DISCUSSION
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MORPHOLOGY AND ANATOMY

Fishes are generally known to have great differences in their food and feeding habits. The morphology of the digestive tract in Indian freshwater fishes undergoes extensive variations due to the nature of food ingested - a feature amply elaborated (Sarbahi, 1939; Islam, 1951; Kapoor, 1953, 1957c, 1958a, b; Das and Moitra 1956 b, c, 1958; 1961, 1962; Mohsin, 1962; Pasha, 1964a, b, c; Khanna and Mehrotra, 1971; Moitra and Sinha, 1971; Sinha and Moitra, 1975a, b, 1976; Moitra and Roy, 1977, 1979, 1980). By using the percentage of ingested food/annum as a criterion, Das and Moitra (1963) have categorised the freshwater fishes of Uttar Pradesh, India, into three primary feeding types viz., the herbivores, the omnivores and the carnivores. They have noticed that the herbivores feed mainly on plant food comprising algae and higher aquatic plants which constitute more than 75% of the average annual feed. The omnivores ingest almost equal amounts of plant and animal food - the plant food component ranging from 11.9% to 79.1% and animal food from 14.6% to 78.1% on an average/annum. The latter category
maintains an intermediate position between the herbivores and carnivores, and is able to change over from one type of food to the other according to change in environmental conditions. They have further sub-divided the omnivores into herbi-omnivores, which feed more extensively on plant food and the carni-omnivores, which feed on larger amounts of animal food. The carnivores feed more on animal food forming more than 80% of the total annual feed. Another system of classifying the freshwater fishes of Uttar Pradesh, India, was proposed by employing the feeding affinities to particular water levels by Das and Moitra (1955c). Thus, they arranged the fishes in three secondary groups - the surface-feeders, the mid-feeders and the bottom-feeders. *M. cavasius* is an omnivorous bottom feeder ingesting mainly higher aquatic plants, byyozoans, crustaceans, insects and their larvae and molluscs. According to Das and Moitra (1963), however such a fish should have been categorised as a mid­feeder due to the comparatively large amounts insects, insect larvae and crustaceans in the diet in addition to molluscs and sand.
The alimentary canal

The mouth:

The structure and position of mouth in fishes are related to the nature of their feeding habits. Nikolsky (1963) categorised mouths of the fishes into six types viz., (a) grasping mouth, (b) sucker mouth, (c) imbibing mouth, (d) crushing mouth, (e) planktophagic mouth and (f) periphyton-eating mouth on the basis of their structure and function. With regard to the mode of feeding, he described the position of mouth as dorsal, terminal and ventral. The mouth of *M. cavasius* is wide, raised, non-protractile and bounded by thick upper and lower lips. A wide mouth has been observed by Khanna (1962) in *Muraenesox telabon, Harpodon nehereus, Notopterus notopterus, Channa (Ophicephalus). marulius*, Khanna and Pant (1964) in *Mystus seenghala* - all carnivorous fishes and by Weisel (1973) in the plankton filter feeder, *Polyodon spathula*. According to Nikolsky (1963), a large mouth is generally found in the predators. Thus, the wide mouth *M. cavasius* may be regarded as a grasping mouth developed as a result of its predatory habits. The slightly upturned mouth may be due to the mid-feeding habit.
Bucco-pharyngeal region:

The bucco-pharyngeal region of all *M. cavasius* is provided with well developed teeth. Suyehiro (1942) observed that fishes which are devoid of efficient swimming abilities, are provided with well developed teeth in order to enable them to hold on to the prey. Al-Hussaini (1947b) stated that pointed and conical teeth are usually present in carnivorous predatory fishes. Khanna and Mehrotra (1970) believe that a precise relationship cannot be established between the extent of dentition and feeding habits. They consider this feature to depend on the environment to which the fishes get adapted. Mahadevan (1950), Kapoor (1953, 1954b), Das and Moitra (1956c), Khanna (1962), Das and Nath (1965), Khanna and Mehrotra (1970), Subla (1970) and Sriwastawa (1970a) Moitra and Ray (1977, 1979) also recorded the presence of well developed teeth in the bucco-pharyngeal region in many carnivorous species. According to Das and Moitra (1956c), the bucco-pharyngeal region of carnivorous fishes bears highly specialized teeth for seizing, holding and tearing the ingested prey. Khanna (1962) studied the special development of teeth and gill rakers in some predatory species. *M. cavasius* may be designated as carnivorous. The bucco-pharyngeal region of *M. cavasius* has an extremely efficient dentition. The jawa
are provided with highly specialized teeth. The maxillary and mandibular teeth are strong pointed and directed inwards. The latter help in seizing the prey and thereafter tearing it. Similar observations have also been made by Das and Moitra (1956c), Das and Nath (1965) and Khanna and Mehrotra (1970). These workers consider the backwardly directed teeth present in the jaws of carnivorous species, do not assist in crushing but help to prevent the escape of prey. In *Ambassis nama* and *Ambassis ranga*, such teeth are small, strong, sharp, hooked and capable of securing small slender animals (Moitra and Roy, 1979). Since these fishes do not grow to a large size in life, the food organisms ingested too, are relatively small organisms. In the omnivorous *Colisa fasciata*, small and feeble teeth are present on the upper and lower jaws (Moitra and Ray, 1977). Omnivorous fishes have been observed to possess a combination of granular and conical teeth (Al-Hussaini, 1947b). Das and Moitra (1956c) stated that in omnivorous fishes there is a gradation in nature of dentition from the herbivorous to the carnivorous condition. Das and Moitra (1956c), Das and Nath (1965) and Khanna and Mehrotra (1970) recorded edentulous mouths in some omnivorous species studied by them. Das and Moitra (1956c), however, reported the presence of well developed jaw teeth in the omnivore, *Eutropiichthys cacha* and stated
that these structures are adapted for biting and holding the pery. *M. cavasius* is provided with palatine, pharyngeal and horny pad teeth in the bucco-pharyngeal region. All these teeth are large and very strong. Das and Moitra (1956c) suggested that gill-rakers, pharyngeal and other teeth are also responsible as supplementary structures for seiving, crushing and mastication of food in fishes. Das and Nath (1965) have also made similar observations. Khanna and Mehrotra (1970) remarked that these teeth probably serve to prevent the regurgitation of food from the gullet. In fact all these teeth work against each other for trituration and mastication of the food ingested. In *Anabas testudineus*, the palatine, pharyngeal and horny pad teeth the stronger than those in *Ambassis nama* and *Ambassis ranga* so that the complex food including worms and molluscs can be crushed more efficiently (Moitra and Ray, 1977, 1979).

Popta (1900) studied the structure and disposition of the gill-rakers in some teleosts and remarked that they are specifically peculiar and diagnostic in all the species. He described their development and arrangement in relation to the structure of mouth and nature of food. Zander (1903) observed the presence of teeth-like gill-rakers in the carnivorous types such as *Esox* and *Lucioperca*. Khann and Mehrotra (1970) consider that gill-rakers may not always be
adapted to the feeding habits of fish. The function of the
gill-rakers in carnivorous species have been described by
several workers. Imms (1904) described the gill-rakers of
Polyodon spathula and found them to be setiform structures
which function as a straining mechanism and prevent the
escape of microscopic food organisms ingested. Al-Hussaini
(1947b) noted gill-rakers to be short or absent in the
carnivorous fishes except in Pterois in: which they are spiny
and assist in catching prey. Kapoor (1953, 1958a, 1965) and
Khanna (1962) observe that in carnivorous fishes, the gill-
rakers have been modified to form pointed teeth-like
structures and help in macerating and preventing the escape
of ingested food. Mahadevan (1950) reported on the gill-
rakers of the posterior gill arches of Caranx and Trichurus,
both of which are carnivorous and found them to be rudimentary
in nature. Das and Moitra (1956c) and Das and Nath (1965)
consider that gill-rakers of carnivorous fishes are modified
for grasping and preventing the escape of the prey in
addition to rasping and crushing the food in the freshwater
fishes studied by them. Khanna and Mehrotra (1970), however,
hold that the "the gill-rakers increase the armature of the
fish and supplement the teeth to prevent the escape of the
slippery prey and are also used for rasping it but they
do not appear to be useful as organs of trituration or
crushing the food". Khanna and Mehrotra (1970), however,
recorded the absence of gill-rakers in the predatory and piscivorous fish, *Muraenestox telabon*. Gill rakers are modified into flat plate like structures with pointed teeth in the carnivorous *Ophicephalus striatus* (Das and Moitra, 1956c, Khanna and Mehrotra, 1970) and *Ophicephalus punctatus* (Das and Nath, 1965). Das and Moitra (1956c) consider that the gill-rakers of *Ophicephalus striatus* are used for trituration of food. Singh (1967a) remarked that the gill-rakers of *Ophicephalus marulius* are used for holding and crushing the prey. It may, therefore, be concluded that the *M. cavasius* also, which is a carnivorous fish, the gill-rakers may be employed for similar functions. It is therefore quite reasonable to conclude that the highly carnivorous and predaceous nature of feeding have induced these adaptive modifications in the gill-rakers. Thin and long gill-rakers in herbivorous fishes have been reported to perform a sieving function (Girgis, 1952b; Das and Moitra, 1956c; Khanna, 1962). In omnivorous fishes, gill-rakers have been reported to be short in *Rutilus* (Al-Hussaini, 1949b), longest in *Clarias lazera* (Al-Hussaini and Kohly, 1953), teeth-like processes in *Puntius sophore* and *Eutropiichthys vacha* (Das and Moitra, 1956c), short and stumpy in *Barbus sarana* (Khanna, 1962) and *Tor tor* (Khanna and Mehrotra, 1970), thorn-like processes in *Puntius conchonius* and *Barbus hexastichus* (Das and Nath, 1965) and knob-like projections
in *Mystus gulio* (Pasha, 1964a). But *Colisa fasciata*, being an omnivorous fish, possesses thin, long and elongated gill-rakers which are used for straining the planktonic food from the incurrent water (Moitra and Ray, 1977). Such gill-rakers which may also form a sieve, have been recorded by Al-Hussaini (1947a) in *Atherina forskali* and Khanna and Mehrotra (1970) in *Tor tor*.

In *M. cavasius* a tongue is present in the anterior region on the floor of the buccal cavity. It is in the form of a mucosal thickening. The fish tongue is known to have various functions. Suyehiro (1942) observed that a primitive tongue in fishes helps in controlling ingested prey to some extent. Tandon and Goswami (1968) stated that in *Channa* species, it aids the teeth in retention of prey and compensates for the lack of barbels and other integumentary sense organs. Schmitz and Baker (1969) observed that the protrusible tongue in the microphagous, *Dorosoma petenense* assists in occasional Zooplankton predation. Khanna (1959) considers that the tongue is more extensively developed in carnivorous fishes, particularly the fish-eaters. The tongue of *M. cavasius* therefore, may be employed for retaining large prey as has been reported also by Tandon and Goswami (1968).
Oesophagus:

The oesophagus is a broad, short and thick-walled tube in *M. cavasius*. Several workers have described the oesophagus as a short and narrow tube in many herbivorous and omnivorous fishes (Curry, 1959 in *Cyprinus carpio communis*; Sarbahi, 1939 in *Labeo rohita*; McVay and Kaan, 1940 in *Carassius auratus*; Girgis, 1952b in *Labeo horie*; Kapoor, 1957c, 1958b in *Barbus stigma* and *Catla catla*; Chaudhury and Khandelwal, 1961 in *Orienus plagiostomus*; Al-Hussaini, 1947b, 1949a in a number of teleosts and Khanna, 1961 in *Barbus sarana* and *Tetradon fluviatilis*).

Mehrotra and Khanna (1969) consider that carnivorous and piscivorous fishes which prey on larger organisms, possess a longer and distensible oesophagus. A similar oesophagus has been described in the carnivores *Muraenesox telabon*, *Harpodon nehereus* and *Channa striatus*, but a short and narrow oesophagus has been reported in the omnivore, *Tor tor* (Mehrotra and Khanna, 1969). Pasha (1964a) observed that the oesophagus in the omnivore, *Mystus gulio* to be a dorso-ventrally flattened tube and a cylindrical short tube in the herbivore, *Tilapia mossambica* (1964b).

Venkateswarlu (1966) observed the oesophagus to be a short, slender, cylindrical tube in twelve species of Gobiids examined by him and remarked that structurally there is
almost no difference in the nature of the oesophagus between herbivorous and carnivorous species. Khanna (1961) observed that the oesophagus is extremely reduced in size in the stomachless fishes. In the present studies however a short and tubular oesophagus has been observed in *M. cavasius*. Mehrotra and Khanna (1969) consider a sac-like stomach with thick musculature generally allows distension and serves the purpose of storage of food and its digestion. The muscular nature of the sac helps in crushing food (Khanna, 1961). Nikolsky (1963) observed that the stomach is generally large in fishes which swallow large prey, or ingest large amounts of food at a time. Naturally, the presence of the sac-like large stomach in *M. cavasius*. The powerful muscles of the stomach probably helps in crushing food. The stomach of *Ambassis nama* and *Ambassis ranga* is tubular and quite muscular. The pyloric region is short and there is a distinct constriction at its junction with the cardiac end (Moitra and Ray, 1974). A similar type of stomach has also been observed in *Glossogobius giuris* (Das and Moitra, 1956b, Mohsin, 1961) and some other Gobiids (Venkateswarlu, 1966). This type of a stomach is developed as a result of the predominance of small animal food in the dietary. The highly developed muscle arrangement of the stomach assists in
crushing the ingested food. The stomach of *Colisa fasciata* is gizzard-like and divided into a thinwalled cardiac and thick-walled pyloric regions (Moitra and Ray, 1977). The latter is more muscular than the former. The presence of a gizzard-like stomach has also been described in *Mugil cephalus* (Ishida, 1935b), *Dorosoma cepedianum* Wier and Churchill, 1945) *Ambassis nama* and *Ambassis range* however, possess short and narrow oesophagus through which smaller food particles like, micro-crustaceans and insect larvae are able to pass (Moitra and Ray, 1979). A similar type of oesophagus has also been described by Sarkar (1959) in *Mystus (Osteobagrus) seenghala*, which according to him, is also a carnivorous fish. In the omnivorous *Colisa fasciata*, the presence of a narrow and long oesophagus probably has some relationship to the mixed diet it consumes. The oesophagus in *M. cavasilus* is bears narrow, branched longitudinal folds which aid in the onward transmission of the food particles into the stomach by peristaltic action.

**Stomach:**

The capacity of the stomach in fishes depends to a great extent on the feeding behaviour especially on the nature and size of the prey (Nikolsky, 1963).
Barrington (1957), however, believes that the morphology of the stomach cannot always be correlated with the type of food ingested. The stomach is known to be a region for storage and digestion of food (Kapoor, 1953; Chandy and George, 1960; Mehrotra and Khanna, 1969). Nikolsky (1963) states that the food bolus is not only comminuted and incompletely digested in the stomach, but the prey may even be killed there. Al-Hussaini (1947b) considers two factors - the duration of interval in between meals and the nature of diet, to influence the size of the stomach. A well formed muscular stomach is present in *M. cavasius*. In *Colisa fasciata* it is divided into cardiac and pyloric regions (Moitra and Ray, 1977) but in *Ambassis nama* and *Ambassis range*, the pyloric region is extremely short (Moitra and Ray, 1979). The presence of cardiac and pyloric stomach in fishes has also been reported by many other workers (Mohsin, 1946, 1962; Chandy and George, 1960; Khanna, 1961; Pasha, 1964b; Khanna and Pant, 1964; Agarwal and Sharma, 1966a; Tandon and Goswami, 1968; Mehrotra and Khanna, 1969). Some workers describe three discrete regions in the fish stomach viz., cardiac, pyloric and fundic regions (Kapoor, 1953; Sarkar, 1959; Saxena and Bakhshi, 1964). Pasha (1964a), however reports the stomach of the omnivore *Mystus gulio* to comprise of two regions
viz., "corpus" and "pyloric" portions. The stomach in
*M. cavasius* is a thick-walled, muscular sac-like structure.
The presence of a sac-like stomach has also been reported
by Kapoor (1953) in *Wallago attu*, Sarkar (1959) in *Mystus*
(Osteobagarus) *seenghala*, Khanna (1961) in *Notopterus*
notopterus, *Clarias batrachus*, *Engraulis telara*, *Mystus*
aor, *Sciaena coitor*, *Mugil corsula*, *Silonia silondia*
and *Hilsa ilisha*, Chitray (1965b) in *Bagarius bagarius*,
Das and Nath (1965) and Tandon and Goswami (1968) in
*Ophicephalus* (Channa) punctatus and Mehrotra and Khanna
*Mulloides auriflamma* (Al-Hussaini, 1946), *Mugil tade*
(Pillay, 1953), *Gadusia chapra* (Kapoor, 1958a), *Chanos*
chanos (Chandy and George, 1960), *Hilsa ilisha* and *Mugil*
cephalus (Khanna, 1961) and *Mystus vittatus* (Agarwal and
gizzard-like stomach occurs in fishes which do not possess
a well developed pharyngeal masticatory apparatus. The
presence of a strongly muscular gizzard-like stomach in
*Colisa fasciata* may be probably due to the weak and minute
pharyngeal and horny pad teeth in the bucco-pharyngeal
region which are of little consequence in mastication
(Moitra and Ray, 1977). Chandy and George (1960) and
Khanna (1961) stated that a muscular gizzard like stomach
in fishes is probably an adaptation to a diet containing large quantities of sand or mud. The mucosal folds of the stomach, in *M. cavasius* are thick and longitudinal in nature. The stomach of *Ambassis ranga* is provided with zigzag longitudinal folds (Moitra and Ray 1979). The closely set longitudinal mucosal folds in the pyloric stomach of *Colisa fasciata* are probably developed for helping in triturating and crushing the ingested food (Moitra and Ray, 1979).

**Intestine:**

The length of the intestine varies in relation to that of the body from species to species (Barrington, 1957). Das and Moitra (1956b, 1958) reported that the ratio between the gut-length and the body-length is approximately constant in any given species of fish. Jacobshagen (1913) remarked that carnivorous teleosts possessed shorter intestines while plant and mud-feeders have a longer ones. Al-Hussaini (1947b) observed the intestine to be a straight tube in certain carnivores such as *Belone* and *Sphyraena* and complicated and arranged in coiled loops in the herbivores. The length of the intestine is considered to be longest in the herbivores, shortest in the carnivores.
with intermediate in length in the omnivorous ones (Mookerjee and Das, 1945; Islam, 1951; Das and Moitra, 1956b, c, 1958; Kapoor, 1958a; Khanna, 1961; Kapoor et al. 1956b, c, 1958; Kapoor, 1958a; Khanna, 1961; Kapoor et al. 1956b, c, 1958; Kapoor, 1958a; Khanna, 1961). Al-Hussaini (1947b), however, found the shortest intestine in the plankton-feeders, the longest in the herbivores and an intermediate type in the carnivorous species. In the present studies, it has been observed that the intestine in _M. cavasius_ is short and the relative length of the gut (R.L.G.) is low (0.77). Al-Hussaini (1947b) noted a looped intestine in _Pterois_, which is a voracious and carnivorous fish. Khanna (1961) and Sinha and Moitra (1975a) believe that the type of food ingested by a fish may influence the intestinal length. The present observations are in agreement with their opinion. Barrington (1957), however, considers that more that one factor appears to be responsible for determining the relative length of the gut. Pasha (1964a) recorded a short intestine in the omnivore, _Mystus gulio_ and a long and coiled one in the herbivore, _Tilapia mossambica_ (1964b). Moitra and Sinha (1971) also found a low R.L.G. (1 to 1.3) in the omnivorous fish, _Chagunius chagunio_ but observed that this did not, however, indicate a tendency towards carnivory since the shorteness of the intestine was amply compensated by the compactness and complexity of the villi which
increased the total absorptive area. Al-Hussaini (1949a) and Unnithan (1965) have also demonstrated that the shortness of the intestine in a fish may be compensated by the increase in the complexity of its average mucosal area. Unnithan (1965) found a larger mucosal area in Trichogaster fasciatus as compared to those in the Carnivorous, Heteropneustes fossilis and Glyptosternum reticulatum.

After careful examination of the mucosal folds, the intestine of M. cavasius studied during the course of the present investigations, has been divided into three regions—the anterior, middle and posterior. Khanna and Mehrotra (1971) also considered the intestine along similar lines on the basis of differences in its mucosal folds in Tor tor, Channa striatus, Harpodon nehereus, Muraenesox telabon and Ilisha filigera. In Ambassis nama and Ambassis ranga the mucosal folds are longitudinal in nature throughout the length of the intestine but in Colisa fasciata, the posterior intestine is provided with transverse mucosal folds. These folds are less raised in the intestine of Colisa fasciata (Moitra and Ray, 1977, 1979). The specialised type of mucosal folds have developed in this species for the retention of food for longer periods so as to ensure proper digestion, absorption and assimilation (Moitra and Sinha, 1971).
Rectum:

In *Ambassis nama*, *Ambassis ranga* and *Colisa fasciata*, the rectum is difficult to distinguish from the intestine externally (Moitra and Ray, 1979). In *M. cavasius* however, it may be distinguished from the rest of the intestine by the presence of an ileo-rectal valve. In the former three fishes, it may be differentiated by the nature of the mucosal folds, which are shorter, shallower and longitudinal. Rogick (1931), McVay and Kaan (1940), Girgis (1952b), Kapoor (1957c 1958b), Sarkar (1959), Sriwastwa (1970a) and Khanna and Mehrotra (1971) could not identify the rectum externally from the intestine proper in the fishes studied by them. Khanna and Mehrotra (1971), however, observed the presence of an ileo-rectal valve in *Muraenotesox telabon*. In many fishes, the presence of an ileo-rectal valve has been recorded by several workers (Dawes, 1929; Blake, 1930; Al-Hussaini, 1946, 1947a; Khanna, 1961). This valve probably helps in the expulsion of faecal matter. Barrington (1957) considers the hind gut not to be sharply differentiated externally from the mid-gut in teleosts but the occurrence of the valve in addition to certain histological peculiarities justify its recognitions as a region concerned with final expulsion of the faeces. The rectum is the region where the
undigested food is lubricated for final ejection. The wall of the rectum in *M. cavasius* has been found to be muscular and thick. This helps in contraction and expansion of the rectal wall for facilitating expulsion of the faecal matter.

**Digestive gland and associated structures:**

The hepatopancreas is the main digestive gland in *M. cavasius*. Pancreatic acini are present in a primitive diffused state and lie in dispersed condition within the lobes of the hepatic tissue and mesenteries, along the sides of the alimentary canal and gall bladder. A compact and discrete pancreas could not be identified. It has not been possible to distinguish the pancreatic tissue morphologically from the hepatic tissue in which it is incorporated. A similar nature of diffused pancreas has been described by Smallwood and Derrickson (1934) in *Cyprinus carpio*, Sarbahi (1939, 1951) in *Labeo rohita* and *Carassius auratus*, Argaud and Gan (1945) in *Anguilla vulgaris*, Ganguly and Sarkar (1949) in *Mugil parsi*, Seshadri (1961) in *Ophicephalus striatus* and Khanna (1963a,b) in *Ophicephalus punctatus*, *Catla catla* and *Ophicephalus striatus*. Ganguly and Sarkar (1949), however, were able to distinguish the pancreatic tissue in the liver only in *Ophicephalus punctatus*. Slipper (1946)
classified the distribution of pancreas in teleosts into five types viz., i) pancreas compactum, ii) pancreas diffusum, iii) pancreas disseminatum, iv) pancreas juxtahepaticum and v) pancreas hepaticum. In the present investigation, both pancreas diffusum and hepaticum of Slipper's classification have been recorded. Khanna (1963a) considers that the structural variations in the pancreas of teleosts, do not appear to be related either to the nature of the food or to the relative length of the alimentary canal. The present observation appears to support Khanna's view as the same type of pancreas has been found in M. cavasius although the fish differ in its food and feeding habits.

The gall bladder is a thin-walled, greenish body lying below the right lobe of the hepatopancreas in M. cavasius. It communicated with the intestine by means of bile duct. The structure and position of the gall bladder does not reflect the feeding habits of the fish.
Studies on certain preliminary aspects of the physiology of digestion of *M. cavasius* has been undertaken during the course of the present investigations. As the pancreas is diffused it is difficult to locate the exact site of enzyme secretion in many teleosts (Barrington, 1957; Kapoor *et al.*, 1975b). The digestive enzymes in fishes originate in the gastric mucosa, the pyloric caeca, the pancreas and the intestinal mucosa, *which are known to secrete several enzymes that hydrolysing are capable of proteins, carbohydrates and fats* (Kapoor *et al.*, 1975b). The activities of protease, lipase and amylase in the stomach, intestine and the hepatopancreas have been observed and an attempt made to correlate their activities with the food and feeding habits of the fish studied.

**Protease activity:**

The mechanism of digestion of protein food ingested by fishes has been described by many workers. Pepsin and hydrochloric acid are known to be secreted by the gastric mucosa. In stomachless fishes however, both pepsin and hydrochloric acid are absent. Barrington (1957) considered the gastric protease as peptidases and remarked
that the earlier subdivision of proteases into proteinases (hydrolyzing native proteins) and peptidases (hydrolyzing oligopeptidases) is no longer in vogue. The identification of pepsin in the gastric contents and mucosal extracts of fish depends upon its hydrolysis of protein substrates, such as gelatin (Bodansky and Rose, 1922), fibrin (Vonk, 1927), casein (Bayliss, 1935), haemoglobin (Alliot et al., 1974) and upon the determination of its optimum pH. Vonk (1929) observed the maximum activity of pepsin in the gastric mucosa at about pH 2 when fibrin was used as a substrate. He (1937) remarked that the gastric protease - pepsin, is present in all vertebrates except the stomachless fishes with an optimal proteolytic activity in the neighbourhood of pH 2. Bayliss (1935) observed that the stomach of the plaice, Pleuronectes platessa is capable of digesting proteins by an extracellular enzyme probably pepsin, at pH 2 if casein is used as a substrate. Kapoor et al (1975b) observed that at a given enzyme concentration, the gastric juice indicates maximum proteolytic activity at pH values lower than 4. Kitamikado and Tachino (1960b) observed an acidic protease in the stomach of rainbow trout at optimum temperatures of 35-40°C after digestion of casein for 24 hours. Alliot et al (1974) reported that the stomach extracts of Dicentrarchus labrax indicate a strong activity of protease
in the acidic range. He regarded this gastric protease as analogous to pepsin. Besides the effect of the pH of the gastric contents, proteolytic digestion is also enhanced by a high pepsin concentration, high temperatures and active stomach mobility (Kapoor et al., 1975b). Proteases are known to be remarkably specific in their requirements for specific types of peptide bonds, e.g., pepsin and trypsin, which can react with protein chains only at specific points (Barrington, 1957). Hence protease activity in the stomach of *M. cavasius* studied during the course of present investigations, may be considered to be similar to pepsin as reported by Alliot et al. (1974) since the gastric glands of the stomach secrete hydrochloric acid and pepsinogen which in effective combination split large protein molecules. Barrington (1957), however, considers that the exact nature of pepsin throughout the vertebrate series cannot be finally settled at the level of analyses so far described.

Beauvalet (1933a,b) observed that the intestinal secretion of protease was of little consequence in fishes possessing stomachs, but that such secretion assume considerable importance in stomachless fish. Al-Hassaini (1949b) agreed with the latter view and remarked that secretions of the intestine in fishes with a stomach do not affect proteins
to any significant degree and the disappearance of the stomach, as in cyprinids, is amply compensated by the production of the pancreatic "trypsin" with an intestinal enzyme of the same nature. An intestinal protease, which is very active in an alkaline pH has been found in several fishes and this is normally considered to exhibit "tryptic" activity (Barrington, 1957; Kapoor et al. 1975b). Barrington (1957) and Kapoor et al (1975b) consider that the exact localization of proteolytic enzyme is difficult in fishes on account of the diffused nature of the pancreas in many of them. Whether the protease is secreted exclusively by the pancreas or that the intestine also participates in its secretion is still not clear. Bayliss (1935), tried to investigate whether the pancreas was the only source of "trypsin" or whether some production also occurred in the intestine. He compared the activity of caecal extracts with those of the more posterior intestine which could be freed from the pancreas. Kapoor et al. (1975b) proposed that it is more appropriate to reserve the term "trypsin" for the pancreatic proteolytic enzyme that is active in between pH 7 to 11, depending on the nature of the substrate. The trypsinogen activity of the bile and the extracts of the liver may, therefore, be the result of mixing with the
pancreatic tissue. Sullivan (1907), found the extracts of the shark pancreas to contain "trypsin" usually in an inactive form. This could be activated by extracts of the intestine presumably produce the activating enterokinase although it does not have any digestive activity itself. Trypsin is an important proteolytic enzyme present in the alimentary system of fish, which is possibly identical with mammalian trypsin Kapoor et al (1975b) Pancreas to be the main source of trypsin.

Protease activity has been recorded in the stomach, intestine, hepatopancreas in M. cavasius. The intestine and hepatopancreas showed more pronounced protease activity probably indicating that the fish is more adapted to digest protein food. Agrawal and Singh (1963) recorded protease activity in the liver of Colisa fasciata only and stated that no proteolytic enzymes are secreted either in the stomach or in the intestine. Agarwal and Dalela (1966) in Rhynchobdella aculea, Agarwal and Sharma (1966b) in Nandus nandus, Gaur and Jaish (1970) in Channa gachua and Tyagi (1970) in Mystus vittatus have also reported the presence of a proteolytic activity in the liver only. MacKay (1929a), was unable to identify any protease in extracts of liver and intestine of Zoarces
but determined a strong protease activity in the stomach at an optimum pH range of 6.4 to 8.2. He concluded that the enzyme possibly originated in the pancreas. Fish (1960) reported a stronger proteolytic activity in the stomach extracts of *Tilapia* and perch than those from any other tissue in an acid medium employing haemoglobin as a substrate. In an alkaline medium however, he recorded a reverse activity of protease. Several authors have also recorded protease activity in the stomach (Kenyon, 1925; Vonk, 1929; Bavliss, 1935; Norris and Elam, 1940; Sarbahi, 1951; Norris and Mathies, 1953; Kitamikado and Tachino, 1960b; Morishita et al. 1964; Nagase, 1964; Kandyuk, 1967; Moitra and Das, 1967; Alliot et al. 1974), intestine (Polimanti, 1912; Baylise, 1935; Al-Hussaini, 1949b; Kitamikado and Tachino, 1960b; Nagase, 1964; Kandyuk, 1967; Moitra and Das, 1967; Alliot et al. 1974) and pyloric caeca (Sarbahi, 1951; Stern and Lockhart, 1953; Croston, 1960; Kitamikado and Tachino, 1960b; Ooshiro, 1971; Alliot et al. 1974; Kalac, 1975) of different fishes investigated by them. Kalac (1975) stated that the pyloric caeca proteases of mackerel, *Scomber scombrus* occur in an inactive zymogen state. Alliot et al. (1974) reported a higher proteolytic activity in the extracts from the pyloric caeca and pancreas than from the intestine in the carnivorous teleost,
**Dicentrarchus labrax.** A proteolytic activity in the mixed liver and pancreas has been reported by Sarbahi (1951) in goldfish and large mouth bass. Agarwal and Sharma (1966b) in *Nandus nandus*, Stroganov and Buzinova (1969) in *Ctenopharyngodon idella* and Sinha (1977c) in *Cirrhinus mrigala*, but unfortunately they have been able to localise the exact source of the enzyme secretion. In the present investigation, the hepatopancreas indicated protease activity but the specific source of the enzyme could not be determined on account of the composite nature of the liver and pancreatic tissues. Babkin and Bowie (1928) identified "tryptic" activity in the liver and bile of *Fundulus* and observed that the enzyme could have originated in the pancreas since the bile itself was free of any enzymatic activity. Kapoor et al. (1975b) observed that the gall bladder, being surrounded by pancreatic tissue, shows greater proteolytic activity between pH 7.5 and 8.5. They observed that as the gall bladder extract was increased by the addition of intestinal extract, an enterokinase activity may be presumed. In the present investigations, it was also noted, that bile indicated a proteolytic activity possibly motivated by the surrounding pancreatic tissue as no precaution was taken to inactivate
the pancreatic enzyme prior to the collection of bile, a procedure adopted by Mackay (1929b).

**Lipase activity:**

Fishes may ingest fatty material along with their natural diet which are generally known to be utilized (Kapoor et al. 1975b). These lipases hydrolyse the fatty components of the food and as in the case of hydrolysis of proteins and carbohydrates, this process is also a progressive one. The occurrence of lipase in the alimentary system has been shown in several fishes (Sullivan, 1907; Vonk, 1927; Babkin, 1929; Beauvalet, 1933a; Schlottke, 1939; Ishida, 1936; Sarbahi, 1961; Gohar and Latif, 1960; Dhage, 1968; Sinha, 1977c). Babkin (1929) demonstrated lipase activity in the pancreatic extracts and juice of *Raja* Sullivan (1907), Vonk (1927) and Beauvalet (1933a) identified lipase activity in the pancreas of the sharks *Scyllium* and *Squalus*. Lipolytic activity has been shown by Chesley (1934) in the pancreas, pyloric caeca and upper intestine extracts of *Scomber*, *Brevoortia*, *Stenotomus* and *Prionotus*. Bayliss (1935) demonstrated lipase activity in the extracts of intestine and liver of *Pleuronectes platessa* but as the pancreas occurs in a diffused condition
inside the liver, the lipase could have been produced there. Chesley (1934) reported evidence of the pancreas participating in lipase secretion in many teleosts. Ishida (1936) also demonstrated lipolytic activity in the pancreas of Salarias, after separating the pancreas from the liver. Babkin and Bowie (1928) observed lipase activity in the intestine of Fundulus. Thus it may be said that the pancreas in most fishes usually indicate lipase activity. Beauvalet (1933b) in Tinca and Cyprinus, Ishida (1936) in Calotomus, Thalassoma and Spheroides, Sarbahi (1951) in Carassius and Sinha (1977c) in Cirrhinus mrigala also observed the occurrence of lipase in extracts of hepatopancreas. Barrington (1957), however, considers that there is no evidence of the pancreas producing lipase, as such an activity might be the property of hepatic tissue. Besides producing bile, the liver converts some of the substances present in the food into beneficial materials essential for the other cells of the body. The liver assumes an important role in lipid metabolism as well. The hepatic cells, accordingly contain a number of enzymes and co-enzymes. Baldwin (1952) considered the lipolytic enzyme of the liver as liver lipase. Hence it is obvious that the actual source of production of lipase in fishes is still to be determined as postulated by Barrington (1957).
Lipolytic activity has been detected in the digestive system of *M. cavasius* during the present studies. The activity has been observed to be strong in the hepatopancreas and intestine. Babkin and Bowie (1928) in *Fundulus*, MacKay (1929a) in *Zoarces*, Ishida (1936) in *Calotomus*, *Spheroides*, *Thalassoma* and Salarias and Nagase (1964) in *Tilapia*, reported a weaker lipase activity in the intestine than in the stomach. On the basis of the present investigations, it may be observed that the enzyme mechanism in *M. cavasius* quite competent to digest the fatty material taken along with their normal food and that the fat digesting enzyme is produced by the hepatopancreas and the intestine. The question regarding the precise source of lipase, however, remains still insolved.

**Amylase activity:**

Work on the carbohydrate splitting enzymes of fishes have been mainly confined to the determination of amylloclastic activity (Barrington, 1957). The occurrence of amylase activity in the alimentary tract of fish has been observed by several authors but the source of the enzyme is till to be established. Babkin (1929) in pancreatic juice of *Raja*, Sullivan (1907) and Beauvalet (1933a) in the
pancreatic extracts of other elasmobranchs, have reported amyloclastic activity and remarked that there appears to be a record of its occurrence in the intestinal mucosa of these forms. In teleosts, however, amylase activity has been reported in the pancreas and intestine, although it has not always been possible to separate the properties of these two organs. Bayliss (1935) reported an amylolytic action in the intestine and liver of *Pleuronectes platessa* which probably was secreted by the pancreatic tissue embedded in the liver surrounding portal vessels, pyloric caeca and the gall bladder. Chesley (1934) identified amylolytic activity in the extracts of the diffuse pancreatic tissue and pyloric caeca of *Brevoortia* and the pancreas and intestine of *Scomber* and *Spheroidees* and stated that the pancreas was the main source of secretion of enzymes, including amylase in the latter two species. Sarbahi (1951) found amylase, maltase and saccharase activity in the extracts of mixed liver and pancreas, oesophagus and intestine of *Carassius* but was unable to detect these enzymes in the alimentary tract of the largemouth bass. McGeachin and Debnam (1960), demonstrated amylase activity in the pyloric caeca, intestine, liver and bile in largemouth bass and bluegill sunfish.
Chesley (1944) considers bile as the main site of amylase action and pancreatic tissue indicated only traces of the enzyme in Brevoortia, Spheroides and Pironotus. In the mackerel, which possesses a compact pancreas, bile did not indicate any amylase activity. Bayliss (1935) could not detect amylase activity in the bile of plaice when it was sampled by cannulating the bile duct. The activity, however, could be demonstrated only when the bile was collected by slitting the gall bladder. Hence the presence of amylase activity in the bile of fish may be caused by the pancreatic tissue which remain dispersed throughout the liver tissue and as a distinct pancreatic duct is not always present, the gall bladder receives pancreatic secretions. Al-Hussaini (1949b) found bile of cyprinids to be "practically devoid of enzymes" but he observed an extremely slight amylolastic activity in Cyprinus and Rutilus. The liver extracts may also be expected to show amylase activity which has been demonstrated by Bayliss (1935) in Pleuronectes who considers that there is no reason to attach digestive significance to this organ unless pancreatic tissue is included in this organ. The activity of amylase has also been recorded in the intestine of Fundulus (Babkin and Bowie, 1928), Zoarces (MacKay, 1929a),
Trachurus trachurus, Gadus aeglefinus and Pleuronectes platessa (Kandynk, 1967), pike, perch, sterlet, roach, bream and Siberian dace (Pegel et al. 1971), digestive trace of rainbow trout (Kitamikado and Tachino, 1960a), pancreas of perch and intestine and pancreas of Tilapia (Fish, 1960), pyloric caeca of Oncorhynchus and cod, intestine of carp and flounder (Ushiyama et al. 1965), intestine and pyloric caeca of yellowtail jack and rainbow trout, intestine, liver and pancreas of eel and carp (Morishita et al. 1964), stomach and intestine of Ophicephalus and Mugil (Seshadri, 1967) and Tilapia mossambica (Moitra and Das, 1967), pyloric caeca of the marine ayu, Plecoglossus altivelis and hepatopancreas of red sea bream, Pagrus major (Kawai and Ikeda, 1971) and stomach, intestine and liver of Heteropneustes fossilis (Saigal et al. 1974). The exact site of secretion of amylase, however, is yet to be confirmed. Kapoor et al. (1975b) regarded the pancreas as the probable site of secretion of carbohydrases and remarked that the intestinal mucosa probably produces less carbohydrases or perhaps none at all. The intestinal mucosa possibly absorbs the pancreatic enzymes. According to the latter workers the existence of amylase activity in the stomach and oesophagus may be the result of regurgitated duodenal contents.
It has been observed during the present studies that the hepatopancreas and intestine in *M. cavasius* indicated stronger amylase activity than the other regions. Maltase has also been identified weakly in the stomach and intestine but strongly in the hepatopancreas in *M. cavasius*. Kitamikado and Tachino (1960a) and Kawai and Ideda (1971) also recorded moderate to strong amylolastic activity in the alimentary tract of carnivorous fishes studied by them. Saigal et al. (1974) reported moderate to strong amylase activity in the stomach, strong activity in the intestine and weak to moderate activity in the liver of a carnivorous catfish, *Heteropneustes fossilis*. They observed that the enzyme equipment of the fish is well suited for digesting carbohydrate foods.

Data obtained from the physiological assay during the present studies, reveal that the relative activity of the digestive enzymes in *M. cavasius* studied may, be correlated with their dietary. Kapoor et al. (1975b) observed that although there is evidence of such a relationship, it has by no means, been established, They further state that such evidence stems mainly from comparisons of amylase activity. The digestive tract of *M. cavasius* showed a moderate to strong amylase activity inspite of its being
carnivorous. This species is therefore better adapted to be carbohydrate diet as it consumes more plant food than in many species. Chesley (1934), however, observed that the amylase activity in the alimentary canal of fishes to be related to the general activity rather than to the diet. Kapoor et al. (1975b) state that no definite correlation has been found between proteolytic activity and diet in the fish possessing a stomach. Chesley (1934) and Morishita et al. (1964) recorded differences in the proteolytic action in the alimentary canal of a number of fishes, that could not be correlated with their diet. Regarding lipase, no such relationship could be established in the fishes studied, as all of them showed a lipolytic activity in the digestive tract in more or less similar concentrations. Volya (1966) however, recorded the strongest proteolytic and lipolytic activities in the predatory species, Trachurus and Scomber and weakest protease activity but the highest amylolytic activity in the herbivorous, Mugil. Sinha (1977c) also reported a similar relationship in the carnivorous fry, omnivorous fingerling and herbivorous adult of Cirrhinus mrigala.