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Additional synopsis of biological data on *Tenualosa ilisha*

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Preface

THE INDIAN SHAD, *Tenualosa ilisha,* is one of the most important food fish of India, Pakistan, Burma and the Arabian Gulf area. It constitutes a fishery of some magnitude in almost all the river systems and estuaries of the area that were found.

The present synopsis is an addition to the previous one prepared by Pillay and Rosa in 1963. It contains information on the different aspects of the biology of *T. ilisha* after 1963.

The same arrangement that followed in the synopsis of Pillay and Rosa (1963) was followed here, except in some places where information is lacking. This lack is due to the shortage of work done on this species during the past 26 years.

I. Identity and General Studies

a. Nomenclature:

Russel (1803) was the first to describe the species from the foreshore waters of Vizagapatan under the name *palash*. Later, Hamilton (1822) studied its systematic position and described it under the name *Clupanodon ilisha*. On the other hand, Regan (1917) created the new genus *Hilsa* to include the *Hilsa*-like clupeoids of the Indo-Pacific and gave clear definition of *Hilsa ilisha* and the related species *H. toli* and *H. kanagurta*. Regan's nomenclature had remained a valid species until Fowler (1941) and Munro (1955) assigned it to other genera.

b. General Studies:

Histology and Anatomy:

The morphology and the histology of the alimentary tract of *Tenualosa ilisha* were studied. The results show that this canal consists of the buccal cavity, a short pharynx, the oesophagus, the cardiac and pyloric stomach, the duodenum, the intestine, and the rectum. No teeth were observed in the mouth, so food materials are swallowed whole. A large number of telostean fishes have been reported to have flask-shaped taste buds lying on the evagination of the connective tissue and are connected with nerve fibres that carry a sensation of taste to the brain. In *Tenualosa ilisha* they are completely absent. One would naturally assume that they have no gustatory sense and are blind-feeders. A contrary result was obtained by Swarup (1959) in which he studied the buccal cavity histologically and shows that mucosal epithelium. These concentrations of nerve fibres seem to function as primitive taste buds in *Tenualosa ilisha*, which is a member of one of the most primitive families of Teleostei. The mucosal epithelium serves as a receptor. Swarup (1959) concluded that in this primitive case of *Tenualosa*, the nerve supply has become rich, but the taste buds have not yet originated in the mucosal epithelium. These nerve fibres are responsible for carrying the gustatory sense to the brain. In the case of

more evolved teleostean fishes, certain parts of the mucosal epithelium become modified into taste buds. Thus, *Tenualosa ilisha* probably is not a blind feeder, but it does apply its sense of taste in the selection of food.

Presence of the concentration of nerve supply in the submucosa in the buccal cavity, pharynx and oesophagus in *Tenualosa* is very characteristic. It becomes more significant because they indicate the primitive step in the development of taste buds. It also points out that the sense of taste is carried to the brain not only from the buccal cavity but also from the pharynx and oesophagus.

The function of the mouth is simply to catch food material and pass it on to the stomach. The mucous-producing goblet cells are present in the buccal cavity. They are scarce in the tip but are present in large numbers on the tongue and posterior part of the buccal cavity. This indicates that the function of the tongue is simply to produce mucus so that the food particles may easily slip into the pharynx.

Gill rakers are characteristically modified in the case of *Tenualosa ilisha* and are closely set on the branchial arches. These are very well adapted for straining microscopic plankton from the water.

The digestive tract of this species is most interesting as far as its pyloric caeca are concerned. The number of these caeca varies in different fishes and families. The clustering of pyloric caeca is very characteristic in Clupeidae, and above all in *T. ilisha* the concentration seems to have reached its maximum limit, as such a high concentration of pyloric caeca has not been recorded from any other fish (Swarup 1959). The function of these caecae seems to be to store the semi-digested food material and also probably absorb the digested food matter as the intestine does.

The histological changes in the liver in relation with migration and spawning in this species were studied by Desai (1978). Accompanying maturation and migration, alterations like vacuolization of cytoplasm, pycnotic nuclei, deposition of collagen material, arterisclerosis, and necrosis of hepatic cells were noticed. The reasons behind those changes as the author described are associated with aging and can be included in the following points:

1. Stress due to spawning and starvation during spawning and migration.
2. Hyperadrenocorticism. Both factors are more pronounced in migrating *T. ilisha* as it has to encounter a change in external medium, and it also has developed more pronounced hyperplasia of adrenocortical tissues (Desai 1967). From the observations presented by Desai (1978), it is evident that *T. ilisha* exhibits more pronounced degenerative changes. Robertson and Wexler (1960) suggested that degenerative changes observed in various tissues and organs were due to increase in adrenocortical tissue associated with aging and increase in the levels of 17-hydroxycorticosteroids in the blood. Thus the histological observations in the case of *T. ilisha* are in line with those of Robertson and Wexler (1960). Hyperactivity of adrenocortical tissue in association with aging may be the cause

of the necrosis of liver as noticed by Robertson and Wexler (1962) in the Kokanee salmon. This case is similar to the case of *T. ilisha* moticed by Desai (1978) where similar degenerative changes were observed.

II. Distribution:

The general occurrence of *Tenualosa ilisha* in the Western part of the Indo-Pacific province is restricted to the estuaries, brackish-water lakes, and fresh-water rivers. In addition, since this species is present in an area where the scientific investigations are poor, so only a few studies have appeared. These studies are concentrated on the Indian waters. In these and nearby areas, the fisheries sciences need to be backed up with more basic information that helps in the application of an advanced method of fish catching and management, which includes *T. ilisha* among other commercial fish species.

Since Pillay and Rosa (1963), nothing has been on record about the adult distribution of *T. ilisha*. On the other hand, very few works have appeared during and after the publication of their biological synopsis on *T. ilisha*. These concentrate on the distribution of eggs and larvae. A general account of the distribution of this species was given in Pillay and Rosa (1963). None of this information will be repeated here, but an additional one will be considered.

The availability of eggs and larvae in surface and subsurface layers of waters would be obtained by observations on the spawning of *T. ilisha*. Different nets were used to collect eggs and larvae of *Hilsa* from different localities. Karamchandani (1961) used spawn collection nets. Ravish Chandra (1962) used a surface tow net for collecting *Tenualosa* larvae from Hooghly Estuary, India. The occurrence of *Tenualosa* eggs is in the subsurface, while the juveniles inhabit the surface waters and more in deeper zones during the later stages (Pillay and Rosa 1963). The bathymetric distribution of *Tenualosa* larvae is limited. Ghosh and Nongpal (1968) determined the bathymetric preference of larvae while making collections with an argandic ring net during water breeding of *Tenualosa* in the lower stretch of the River Ganga. According to Ghosh and Nangpal (1968), the larvae are present in surface and subsurface layers in a total water column of 1.3 meters, but they have not given a further split-up range showing the depth limit. Chandra *et al.* (1983) observed the bathymetric distribution of *Tenualosa* larvae in the middle state of the River Ganga near Allahabad, India. They designed a special net made of mosquito netting (1/16″ mesh), comprising three portions viz., upper, middle, and lower. This setup of nets like a set of these spawn collection nets stuck together vertically. The results obtained by Chandra *et al.* (1983) were based on the availability of *Tenualosa* larvae in relation to water depth during post-monsoon breeding of 1970 and 1971. The net was operated at each center for a period of 6 hours from 10.00 a.m. to 4.00 p.m. It is evident from their results that the larvae were more commonly encountered in the collections of the upper and middle buckets, thereby indicating their availability in surface and subsurface depths ranging from approximately 10 to 50 cm, whereas the number of larvae was not significant in the lower bucket, i.e. in subsurface depths exceeding approximately 50 cm.

III. Bionomics and Life History

a. Reproduction:

1. Fecundity:

Although there are some works being published on the fecundity of *T. ilisha* since the review of Pillay and Rosa (1963), it is still far from being a complete picture. The earliest work has been done by Islam and Talbot (1968), in which they studied the fluvial migration, spawning and fecundity of *T. ilisha* in the Indus River area. The fecundity varies between 755,000 and 2,917,000 eggs per female, and there is no close relationship between length or weight and fecundity in general.

The next report on fecundity came from Doha and Abdul Hye (1970) in the East Pakistan area (River Padma). They concluded that the estimated number of eggs produced by this species ranged between 348,318 and 1,465,969. This range finally well compared with the estimation made by Pillay (1958) for the Hooghly River, but was lower than the estimates for Godovari (Pillay and Rosa 1968). Great variation was found in the fecundity of *T. ilisha* in this river of the same size. On the other hand, Ramakrishnaiah (1972) determined the fecundity of the species in the size range 333 – 515 mm varied from 390 to 1,120 thousands from the Chilka Lake, India.

Recently De (1980) estimated the fecundity of *T. ilisha* by the number of eggs per female and found it varies from 3,730,120 to 13,230,500; the average being 6,320,305 eggs per female. The previous estimations of the fecundity of this species were: from 250,000 to 1,600,000; from 289,000 to 1,168,622; from 400,000 to 1,200,000, and from 316,316 to 1,840,179 per female (Pillay 1958; Swarup 1961; Pillay and Rosa 1962, and Mathur 1964). The average egg number obtained by De (1980) is higher than any previous estimated figures. The average numbers of mature eggs per gram of body weight (fecundity factor) and per gram of ovary weight of the fish were computed to be 828 and 7,888 respectively (De 1980).

Quddus *et al.* (1984c) studied the spawning, fecundity, and sex ratio of two different stocks of *T. ilisha*. They called them stock A and B, respectively. Fecundity was found to range from 660 to 1,547 thousand for fish between 342 to 520 mm in Stock A, and 399 to 670 thousand for fish between 260 and 470 mm in total length in Stock B.

2. Maturity:

As with the other biological topics, the maturity of *T. ilisha* has been poorly studied. Only a few works in this field are on record, and they have been done on the fishes of the Indian waters. The early information after the review of Pillay and Rosa (1963) came from Islam and Talbot (1968) in the Indus River area. The maturing individuals entering the river ranged between 250 and 600 mm in length, while a few immature ones entered the same waterway when as small as 220 mm. Most of the male fish appear to be in their

4th year of life, while the females are represented predominantly by two age classes that appear to be their 4th and 5th year respectively.

Ramakrishnaiah (1972), on the other hand, studied the maturity of *Tenualosa* from another Indian water body, the Chilka Lake. His results show that the size at first maturity was 187 mm for both males and females.

De (1980) studied the maturity of the fish from the Indian waters, including the egg diameter, and found that the diameter ranged from 0 to 54 ocular micrometer divisions, and that there were only two distinct groups of eggs present in the ovaries in all the different stages of maturity representing the immature and maturing ova.

The immature group of ova (0 to 14 ocular micrometer divisions) is present in the ovaries of all stages of maturity and considered as the general egg stock. On the other hand, the fully mature eggs have a mode at 46 ocular micrometer divisions. The modes representing the immature and mature ova are well separated from each other and there is no appearance of a second maturity group of ova. Moreover, the spread of the mode of mature ova in different stages of maturation is not wide. These observations clearly indicate that there is only one single batch of eggs undergoing maturation at any one time. From the results of De (1980), it is possible to deduce that the species spawns during the period of September and October and the maturity occurs at about 34.1 cm length, while Pillay and Rosa (1963) found the smallest mature size at 370 mm and Karamchandani (1961) reported the size of 265 mm. In almost all cases the age was placed at 2 years at maturity. On the other hand, Ramakrishnaiah (1972) found that females below 300 mm in length do not participate in spawning in the Chilka Lake area, India.

It seems that there is a great deal of variation in the size at maturity reported from the different areas studied. This variation may be due to the geographical variation which leads to the variation in the environmental factors.

3. Spawning and Spawning Grounds:

The spawning habit and duration of spawning in *Tenualosa* could be judged from the diameter of the eggs. The diameter of the eggs recorded by Doha and Abdul Hye (1970) range from 430 to 729.2 μ. Comparing this range of diameter with the range being recorded for the mature eggs of *Tenualosa* from the different Indian subcontinent waters, it is possible to conclude that it lies near the top of the range given by Southwell and Prasad (1919) and Jones and Menon (1951). Therefore, and according to this range of mature eggs, the spawning period of *T. ilisha* is probably long and continuous (Doha and Abdul Hye 1970).

In the Bangladesh waters the situation for spawning seems to be different from that of Indian waters. As Quddus *et al.* (1984) reported the presence of two stocks of *T. ilisha* in the Bangladesh waters, A and B, they behave differently in the spawning habit. Stock A appeared to spawn from July to October and Stock B from January to March.

Length frequency and size groups in relation to spawning are another subject with which Karamachandani (1961) has dealt. His results show that all size groups of ripe *Tenualosa* (males 265 – 505 mm; females 295 – 605 mm) occurred in the tidal zone; only adult fish (males 315 – 485 mm; females 415 – 555 mm) migrated to fresh-water areas. It is thus significantly interesting that younger (probably two years old) ripe *Tenualosa* (males 265 – 315 mm; females 295 – 415 mm), which are encountered in abundance in tidal areas, are totally absent from the fresh water areas, indicating the upstream migration of only older *Tenualosa*. In the end of his observation, Karamachandani (1961) suggested that probably the younger *Tenualosa*, perhaps maturing for the first time, ascend only up into the fresh-water areas for breeding. This result might agree with the suggestion of Southwell (1914), which was quoted by Sujansinghani (1957), that "old *Hilsa* probably spawn in the high reaches of the river, while young ones, more susceptible to changes involved in the transition from the sea to the fresh water, probably spawn lower down the river."

Spawning grounds were studied by Karamchandani (1961), which were located about 1600 km from the sea, near Goa, India. The previously known spawning ground of *Tenualosa* is about 65 km from the sea (Kulkarni 1950). Three batches of eggs, each containing 700 – 800 eggs, were obtained and successfully reared in the field laboratory up to 8, 13, and 14 days after hatching. This result showed the time of spawning which takes place mostly in the afternoon and evening from 2 p.m. to 6 p.m.

The observations on the availability of *Tenualosa* eggs in relation to fluctuation in water level in the river were discussed by Karamachandani (1961) and showed that the times when the water level decreased in the upper reaches of the river were the 2nd to the 4th day and the 10th day after new moon and full moon. The upstream migration and, in consequence, the spawning activity, were delayed by a few days until the water level in the river began to rise again.

b. Larval History:

Artificial fecundation was attempted by putting the eggs of *Tenualosa* in hapas cloth and fixing it in confined fresh water, *viz*., river pools and nursery ponds. It appears that the index of visibility has a great effect on the process of hatching of the eggs. When the value of the Secchi disc is 20 cm or less, the water will not be conducive for hatching. Malhotra *et al*. (1970) found that in a confined freshwater body, the water will be suitable for hatching when the index of visibility reaches 14 and 67 cm in the pool, and was 27 cm in nursery ponds.

c. Adult History:

Parasites:

In addition to the parasite species recorded from *Tenualosa ilisha* (Southwell and Prashad 1918), *Lecithocladium ilishae*, a new species of trematode, was recorded from the

stomach of the fish (Bashar Allah and D'Silva 1973). This species appears most similar to *L. harpodontis* Srivastara 1937 (emend. 1942) and differs in several aspects.

d. Nutrition and Growth:

1. Food and Feeding Habits:

The food and feedng habits of *Tenualosa ilisha* were studied in the Chilka Lake, India. The food of the young individuals appears to consist mainly of organic detritus (48.56%), copepods (25.82%), algae (10.32%), molluscan larvae (7.85%), mysids (5.34%) and diatoms (2.10%). This result reveals that the juveniles of the *Tenualosa* of Chilka Lake are predominantly bottom feeders as observed by Hora and Nair (1970a, b) and Halder (1968) in Bengal waters.

In addition to the above-mentioned information, and the information presented by Pillay and Rosa (1963), the stomach contents of this species were analyzed and studied and found to contain predominantly species and varieties of the diatom genus *Melosira*. On the other hand, *Synedra ulna* and *Daphnia* sp. were present in lesser numbers (Nurul Islam 1974). In some regions, *i. e.*, Allahabad, India, the fishes show two periods of maximum feeding alternating with a period of starvation or semi-starvation in both males and females. The juveniles are voracious feeders, and sand particles are comparatively more abundant in their stomachs. Rajyalakshmi (1973) states that the feeding condition in the adults in the monsoon season in the Godavary River was always very negligible, whereas juveniles showed fully fed guts with predominantly copepods and rotifers. Where copepods were dominant, *Spirogyra*, diatoms, and other calonid algae were also prevalent, the average proportions being 50% copepods, 35% *Spirogyra* filaments, 1% *Oscillatoria*, 1% diatoms, 2% nematodes, 0.5% colonial algae, 0.5% Cypredae, and 10% organic detritus. Nurul Islam (1974) states that the food contents in the *Tenualosa* stomach analysed in March of the year were found to be predominantly diatoms with enough sand particles and very few *Daphnia* sp. His observations agree with those of Swarup (1959) in that sexually mature *Tenualosa* feeds during the spawning migration on the diatom genus *Melosira* forms about 98% of the entire population inside the fish stomach in Nurul Islam's (1974) samples.

On the other hand, Al-Nasiri and Al-Mukhtar (1988) determined the food of *Tenualosa ilisha* from Ashar Canal, Basrah (Shatt al-Arab River), Iraq. They concluded that the main food of this species of fish is zooplankton (mainly copepods – *Cyclops*) and phytoplankton such as dinoflagellates and diatoms. The main food items were *Cyclotella, Planktosphera, Oscillatoria,* and *Cyclops*, and they were found in 100% of the stomachs. The remaining food items, such as *Ceratium, Melosira, Bacillaria,* and *Navicula*, were found in high occurrence but not in all stomachs. It was also found that the average volume of food in each stomach is more in small fishes than in large ones.

2. Age and Growth:

The length and weight of *Tenualosa* species and the relationship between them was investigated in the rivers of East Pakistan (Ahsanullah 1967). The fish usually migrate into the rivers of East Pakistan from the Bay of Bengal for the purpose of breeding. They range in total length between 240 – 540 mm. Of those sizes, 330 – 450 mm were found in much abundance in the rivers and they constitute 84% of the entire population of the migrants. The abundance of fish in a particular length group varies from year to year. On the other hand, the average weight of the fish varies with season and area. The maximum weight of *Tenualosa* recorded by Ahsanullah (1967) is 2 kg, while the range of 250 – 1375 g constitutes the bulk of the population. Some factors such as type of gear employed and much size selected vary from zone to zone might have some bearing on the variation in the size and weight of fish in different zones. Those factors should not be ignored in drawing any conclusions as to the distribution of size and weight of *Tenualosa* in different zones. Seasonal variation in the weight was evident. *T. ilisha* appears to have greater weight during the summer (May – September) than in the winter months (December – March) (Ahsanullah 1967).

The age and growth of two types of *T. ilisha* from the Rivers Padma and Meyhna were examined by means of otolith readings (Quddus *et al.* 1984b). The otolith readings revealed that the otolith of *T. ilisha* is laterally compressed and somewhat oval in structure. Anteriorly, it is deeply bifurcated into a long ventral arm and a short dorsal arm. The posterior edge is blunt, round, and slightly indented. The outer (distal) surface is concave and the inner (proximal) surface is convex with a deep longitudinal furrow lying between the two ridges. Both the surfaces taper off outwardly in all directions to a thin edge. The margins are irregularly indented.

They found that the relationship between body length and otolith size is linear for both Types A and B, and significantly different between types. A possible differentiating character between the two types noticed by the authors was the hyaline zone, which appeared during June and July in Type A and in January and February in Type B. This indicates their respective spawning season. Another difference was observed between the two types, that is, in the growth by weight.

3. Chemical Composition:

Samples of flesh from lean *Tenualosa ilisha* were dried to various extents in a mechanical drier at 30 C. Similar blocks of muscle were subjected to the same temperature conditions but wrapped to prevent dehydration in order to compare the effect without dehydration. The amount of extractable myofibrillar protein decreases markedly during both heating and drying, the rate being low for *Tenualosa.* The bacterial count increases continuously with time in the case of the heated samples, but reaches a steady value and then decreases during drying. It is concluded that most of the protein changes during drying are due to the effects of heating rather than dehydration (Howgate and Ahmed 1972).

On the other hand, the lipid content of the fish was studied by Mathers *et al.* (1977). The seasonal variations in the analytical characteristics of the lipid, both from skin and muscle of this fish, were also studied. Their results show a high lipid content in both the skin and muscle. The muscle lipid had only very low iodine value. The unsaponifiable matter in the muscle oil was also high. The percentage of unsaponifiable matter in muscle lipid was generally higher during September through January, when the total lipid content was also high. The skin lipid of *T. ilisha* had higher saponification and iodine values compared to the muscle lipid.

The fat components during frozen storage were also studied for this fish (Hug and Rubbi 1978). This work was aimed to investigate any possible changes that might happen to the fat content of *T. ilisha*. Their results show that the saturated and monounsaturated acids amounted to about 88% of the total acids and 7.8% were polyenic acids. The dienic and trienic acids were insignificant. The unsaturation varied from 0 to 6 double bonds and chain length from C_{12} to C_{22}.

e. Migration and Local Movements:

T. ilisha has long been considered as a fluvial anadromous fish with feeding grounds in the sea and spawning grounds along considerable stretches of the lower and middle reaches of big as well as small rivers of India (Dutt 1966). On the other hand, Prasad (1919) and Hora (1938) cast doubt on the true anadromous habit of this valuable clupeid and considered it as a fluvial fish that does not go down beyond the estuary. Since then, although various workers have observed either juveniles or adults in inshore waters (Dutt 1966), there has been some reluctance to consider the anadromous habit of *Tenualosa*.

In the River Shatt al-Arab, Basrah, Iraq, a similar situation is present. There is a great belief that there is a restricted stock of *Tenualosa ilisha* found in the estuary of Shatt al-Arab near Fao city. During the spring season the adults with some young individuals ascend the River Shatt al-Arab to the marsh area north of Basrah city for spawning. This is only the author's observations and needs to be confirmed by wide and applied research.

It was stated by Jones (1957) and Pillay (1958) that even if *Tenualosa* fish do enter the sea, it is confined to inshore waters on the "foreshore." It is, however, most unlikely that this medium-sized active fish resorts to an intertidal habitat during its extra-fluvial phase. A review of the literature shows that the fluvial anadromous stocks of *Tenualosa* do enter the sea, but that the available data on the movement in the sea are inadequate to determine the extent of their seaward migration because there are just no observations, negative or positive, beyond the continental shelf.

The record by Pillay (1964) of maturing, mature, and spent *Tenualosa* in the sea, 16 to 18 km off Veraval in the northwest of India, adds a new dimension to the known behaviour of this fish. Pillay (1964) offers evidence that this particular stock of *Tenualosa* probably spawns in the sea. It appears that several problems will face the stock if they spawn in the sea as Dutt (1966) discusses them. They fall in a few categories such as the problem of spawning in the new environment, the problem of protection of eggs and larvae, and

the problem of osmoregulation. As a conclusion, Dutt (1966) suggested that there are ecotypes of *Tenualosa*. These are:

1. Fluvial anadromous stocks that feed and grow in coastal waters and spawn in middle or lower reaches of the river above the level of tidal influence. Such should be the *Tenualosa* of Hooghly, Godavari, and Narbada.

2. Fluvial *Tenualosa* (physiologically but not geographically land-locked stocks) that inhabit the middle reaches of rivers and are potamodromous. Such as probably the *Tenualosa* that occur at Delhi, Agra, Allahabad, and Buxar, in the Rivers Jamna and Ganga.

3. Marine *Tenualosa* as have been observed by Pillay (1964) off Veraval on the Saurashtra coast.

The first of the above three types is the normal condition in this species, and there is an extensive literature pertaining to these types (Jones 1952). In the Shatt al-Arab River, Basrah, Iraq, these fish ascend the river and reach the marsh area to the north of Basrah city, but there is no record of them farther up Mesopotamia. Thus, the Iraqi stock of *Tenualosa* might well fit the fluvial anadromous type of the fish *Tenualosa*.

Dutt (1966) suggests several ways by which one can solve the problem of the extent of migration of *Tenualosa.* These are employing, at frequent and regular intervals throughout the year or the season, suitable least selective types of gear at various points in the river, in the estuaries, and in the sea, on a large scale.

The fluvial migration of this species was also studied by Islam and Talbot (1968) in the Indus River area. This migration starts about the middle of January. The fish proceed up the river and reach the Hyderabad zone, just to the mid-length of the Indus, in April, but in some years as early as the latter part of February. Peak catches are made in the lower reaches of the Indus in April or May, but some maturing fish are caught as late as August, indicating that *Tenualosa* may enter the river each year over a period of about seven months.

The study of Ramakrishniah (1972) about the migration of *Tenualosa* fish confirms the studies of Jones and Sujansingoni (1951) and Jhingram (1963). It appears that there are two waves of *Tenualosa* migration in Chilka Lake; one at the close of winter and the other at the commencement of the monsoon season. Mature fish comprised the monsoon catches, which migrated to the lake for breeding, while winter catches consisted of smaller size groups and were all immature. In spite of those two waves of migration, only a single breeding season was observed in Chilka Lake.

Tagging and recovery is a usual method to study the movement and migration of the fish. The procedures of this method were described by Pillay *et al.* (1962) in three river systems of India. The migration of the fish was studied, and their results show that there is little or no movement between the three rivers studied.

IV. Population (stock):

a. Identification

The majority of workers are of the opinion that *T. ilisha* is composed of two distinct stocks. This idea is based on the several works concerning the migration of this species in the Indian waters. There is a possibility in distinguishing between the different races of *T. ilisha* by means of their shapes. Quddus *et al.* (1984a) studied the biometric differences between the two types of *Tenualosa* in Bangladesh waters. Their study revealed a significant intertype difference in the mean number of six meristic characters and seven morphometric measurements. The study of Quddus *et al.* (1984a) agrees with the previous findings by different workers and confirmed the distinguishable characters such as height of the body at the origin of the dorsal and anal fins, head length in relation to eye diameter, length and height of the caudal peduncle, and thickness of the body.

On the other hand, in the Arabian Gulf area, Al-Abaychi in 1973 (personal communication) studied the population of *Tenualosa* in the Shatt al-Arab River and its estuary in Fao city. He used both morphometric and meristic characters to identify the population. He also compared the Basrah population with that of Pakistan (Arabian Sea) and found that there is a significant difference between the two populations (Al-Hassan 1982).

The above observations are relevant since they are based on statistical analyses, but one question remains to be answered: How can we know the causes of these differences? By using the electrophoresis technique we can be certain about the causes behind these differences. This can be achieved by finding out the gene frequency in both populations and by comparing them.

b. Population Dynamics:

Production of *Tenualosa* and its population dynamics were studied by Ahsanullah (1964) in east Pakistan. The results show that the maximum production of *Tenualosa* was in the year 1958-1959 (147,065 tons) and the minimum in the year 1960-1961 (95,255 tons). The production varies from year to year and also in the same month of different years. There are several possible causes for the fluctuations in the production of *Tenualosa* and of decline of its populations, including the following:

a. Impact of biological cycle.
b. Sitting of rivers.
c. Operation of fixed nets.
d. Catches of young individuals, especially in the rivers where the spawning grounds are found.
e. Level of water.

f. Small sizes of mesh of the nets used in some localities.

V. Exploitation

a. Fishing Equipment:

Factors affecting fishing gear: Colour of the net influences the visibility and consequent response of the fish (Kunjipalu *et al.* 1985). In clear water, visibility is a prime factor for efficiency of the gear. Influence of colour of webbing on the catch of gill nets for the commercially important *Tenualosa ilisha* has been studied in some coastal waters of India. Among the colours tested, yellow and white are recommended for the fishing of *T. ilisha* (Kunjipalu *et al.* 1985).

b. Fishing Season:

1. Factors affecting the fishery:

A close correlation is observed between the total annual rainfall and the role of landing of *Tenualosa* with drift gill nets (r = 0.6). The years of heavy precipitation are characterized by an abundance of *Tenualosa*. The normal rainfall associated with the southwest monsoon is in better correlation with the *Tenualosa* catch (r = 0.6) than the residual rains of the northeast monsoon (r = 0.16) (Pati and Pati 1983). The rainfall data of Balasore district for the years 1967-1968 to 1976-1977 and the catch rate of *Tenualosa* from another Indian district were presented graphically (Pati and Pati 1983). From these data it is clear that corresponding to the three peak years of heavy rainfall, these peaks were observed in the catch rate and the highest catch rate was achieved in the year of the heaviest rainfall (1973-1974). Statistical treatment indicated a high degree of correlation between total rainfall and catch rate of *Tenualosa* (r = 0.6).

A similar relationship was observed between the normal rainfall and the catch rate (r = 0.6) and corresponding to the peaks in the normal precipitation during the rainy season. These modes are also visible in the catch ratio. On the other hand, the residual rain of the northwest monsoon has a poor relationship with the rate of landing of *Tenualosa* with drift gill nets (r = 0.16). Thus, between the rain of the two opposite winds, the bulk of rainfall associated with the southeast monsoon has a profound effect on the *Tenualosa* fishery.

The close correlation between the seasonal and annual rainfall can be described as follows. During the rainy season, the rivers carry huge quantities of nutrient-laden freshwater to the coastal waters. The river discharge and the salinity also makes the inshore highly productive (Pati 1980) during the months of September, October, and November. This, in turn, ensures a rich crop of phytoplankton and zooplankton, which is likely to attract plankton feeders such as *Tenualosa*, resulting in a lucrative fishery towards the later part of the southwest monsoon. Pati and Pati (1983) have another opinion concerning the good harvest of *Tenualosa*. This depends on the amount of nutrients consumed by the phytoplankters that are replenished by the riverine discharge

and mainland runoff, and heavy precipitation with intermittent showers. On the other hand, retreological conditions may affect the vertical mixing of nutrients, which in turn affects the fish catch. Pati (1982) studied the influence of temperature and salinity on the fishery of *T. ilisha*, and he concluded that a low salinity is low. [?] This would attract pelagic and semipelagic fishes to the area, resulting in better gill net catches.

c. Fishing Operation and Results:

The occurrence of planktonic indicator species in relation to commercial fisheries has been the subject of many reports (Shelty and Saha 1971). For the *Tenualosa* fishery in the lower Sundarban areas of the Hooghly-Matlah estuarine system in west Bengal, the bloom of the centric diatom *Hemidiscus hardmoniances* was considered as an indicator species for the large shoals of *Tenualosa* fish and a heavy landing after that. The high-tide collection recorded as many as 2,976 of these diatoms per litre. The concentration of the fish, as Shelty and Saha (1971) explained, might be due to the availability of optimal conditions at the edge of the diatom patches, or due to these patches acting as barriers to *Tenualosa* migration, as surmised by Savage and Winpenny (1934) in the case of the North Sea herring. The third possibility is that this diatom constitutes a preferred food item of *Tenualosa*, as diatoms are known to form one of the major components of the food of this fish.

On the other hand, Rajyalakshmi (1973/1974) studied the monsoon-migrating anadromous species of *Tenualosa* to the freshwater stretch of the River Godavari. The population size structure shows composition of Groups III to V in the fishery, with males dominating in Groups III and IV, and females in Group V and above. He suggested that the mesh variation in the drift gill net and, consequently, the selectivity factors are highly variable.

As a suggestion for culture and improvement of the *Tenualosa* fishery, Rajuylakshmi (1973/1974) thinks that the best means to increase production of *T. ilisha* is by rearing the juveniles to adult stages. Several workers have attempted rearing of the young through egg to post-larval stages. This, however, did not meet with success, and further attempts were not continued. An anadromous fish like *T. ilisha* ought to be very pliable for culturing in fresh or brackish waters. He also enumerated a few other suggestions that he thinks will work if they are followed carefully.

1. The young ones that grow to a size of 230 mm in fresh waters should be utilized for farming.

2. In order to improve the juvenile abundance, a greater number of spawners should be assisted to move into the waters over the barriers that may impede their way toward the rivers, by physical lifting and transplantation if necessary.

3. The reduction in mesh size of gill nets is not a welcome sign for the highly fluctuating fisheries. A mesh size range from 9.5 to 14 cm should be fixed for the general *Tenualosa* fishery.

d. Fish Landing:

Fish landing and specifically seasonality in fish landings has been studied in the Indian waters. Mitra and Ghosh (1979) discussed the seasonality in landings of various important fishes in different zones of the Hooghly - Matlah estuarine system, and they come to the conclusion that the landing of *T. ilisha* with an average index of 228 for the winter months (November-December) and 146 for the monsoon season (July-October) showed two principal seasons. The winter fishery dominates in the area of Diamond Harbour to the mouth of the estuary, including the estuarine area of Lower Sunderbares and monsoon in Nabadwip to Baranagore area and from the latter area to Diamond Harbour. The study of seasonality in landing has been done by building seasonal indices from monthly landings based on 12 months of results. In Bangladesh waters, the production of *Tenualosa* ranged from 140,000 tons from the sea and 90,000 tons from the inland waters (Hossain *et al.* 1987).

e. Fisheries:

The interaction of the species in the commercial landings along the Balasore coast of India was studied by Roy and Roy (1974). They found out that there are two species of fish whose occurrence interacts with that of *Tenualosa*. These are *Pampus argenteus* and *Scomberomorous guttatus*. *Tenualosa* and *Pampus* appear to be in an inverse relationship in occurrence. Both species contribute to a major part of the catch over the period September-November. However, the catch rate drops in the subsequent months up to February, after which the catch of *P. argenteus* goes up substantially.

The annual pattern of these two species also reflects an inverse relationship. Of these two, *P. argenteus* showed peak abundance once in three years. A peak year of catch was noted in 1965-1966 and in 1968-1969. On the other hand, *T. ilisha* showed a four-year cycle of occurrence. This species was caught in abundance in 1966-1967, followed by a similar high in 1970-1971.

The monthly pattern of abundance of *Tenualosa* showed that the percentage of catch of this fish was highest in October, then dropped abruptly until February (Roy and Roy 1974).

In the opinion of Naidu (1939), the natural habitat of this fish is located in the high seas and the high percentage of catch in the coastal waters in the post-monsoon period is due to the rich grazing ground of that area. Jones and Menon (1950) have remarked that this species ascends the estuaries for breeding during the monsoon, and has been observed as far as Delhi (Pillay 1955). *Tenualosa* therefore has the capacity to withstand variable salinity conditions, especially low salinity. According to Mitra and Dersundaram (1954), *Tenualosa* has a preference for low salinity.

It is possible that the temperature tolerance and other factors connected with the spawning of *Tenualosa* may be the pointer to thin congregation in inshore waters. Malhotra *et al.* (1970) report that, under laboratory conditions, the hatching of *Tenualosa* varies between 5 to 8% where the surface temperature ranged between 26.5 C to 30 C with a pH value of 8.2 to 8.3. The secondary rise in the catch of this species corresponds to the spawning migration, which is coupled with the slow rise in temperature in the post-winter days.

Sarma (1984), in his paper on the *T. ilisha* fishery, discussed the importance of the fishery of this fish and its relationship with the socioeconomic conditions of the fishermen in India. The Indian consumer, particularly in the eastern and the northeastern region of India, favors this kind of fish. *Tenualosa* gives greater consumer satisfaction per unit weight when compared with carp fish flesh because of its delicacy and special method of cooking.

On the other hand, Sarma (1984) reported on the present status of the *Tenualosa* fishery. It has registered a decline in India over the years as a result of both natural causes and human intervention. The siltation of the river mouth restricting the water flow and thereby increasing salinity in the estuaries is considered the main natural cause of decline of the fishery. Pollution of river water by industrial effluents containing toxic substances, city sewage, and washings from agricultural fields treated with pesticides and insecticides that are harmful to aquatic life have also contributed to the decline of the fishery of this species.

As a conclusion, Sarma (1984) urged adopting a special strategy for conservation and development of the *Tenualosa* fishery in India. Special measures should be adopted through legislation for conserving the spawning areas of this fish, and fishery regulations should be strictly enforced in order to ensure that *Tenualosa* fry and juveniles are not exploited. There should also be a closed season for fishing of *Tenualosa*. Suitable anti-pollution measures should be taken in the rivers where the fish breeds and young ones grow. For the development of the *Tenualosa* fishery, it is therefore essential that a social fishery approach be adopted. A programme such as ranching of *Tenualosa* on the pattern of ranching of salmon in the rivers of Europe may be undertaken during the ensuing seventh five-year plan. For this purpose, *Tenualosa* may be raised through hypophysation of the fish, and the fry may be released in rivers for growing and breeding.

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