 Sandoz (100 ppm), blotted dry, and weighed to the nearest 0.1 mg. No regurgitation occurred during handling. After sampling, the alimentary canal was removed and the two ends ligated to prevent loss of food material; it was

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Table 1. Summary of experimental conditions employed

Salinity (‰)	Size range (g)	Mean weight (g)	No. of fish
<1	1-2[a]	1.500	32
<1	4-5	4.337	18
<1	7-9	8.052	16
10	1-2[a]	1.145	24
10	3-4	3.829	26
10	4-5	4.865	27
10	7-9	7.594	31
20	1-2[a]	1.285	23
20	2-3[a]	2.283	26
20	3-4	3.062	24
20	4-5	5.001	30
20	7-9	7.352	18
30	1-2[a]	1.362	26
30	3-4	3.295	24
30	4-5	4.134	23
30	7-9	8.416	17

[a]Sacrifice intervals were 15 min. All other size groups were sampled at 30-min intervals.

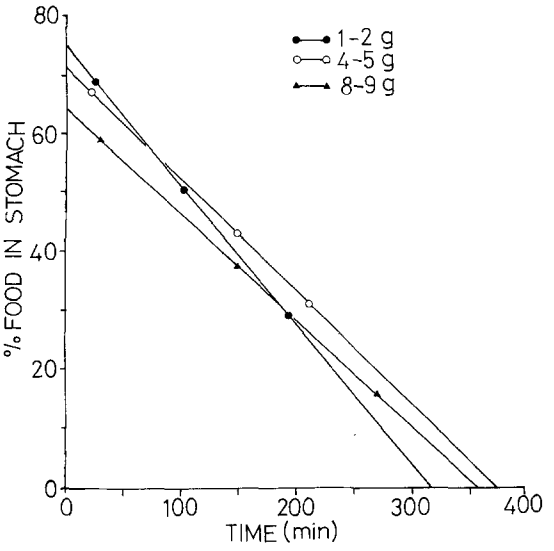

Fig. 1. *Mugil cephalus*. Relationship of percent food in stomach to time for three size-groups of fish in freshwater

then preserved in 4% formalin for later analyses. The gut was slit open and the contents of the stomach and the intestine removed. The contents were weighed separately to the nearest 10 µg, care being taken to remove all contents from the stomach and the intestine; thus, the total food ingested by individual fish was obtained. Digestion rate was calculated in terms of percentage of stomach evacuation by weight. Table 1 summarises the experimental conditions to which the fish were subjected and other relevant data.

Results

The weight of food in the stomachs of *Mugil cephalus* is expressed as a percentage of the total food ingested at different time intervals, and these data were used to compute the time for complete gastric evacuation (0% food in stomach) by regression analysis. Throughout the text, the term "gastric evacuation time" refers to the rate of gastric digestion and/or the rate of digestion. The percent of food in the stomach appeared to be linearly related to time, and this is shown in Fig. 1 for three size groups of young mullet in fresh water. The time calculated for completion of gastric digestion for each experimental group of fish is given in Table 2.

Time taken for complete digestion, which was calculated using the regression equations for each size group at different salinities, appears to increase with size (Table 2 and Fig. 2). Although the general trend is an increase in digestion time with size, for all size groups at the four experimental salinities there is a noticeable decrease for 7 to 9 g individuals at 10‰ S. The relationship of total gastric evacuation time or rate of gastric digestion to salinity is shown in Fig. 3. It is evident from this figure that digestion tends to proceed faster with increasing salinity. Generally, for any given size group digestion proceeds fastest at 30‰ S and slowest at <1‰ S; however, this relationship is not as clear at the two intermediate salinities. It can also be seen from Figs. 2 and 3 that, for any given size, the difference between the digestion time at <1 and 30‰ S is greater than the difference at the other two salinities.

Discussion

The results show that digestion occurs fairly rapidly in young *Mugil cephalus*. However, as most of the work done on rates of digestion of other species of fish are for individuals over 10 g, a strict comparison with the present work is not possible. The present experiments throw

Table 2. *Mugil cephalus*. Results of regression analysis of relationship of percent of food in the stomach (y) to time (x) for the series of experiments, and time calculated for complete gastric evacuation

Salinity (‰)	Size group (g)	Regression equation	r	P	Gastric evacuation (min)
<1	1-2	$y=76.777-0.240x$	-0.73	0.010	317
<1	4-5	$y=65.202-0.183x$	-0.79	0.020	357
<1	7-9	$y=73.271-0.200x$	-0.77	0.050	367
10	1-2	$y=94.489-0.647x$	-0.95	0.001	146
10	3-4	$y=77.075-0.294x$	-0.96	0.001	187
10	4-5	$y=82.547-0.368x$	-0.93	0.001	274
10	7-9	$y=69.738-0.302x$	-0.92	0.010	235
20	1-2	$y=115.775-0.739x$	-0.96	0.001	180
20	2-3	$y=82.391-0.431x$	-0.97	0.001	194
20	3-4	$y=76.422-0.376x$	-0.92	0.010	203
20	4-5	$y=87.934-0.372x$	-0.97	0.001	235
20	7-9	$y=65.964-0.216x$	-0.95	0.001	305
30	1-2	$y=87.871-0.617x$	-0.95	0.001	142
30	3-4	$y=89.785-0.471x$	-0.93	0.010	190
30	4-5	$y=94.047-0.625x$	-0.95	0.001	152
30	7-9	$y=69.757-0.360x$	-0.86	0.050	194

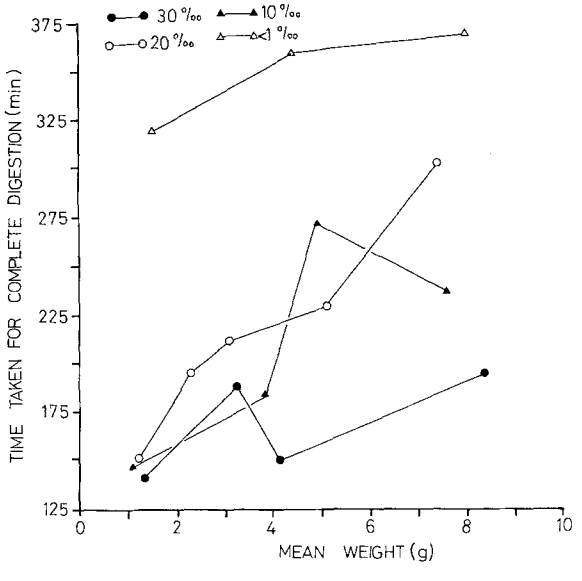

Fig. 2. *Mugil cephalus*. Relationship of time calculated for complete digestion to mean weight at the 4 experimental salinities

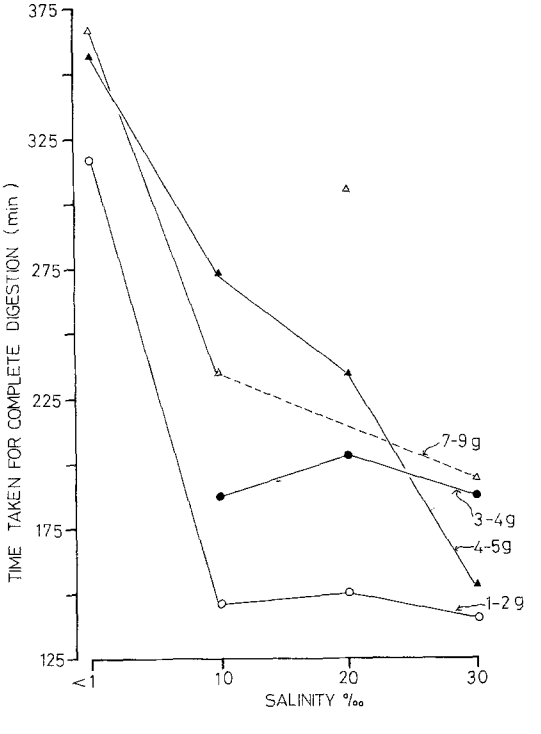

Fig. 3. *Mugil cephalus*. Relationship of time taken for complete digestion to salinity for different size-groups of young mullet

light on two factors which effect digestion in young mullet:

(1) Size. The effect of size on digestion rate has been also reported for other species of fish (Hunt, 1960; Seaburg and Moyle, 1964). The factors responsible for this, however, are not yet clearly understood. According to Ricker (1946), digestion rate is a function of the surface area of enzyme-secreting organs, the absolute size of which decreases with increasing body weight. Protein absorption efficiency among fish of different weights remains more or less constant (Gerking, 1955; Davies, 1963, 1964; Pandian, 1967a, b), and on this basis it has been suggested that differences in digestion rates may not be due to enzyme activity or composition but rather to the quantity of enzymes secreted. Hunt (1960) was the first to recognise a relationship between the rate of digestion and the activity of fish. Although Hunt based his observations on experiments using three different species it may well be that even within one species digestion is related to activity.

(2) Salinity. The present experiments also reveal that the rate of digestion is salinity-dependent. Little work has been done on the effect of salinity on digestion. Western (1971), working on two species of cottids, one marine and the other freshwater, did not detect any modification in gut morphology or function directly attributable to the environmental salinity. On the other hand, Kinne (1960), in his experiments with *Cyprinodon macularius*, found that food intake was salinity-dependent, and similar results were obtained for young grey mullets by De Silva and Perera (1976). In young mullet, food intake was highest at <1‰ S and lowest at 30‰ S. The higher intake at <1‰ S probably leads to a lowering of the rate of digestion. It is also possible that both food intake and digestion are interrelated to the metabolic cost for osmoregulation. There are no data, however, available at present on the metabolic cost and its relationship to osmoregulation in the grey mullet.

Digestion is known to proceed faster when food consumption is increased. Baur (1969), working on Clear Lake bullhead, found that when meal size was tripled the digestion rate increased 2.4 times. Similar results were reported by Hunt (1960) and Windell (1966) for other species. The opposite trend observed in the present experiments may be due to the intervention of an additional factor, salinity, the effects of which on the rate of digestion is yet to be understood. Winberg (1956) showed that food intake is directly related to metabolic expenditure. Since digestion is an intermediate step in the transformation of food energy to metabolic energy, it follows that digestion could also be affected by salinity. Thus, a higher food intake along with a slower digestion rate at <1‰ S may be a response to a combination of salinity with other metabolic factors (Alderdice, 1972). Further, the role played by the gut of young grey mullet in osmoregulation may be an additional factor on which the rate of digestion is dependent.

An artificial diet was used in the present study, but this should not affect the validity of the results, on a relative basis, obtained under different experimental conditions. According to Kapoor *et al.* (1975), gastric emptying in fish is a complex and complicated process, and is incompletely understood; it may be dependent on the quality and quantity of food, gastric motility, rate of secretion of gastric juices, and the capacity of the intestine to accept chyme from the stomach. The present study has clearly shown that in young grey mullet, and probably in euryhaline fish in general, salinity is an important factor determining gastric digestion and/or evacuation, and therefore food assimilation and thereby growth.

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Literature Cited

Alderdice, D.F.: Factor combinations. Responses of marine poikilotherms to environmental factors acting in concert. *In*: Marine ecology, Vol. 1 Part 3. pp 1659-1722. Ed. by O. Kinne. London: Wiley-Interscience 1972

Barrington, E.J.W.: The alimentary canal and digestion. *In*: The physiology of fishes, Vol. 1. pp 109-161. Ed. by M.E. Brown. London: Academic Press 1957

Baur, R.J.: Digestion rate of the Clear Lake black bullhead. Proc. Iowa Acad. Sci. 77, 112-121 (1969)

Bernard, F.: La digestion chez les poissons. Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble *43*, 61-95 (1952)

Davies, P.M.C.: Food input and energy extraction efficiency in *Carassius auratus*. Nature, Lond. *198*, p. 707 (1963)

- The energy relation of *Carassius auratus* L. I. Food input and extraction efficiency at two experimental temperatures. Comp. Biochem. Physiol. *12*, 67-80 (1964)

De Silva, S.S. and P.A.B. Perera: Studies on the biology of young grey mullet, *Mugil cephalus* L. I. Effect of salinity on food intake, growth and food conversion. Aquaculture *7*, 327-338 (1976)

- - Studies on the biology of young grey mullet, *Mugil cephalus* L. III. Aspects of the chemical biology. (In preparation)

- and M.J.S. Wijeyaratne: Studies on the biology of young grey mullet, *Mugil cephalus* L. II. Food and feeding. Proc. F.A.O. tech. Conf. Aquacult. (Kyoto, Japan) 1-12, 1976

Gerking, S.D.: Influence of the rate of feeding on body composition and protein metabolism of bluegill sunfish. Physiol. Zoöl. *28*, 267-282 (1955)

Hunt, B.P.: Digestion rate and food consumption in Florida gar, warmouth and large mouth bass. Trans. Am. Fish. Soc. *89*, 206-210 (1960)

Kapoor, B.G., H. Smit and I.A. Verighina: The alimentary canal and digestion in teleosts. Adv. mar. Biol. *13*, 109-239 (1975)

Kinne, O.: Growth, food intake and food conversion in a euryplastic fish exposed to different temperatures and salinities. Physiol. Zoöl. *33*, 288-317 (1960)

Luther, G.: The food habits of *Liza macrolepis* (Smith) and *Mugil cephalus* L. Indian J. Fish. *9*, 604-626 (1962)

Maynard, A.L. and K.J. Loosli: Animal nutrition, 533 pp. New York: McGraw Hill 1962

Odum, W.E.: The ecological significance of fine particle selection by the striped mullet, *Mugil cephalus*. Limnol. Oceanogr. *13*, 92-98 (1968)

- Utilization of the direct grazing and plant detritus food chains by the striped mullet *Mugil cephalus*. *In*: Marine food chains, pp 222-240. Ed. by J.H. Steele. Edinburgh: Oliver & Boyd 1970

Pandian, T.J.: Intake, digestion, absorption and conversion of food in the fishes *Megalops cyprinoides* and *Ophiocephalus striatus*. Mar. Biol. *1*, 16-32 (1967a)

- Transformation of food in the fish *Megalops cyprinoides*. II. Influence of quantity of food. Mar. Biol. *1*, 107-109 (1967b)

Perera, P.A.B.: Contributions to the biology of young grey mullet, *Mugil cephalus* L. and its potential as a culturable species in Sri Lanka, 178 pp. M. Sc. thesis, Vidyalankara Campus, University of Sri Lanka 1976

Ricker, W.E.: Utilization of food by bluegills. Invest. Indiana Lakes Streams *3*, 311-319 (1946)

Seaburg, K.G. and J.B. Moyle: Feeding habits, digestion rates and growth of some Minnesota warm water fishes. Trans. Am. Fish. Soc. *93*, 269-285 (1964)

Suzuki, K.: Biology of the striped mullet, *Mugil cephalus* L. I. Food contents of young. Rep. Fac. Fish. prefect. Univ. Mie *5*, 295-305 (1965)

Western, J.R.H.: Feeding and digestion in two cottid fishes, the freshwater *Cottus gobio* L. and the marine *Enophrys bubalis* (Euphrasen). J. Fish Biol. *3*, 225-246 (1971)

Winberg, G.G.: Rate of metabolism and food requirements of fishes. Nauch. Trudȳ belorussk. gos. Univ. V.I. Lenina 1-253 (1956). [Transl. Fish. Res. Bd Can. No. 194]

Windell, J.T.: Rate of digestion in the bluegill sunfish. Invest. Indiana Lakes Streams *7*, 185-214 (1966)

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