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Marine Fishery Resources Management

A REVIEW OF THE BIOLOGY
AND FISHERIES OF *HILSHA ILISHA*
IN THE UPPERBAY OF BENGAL

BOBP/WP/37



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A REVIEW OF THE BIOLOGY
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This paper describes the Hilsa shad fishery in the upper Bay of Bengal (Orissa and West Bengal in India; Bangladesh and Burma). It reviews current knowledge on the biology and fishery of *Hilsa ilisha*, sets out the findings of field observations in these areas, and makes recommendations on future work needed to understand better the nature of the stocks exploited in India and Bangladesh.

The study on which this paper is based was initiated in September 1983 and continued in intermittent spells till March 1984.

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The project has a duration of four years; it commenced in January 1983. Its immediate objective is to improve the practice of fishery resources assessment among participating countries and to stimulate and assist in joint assessment and management activities between countries sharing fish stocks.

This document is a working paper and has not been officially cleared either by the governments concerned or by the FAO.

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I. INTRODUCTION

The hilsa shad, *Hilsa ilisha*, belongs to the sub-family Alosinae of Family Clupeidae and is largely an anadromous species, but two other eco-types—a fluvial potamodromous type and a marine type—have been recognised. Although the systematic name of the species has been revised recently to *Tenualosa ilisha* (Fischer and Branchi, 1984), in this report the earlier scientific name, which has been popular for more than a century in the region, has been retained.

The hilsa shad occurs in the foreshore areas, estuaries, brackishwater lakes and freshwater rivers of the western division of the Indo-Pacific faunistic region. Its marine distribution extends from Iran and Iraq in the Persian Gulf to the west coast of India in the Arabian Sea, and the Bay of Bengal. It has also been reported to have been recorded from the coastal waters of Sri Lanka and Cochin China (Laos) (Pillay and Rosa, 1963).

The hilsa fishery is essentially confined to the artisanal sector—traditional non-mechanized and small mechanized boats, both in inland and inshore waters.

Russet (1803), to whose credit goes the first description and drawing of the fish (though his nomenclature was faulty), remarked that the hilsa is a '...rich and luscious fish with much of herring flavour'. The popularity, socio-religious significance and traditional public knowledge of the fish are well reflected in the proverbs and ancient sayings as recorded by Hora (1954c) on the basis of which it would appear that there is no other dietary fish so well relished and so prized in Bengal as the hilsa. One such proverb is that hilsa 'surpasses nectar (in taste and quality)'. The hilsa is highly prized not only in Bengal (West Bengal of India and Bangladesh) but also in Tamil Nadu, India, (south-west coast of the Bay of Bengal) where a saying goes; 'give whatever you have to buy hilsa'. The fish occupies the pride of place in the offerings to the Hindu goddess Durga at the time of 'Durga Pooja' festival (September-October).

According to Chopra (*Indigenous Drugs of India*, 1933, p. 546) as quoted by Hora (1954), the medicinal qualities of hilsa are: flesh demulcent (soothing), stomachic (promoting functional activity of the stomach), phlegmatic (characterised by excess of phlegm), and carminative (relieving flatulence). However, the fish is also reportedly rich in arsenic, and diarrhoea caused by hilsa has been traced to mild arsenic poisoning. Also reported is a household recipe, a green banana preparation, for rendering the fish harmless when people over-indulge themselves during seasons of plenty. A hypothesis that hilsa may be the carrier of cholera vibrios during inter-epidemic periods was formulated. However, investigations carried out by the Indian Council of Medical Research showed that cholero-genic vibrios are not found in hilsa but there were indications of the possibility of cholera vibrios undergoing mutational changes in the gut of the fish (Pandit and Hora, 1951; Pillay *et al.*, 1954).

The largest yield from the hilsa fishery comes from the deltaic region of the Gangetic system of India and Bangladesh, where it is reported to be more valuable than any other single species of fish. Of the three countries of the upper Bay of Bengal region, where the hilsa forms a commercial fishery, Bangladesh reportedly secures the largest share of the landings with about 150,000 tonnes per annum; in India the annual landings may amount to 27,000 tonnes, and in Burma about 4000-5000 tonnes. These include both inland and marine catches. Taking an average boat side value of US \$600 per tonne, the total value of production in this area is a little over US \$1 10 million.

On account of its economic importance, as well as its interesting migratory habits, the hilsa received the attention of fishery workers in India at a comparatively early date. After some anecdotal reports, investigations on hilsa appear to have commenced in 1907 in the Department of Fisheries, Madras, followed by a year or so later, in the Departments of Fisheries, Bengal,

Bihar and Orissa. The earliest investigations were directed towards two aspects: (i) appraisal of the effects of dams, weirs, and anicuts on the migratory movements of hilsa, and (ii) artificial propagation to supplement the stocks of fish in the rivers.

However, very little authentic information on the bionomics of the fish existed till 1938, when the Zoological Survey of India, during a faunistic survey of the Pulta Waterworks near Calcutta, accidentally became interested in the problem with the finding of very small hilsa in the settling tanks of the Waterworks. The studies of Hora (1938 & 1941), Hora and Nair (1940 a & b), and Prashad, Hora and Nair (1940) brought out very interesting facts on the life history and bionomics of the fish. Subsequently, the research tempo could not be sustained till the establishment of the Central Inland Fisheries Research Station at Barrackpore (Calcutta) in 1947.

Recognising the importance of hilsa in the Indo-Pacific region, especially for Burma, India and Pakistan, the Indo-Pacific Fisheries Council of the FAO of the United Nations at its third meeting in 1951 recommended the formation of a Hilsa Sub-Committee to develop the Council's interest in the subject. In conjunction with the meetings of the Sub-Committee, a symposium on hilsa was arranged in 1952. The symposium helped bring together all the salient information on the prevailing status of the hilsa fishery; the contributions made therein are available in Volume 20(1) of the *Journal of Asiatic Society, Science*, 1954. Consequent upon the recommendations of the Sub-Committee, the research activities were energized in India and Pakistan (both West and East Pakistan), resulting in a good number of scientific publications during the '50s, including a bibliography on hilsa (Jones, 1952) and a review of its biology and fisheries (Pillay, 1955).

During the 10-year period following the recommendations of the Sub-Committee and as a result of increased output, over 35 publications on the fishery and biology of hilsa were added to the literature, which probably prompted the FAO to have a synopsis of biological data on the fish prepared (Pillay and Rosa, 1963). Subsequent to the publication of this synopsis, more than 40 publications have been made till date focussing exclusively on the fishery and biology of fish pertaining to the upper Bay of Bengal region. This has not only enriched our knowledge considerably on the different aspects dealt with by the earlier works—some confirmatory, some complementary and some contradictory—but has also indicated the emergence of other possible explanations/interpretations on the biological features of the fish. This certainly calls for an exercise to take stock of our existing knowledge on the fishery and biology of the hilsa with an appreciation of the past and a realisation of the present for a fruitful future.

In spite of the fact that Prashad, Hora and Nair (1940a), through their very interesting account of seaward migration of hilsa, pointed out that very little attention has been paid to the marine phase of the fish's life history and in spite of a regular commercial fishery off Balasore-Digha coast (Orissa/West Bengal of India), and Cox's Bazar/Chittagong coast (Bangladesh), it is unfortunate that but for a couple of contributions, there has been a total lack of interest during the past four decades on that part of the fish's life history which is spent in the sea. The principal reason for such a lag in the scientific enquiry seems to be that the main fishery for hilsa depends on its migration and availability in the freshwater rivers and estuaries. But the scene is changing fast, with increasing exploitation of the marine stocks from the inshore areas, both on the Balasore coast of Orissa, India, and off Chittagong and Cox's Bazar belt, Bangladesh. There has also been no effort to look at the fish and its fishery from a broader base, taking all the habitats of the fish in totality, viz., freshwater, estuaries and the sea.

It was indeed an interesting coincidence that at the same venue of the IPFC meeting, namely, Madras, the need for yet another cooperative endeavour was expressed to fill the lacunae in our knowledge on the fishery and biology of the species and to judiciously manage the stocks believed to be shared by India and Bangladesh and perhaps by Burma too. At its first meeting of the FAO/UNDP Project 'Marine Fisheries Resources Management in the Bay of Bengal' (RAS/81/051), held, 16-20 August 1983, the Technical Liaison Officers of Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand, identified the hilsa as one of the resources of the upper Bay of Bengal of mutual interest to Bangladesh and India. As a beginning, it was decided that an evaluation of all historical data on the subject, including unpublished material to the extent possible, be made.

The FAO's Bay of Bengal Programme engaged the services of the author as Consultant for carrying out this task. The study was initiated in September 1983 and continued in intermittent spells till March 1984 for a period of three months.

The broad term of reference was to conduct a preliminary study of the hilsa fishery in the upper Bay of Bengal and to prepare a report which would include:

- a review of our current knowledge on the biology and fishery of *Hilsa ilisha* off the coasts of Orissa, West Bengal and Bangladesh,
- the outcome of field observations/study in the areas referred to, and
- recommendations for future work on sampling programme/techniques for better understanding of the status and nature of the stocks exploited in the respective countries.

This paper attempts to bring together in one place the existing information on the biology and fishery of the hilsa shad of the upper Bay of Bengal region, namely, the Orissa and West Bengal states of India, plus Bangladesh and Burma, (Figs. 1 to 4) and critically analyse the information with the intention of raising the awareness of the complicated but interesting history of this fish, to identify the nature and magnitude of the problems to be tackled, and to offer a basis for future scientific deliberations. Wherever necessary, information from regions other than the upper Bay of Bengal has also been considered. In this account, aspects such as reproduction, age, growth, fishery, migration, and racial studies, have been given importance and other aspects, such as larval development, have either been touched upon lightly, or totally omitted, such as material on parasites. Due to limitations of time and non-availability of ready references while reviewing the historical information on this subject, the author has relied heavily on the review made by Pillay (1955) and on the synopsis of biological data compiled by Pillay and Rosa (1963).

This review paper was completed in March 1984; at the time of publication it was slightly revised and updated.

II. ENVIRONMENT AND DISTRIBUTION

Environment

Oceanographically, the marine distribution of the species coincides with the Indian monsoon region (Arabian Sea, with the Gulf and Red Sea, Bay of Bengal, South China Sea with Malay Archipelago). In general, this region is characterised by: relatively large continental shelf, monsoon winds, medium to high precipitation and run-off, surface temperature of 20°C-30°C, surface currents changing with the change of monsoons, medium to low organic productivity, presence of sub-surface oxygen minimum layer and relatively low salinity of coastal waters (Pillay and Rosa, 1963).

The north-western part of the Bay of Bengal is characterised by a narrow range of temperature variation (24.9°C-29.4°C) and in contrast, by a wide fluctuation in salinity (22.4 ppt to 33.4 ppt). This is largely due to the reversal of the coastal current and an excess of evaporation over precipitation; maximum values of salinity are observed in May (Pati, 1982).

The estuarine areas of the rivers and the brackishwater lakes in the area are characterised by strong tidal action, high turbidity and heavy silting. The salinity fluctuates considerably and, in areas far inland, the water may become entirely fresh during the monsoon months. There is a fairly rich growth of plankton except during the rainy season. A greater abundance of zooplankton than phytoplankton is usually noticed (Pillay and Rosa, 1963).

The water level in the freshwater areas of rivers falls very appreciably during the dry months; very often large areas and long stretches of the river bed are converted into chains of pools

in which the fish fauna takes refuge. During the rainy season, the rivers swell, often suddenly, and result in heavy floods. The turbidity, which is usually low, tends to be high during the rainy months and during this period plankton crop is also comparatively low. In the river Hooghly, the usual range of surface water temperatures is between 18°C and 33°C (Pillay and Rosa, 1963).

Distribution

Eggs, larvae and juveniles have been found in the upper reaches of the rivers during the south-west monsoon (July to September) and *again* during the second half of winter (January to February). From October till about the end of November and again during March, juveniles and young ones up to about 8 cm length, are found in the lower reaches and estuarine areas. Young fish of about 15 to 22 cm length occur along the foreshore areas during the winter months (December to February) (Pillay and Rosa, 1963).

While the eggs occur in the sub-surface zones, the juveniles appear to inhabit the surface waters, but later age groups move in deeper zones as well (Pillay and Rosa, 1963). In the Hooghly, during the winter season, the males have been observed to move in the surface zone and the females in deeper areas (Pillay, 1958a).

The normal habitat of the estuarine stocks is the lower regions of the estuaries and the foreshore areas. During the breeding season they ascend the rivers and after spawning, return to the original habitat where they remain till the next breeding season. The riverine stocks appear to remain in the freshwater areas throughout the year but there is a greater concentration in the lower reaches during the period between breeding seasons (Pillay and Rosa, 1963), thus indicating that one segment of the population is not truly anadromous.

III. MIGRATION AND BEHAVIOUR

Migration

The upstream migration during the main breeding season appears to depend largely on the commencement of the south-west monsoon and consequent flooding of all the rivers of Bangladesh, Burma and India. The variations in the intensity of the monsoon during the breeding season appear to cause considerable fluctuations of the fish catches in different places. According to Day (1873a) the minor breeding migration in March-April in the upper Irrawaddy takes place when the rivers are flooded by melting snow, not by monsoon rains.

Day (1873a) expressed the opinion that the fish spends a part of its life in the sea not far from the shallow coastal belt, a view shared by Prashad, Hora and Nair (1940). Day (1889) further observed that hilsa continues its ascent throughout the south-west monsoon to nearly the end of the year in the Hooghly. However, Prashad (1919) doubted whether the fish is truly anadromous as it is found in the Ganga and Gangetic delta practically at all times of the year. His contention was supported by Hora (1938) who surmised that hilsa is a permanent resident of the rivers and coastal estuaries, and rarely goes out into the sea. However, the latter two authors changed their views subsequently (Prashad, Hora and Nair, 1940a).

With reference to hilsa of the south Indian rivers, Raj (1937) stated that the fish spends the first year of its life in the lower reaches of the rivers and goes to the sea in the third year, but Jones and Menon (1951) observed that this is not the case in Bengal waters. Raj (1932) also reported that shoals of hilsa visit the Palk Bay annually from November to May when a regular sea fishery is noticed. Naidu (1939) argued that there is not sufficient evidence to say that hilsa is not anadromous. Based on the information that adults are seldom, if ever, caught

during November to May, he presumed that they go far out into the sea, which according to him, is the natural habitat of the fish. He added that the general migration of adult hilsa takes place in the Ganga from May or June and they disappear by the second week of October. He could not determine whether the absence of spent fish in the catches was due to the annihilation of the migrants by extensive fishing, or because the spent fish during their return migration swim along the bottom. He stated that shoals of small sized hilsa of 9"-10" begin to make their appearance during October-November every year in the foreshore of the Bay even down to Cox's Bazar and the mouths of rivers including the Hooghly, evidently to feed on the rich plankton. After a short stay in the lower reaches, these small sized hilsa are said to migrate higher up in shoals around January-February.

Hora and Nair (1940a) observed that the *jatka* caught in East Bengal (Bangladesh) rivers are juvenile hilsa which migrate from estuaries into freshwater for feeding purposes. Hora (1941) pointed out that among the mature hilsa that swarm into the rivers during the flood season for spawning purposes, there are a number of young individuals also and these travel far up before they become sexually mature. He stated that spawning takes place in the tidal waters and in the middle reaches of the large rivers and inferred that the floods and sexual maturity induce the fish in the sea to undertake the upward migration. On the basis of samples examined from Chandipur on the Balasore coast, Prasad et al. (1940) and Hora (1941) concluded that hilsa in all stages of growth are found in the sea all along the foreshore area and that the fish feeds and continues to grow in the sea, except during November and February, and possibly also during May-June. It was surmised that after leaving the rivers they do not go far into the sea, but move about in shoals in the estuaries and foreshores.

Pandit and Hora (1951) summarised the extant hypothesis on the movements of hilsa as follows: (i) during the flood season, the adult hilsa swarm up the rivers for breeding. While they probably breed in the lower reaches of the rivers, some immature fish associated with these swarms move up and probably breed much higher up next year; (ii) the young fish fall back to the sea or estuarine areas in larger numbers during October-November; the numbers get reduced by February; (iii) at about the same time, November to February, the young which had migrated to the sea during the flood season and had grown to 7"-9", form a big-fishery; (iv) during March-April, the young ones known as *jatka* enter East Bengal waters in large swarms for feeding and form an independent fishery, and (v) these swarms move upriver and fatten as they grow and mature in the middle and upper reaches, the movement being facilitated by the increase in the volume of water in the rivers due to the melting of the snow in the Himalayas during the spring and hot months.

Jones (1957) was of the view that the winter migration of hilsa is influenced by the rise in the temperature of water in January. Based on observations of fishermen's catches, Pillay (1958?) has observed that hilsa ascend rivers only for spawning, that the spent fish as well as their progeny migrate down the rivers and the estuaries and that the coastal areas form the habitat of the species. His observation that young hilsa—often referred to as the *jatka* hilsa—which ascend the rivers from January to February are mature fish migrating for spawning, is of special significance as the fishery for this size group has so long been considered to be destructive to young ones. In the Chilka lake, Mitra and Devasundaram (1954) held the view that hilsa is a permanent resident preferring less saline waters.

The extent of migration in the rivers varies considerably. In the Irrawady, hilsa is known to ascend to a distance of about 724 km from the sea. The range of migration in the Brahmaputra is up to Tezpur, a distance of about 306 km from the Bangladesh border. The stock of hilsa in the river Ganga is reported to migrate as far as Agra and Delhi, covering a distance of about 1287 km. In West Bengal, hilsa ascend the river Hooghly for about 298 km. The hilsa of Chilka lake ascend the river Daya probably for a short distance for breeding. Only the older hilsa, which are apparently stronger, seem to be able to negotiate the rapids and reach the upper limit of distribution of the species of the river. In Bangladesh, they are reported to ascend the full span of the Gangetic delta system (Pillay and Rosa, 1963). Pillay (1952) and Pillay et al. (1963) have, however, expressed the view that the range of migration of hilsa is not as great as was originally believed.

It has been observed that during years of great abundance, the usual limits of distribution may be extended. Such instances have been recorded above Tezpur (Pillay and Ghosh, 1958) and in the small tributaries of the Ganga, through which the fish have ascended into lake Mahasra tal (Banerji, 1955).

Observations have also been made on the effect of weirs on the migration of the hilsa. Southwell and Prashad (1918) have stated that the effect of weirs in the Gangetic rivers is disastrous for the hilsa fisheries. But their effect in Bengal and neighbouring states differs from that in the erstwhile Madras state, in that in the former states, hilsa are found only very exceptionally beyond the anicuts even though the water level on the two sides of the weirs may be the same. Devanesan (1942) observed that the migrating fish gather below the obstructions and are caught in large numbers by the fishermen with disastrous effect on the fisheries.

Day (1873a) considered it essential to provide fish passes to facilitate the migration of hilsa to the upper reaches of rivers in which artificial obstruction have been constructed. However, the fish passes tried across the Coleroon river (*Day, loc cit.*) and across the Mahanadi (Southwell and Prashad, 1918) were found not suitable for hilsa. Later investigators have all expressed the opinion that it will not be feasible to erect suitable fish passes in Indian rivers (Nair, 1954). Malhotra and Shah (1979) have mentioned that fish passes at the Farraka Barrage also proved futile.

Besides the obstructions of rivers by the construction of weirs and anicuts, silting also appears to affect the migration of hilsa. Chacko and Dixitulu (1951) have observed that when the water level in the river Godavari was low due to failure of floods and silting during the season in 1950, the fish migrated along the shore and afforded a lucrative fishery on the Kakinada coast.

The occurrence of two runs of hilsa in the main river system, one during the south-west monsoon and the other during late winter, has been established. The late winter run is of a smaller magnitude and has been clearly recognised in the Hooghly (Jones, 1957; Pillay, 1958a), in the Chilka lake (Jones and Sujansingani, 1951), in the Godavari (Rao, 1969) and in Bangladesh rivers (Ahsanullah, 1964; Quereshi, 1968). The report that during winter, migration takes place in the opposite direction when the spent fish, larvae and juveniles move to the sea (FAO, 1971) may appear to indicate that there is no winter run in the Burmese rivers. However, read with the report of Day (1873a) that the minor breeding migration in March-April in the upper Irrawady takes place when the rivers are flooded by melting snow, the actual position is not clear.

While the estuarine stocks migrate up the river for spawning and return to the river mouths and adjacent foreshore areas, the stock in the freshwater regions of the Ganga do not seem to migrate to the sea. However, even among these freshwater stocks, an upstream migration has been observed during the breeding season (Pillay and Rosa, 1963).

Some earlier reports hold the view that of the two migrations of the hilsa in the Gangetic system, one is for breeding and the other for feeding (Howard, 1938; Hora, 1941). Pillay (1958a) has stated that the hilsa ascend the rivers only for spawning and the spent fish as well as their progeny migrate down the river. Tagging experiments of Pillay *et al.* (1963) confirm this view. Pantulu (1966), as cited by Gopalakrishnan (1973), has concluded that temperature, current, velocity, and volume of discharge are probably the significant directive factors to which the hilsa responds in its movements from the sea to the estuary.

The only studies on the migration of hilsa through tagging experiments are those of Pillay, Rao and Mathur (1963). The authors used an inexpensive type of nylon streamer tag earlier developed and described by Pillay (1959). The tag consists of a rectangular strip of yellow or red soft upholsterer's vinyl plastic, one end of which is rounded; a hole is punched at the other end. A braided nylon thread is doubled and the free ends are drawn through the punched hole and tied over the rolled-up end of the plastic strip. The two free ends of the thread are then sealed together over a candle flame. For marking hilsa, the tag is tied on the dorsal side of the fish. The nylon thread is passed through the dorsal musculature of the fish immediately

behind the dorsal fin with the help of a surgeon's needle. The explanatory legend is written on both sides of the tags.

A total of 5,875 fish were tagged during 1958 and succeeding seasons. Most of the tagging was done during winter fishing season, reportedly on mature fish which were caught in the clap net, *sangba jal*, and released in the Hooghly, the Padma, and the Ganga. The percentages of recovery were, respectively, 10.81, 4.13, and 3.48. About 30% of the recovery was obtained within 10 days after tagging and nearly 80% within a month. The maximum time interval between tagging and recovery was 770 days. While in a number of cases the fish were recovered from the same area after 2 to 4 days, there were instances of the fish having covered fairly long distances in very short periods of time, even as much as 38 to 44 miles in one day. The longest distance reported to have been covered was 212 miles in 58 days.

On the basis of six instances of recoveries made in the same area of tagging or its vicinity after periods of one to two years, the authors came to the conclusion that the same fish comes up the river during subsequent seasons, probably more than once. From the observations made by the authors, it would appear that the fish taking part in the winter spawning run also takes part in the succeeding monsoon spawning run, thus confirming the earlier observations of Pillay (1957b) that the hilsa which come up the Hooghly during winter and monsoon seasons belong to the same stock.

With regard to the pattern of migration, the authors could not find strictly correct the general assumption that the maturing hilsa ascend the river till they reach the spawning grounds and after spawning, migrate downstream. With the recovery data from Hooghly and Padma, the authors found that the downstream migration was pronounced during March. In the Padma, in April and May, there appeared to be upstream as well as downstream migrants. The trend of upstream migration started in August and ended by October. In November and December, only downstream migrants were recorded. The authors presumed that this represented the spent fish migrating to the lower reaches.

The authors came to the conclusion that the hilsa stock in the Padma and the lower Ganga finds its way to the lower estuaries through the main Padma that lies in Bangladesh. Since no tagged fish were recovered from areas far downstream of the Ganga, the authors were inclined to believe that hilsa stock in the upper Ganga is different from that of the lower Ganga and Padma. This is also the view of Pillay, Pillay and Ghosh (1963) as a result of their comparative morphometric studies on the hilsa population.

Behaviour

The fish is known to be a fast swimmer (Southwell and Prashad, 1918). Tagging experiments have shown that a fish may cover as much as 70.8 km in one day (Pillay *et al.*, 1963). Raj (1917) observed that a tendency to jump in the sea is predominant among the species, but Southwell and Prashad (*loc cit.*) have stated that such behaviour has never been observed in the Bengal waters.

According to Mojumdar (1939b), hilsa move in the sea on the surface whereas in the river they move at a depth of 14 to 18 metres, though on a cool or drizzly day they may rise to within **2 metres from the surface.**

During migrations upstream, the fish do congregate, but they have never been observed to form very dense schools as observed in the case of many pelagic fishes. During winter months, however, they have been found to form very large schools at the entrance of the Hooghly estuary. (It is learnt that such is also the case off Cox's Bazar during January to March.) Hilsa congregate in large numbers below dams or other obstructions to their upstream migrations (Pillay and Rosa, 1963). According to Southwell and Prashad (1918), hilsa that move near the bottom of rivers rise to the surface when they meet obstructions such as dams or anicuts.

IV. BIONOMICS AND LIFE HISTORY

Reproduction

Sexuality

The species is heterosexual, though one instance of hermaphroditism has been noted (Chacko and Krishnamurthy, 1949). The females, due to faster growth rate, attain larger sizes than the males (Pillay, 1958a; Pillay and Rosa, 1963; Jhingran and Natarajan, 1966; Quddus, 1982). Shafi, Quddus and Islam (1977) have observed that the body of females is broader and the girth comparatively larger. They have also mentioned that the urino-genital opening of the gravid female is flat, but narrower in the case of males where the papillae are comparatively prominent.

Sex ratio

Opinions differ whether one sex predominates over the other in different phases of the life history of hilsa or whether the distribution conforms to the normal 1 : 1 ratio. In the case of Hooghly hilsa, Jones and Menon (1951) reported that the ratio of males to females is generally constant, with a preponderance of males at the commencement of the breeding season, and of females during the period of spawning. Pillay (1958a) did not find any significant deviation from the expected ratio of 1 : 1 in the monsoon run of the fish and he was of the opinion that the predominance of males in the winter catches is attributable to selective fishing. Studies of catches from the Ganga have also shown that there is no heterogeneity in the sex ratio. (Jhingran, 1957; Mathur, 1964). However, Swarup (1958) observed the constant preponderance of males over females with a ratio of 2 : 1 in the river Ganga at Allahabad.

In the case of Chilka lake, Ramakrishnaiah (1972) found statistically significant differences in the sex ratio and dominance of females almost throughout the year, except in October. Similar observations have been made by Shafi, Quddus and Islam (1976 & 1977) in respect of Padma and Meghna hilsa. Quereshi (1968) further observed that although the sex ratio was 1 : 1 during the monsoon, the females dominated in October. Again in the winter catches, the males generally dominated except for the month of February. Quddus (1982) found that there was no significant departure from the expected ratio in the 'slender' type in the Padma and Meghna; however, in respect of the 'broad' variety, he observed that the males were preponderant in the months of June, October and December.

Maturity

Conflicting views have been expressed on the minimum size of hilsa at first maturity. Day (1873a) observed that the hilsa may attain first maturity at the end of the first year, or at the beginning of the second year. Jones and Menon (1951) agree with this view on the basis of their observations in the Hooghly, Chilka lake and the Mahanadi. They have recorded that the males become mature when $8\frac{1}{2}$ "-10" in length and presumed them to be over one year old, while females become mature in the second year when they are $10\frac{1}{2}$ -12" long. However, Pillay (1958a) found still smaller sizes in the Hooghly river at first maturity—males at 16-17 cm and females at 19-20 cm in total length when they are $1\frac{1}{2}$ years old; however, he did not find any evidence to support the view that males mature earlier than the females during the spawning season. Mathur (1964), studying the Ganga hilsa at Allahabad/Varanasi, observed that the males mature at a length of about 20 cm; he also recorded that 50% of females mature at 35 cm, the smallest sizes being 33 cm at Allahabad and 31 cm at Varanasi. In respect of females, a roughly similar size (34.1 cm) was indicated by De (1980) for the hilsa of the upper stretch of the Hooghly; it has, however, to be noted that the author's material related to fish 32 cm and above, and also was limited to the September-October period. A slightly larger size (37 cm) was observed for the female hilsa of the Godavari by Pillay and Rao (1963) who recorded for the male a size of 25.6 cm. These authors also mentioned that the modal size of 35.5 cm in the length frequency studies, the age of which was placed at 1+year, represents the group at first maturity. In all other cases the age was placed at 2 years at first maturity.

Ramakrishnaiah (1972), working on the hilsa stocks of Chilka lake, found three peaks in the relative condition factor. He attributed the first peak at 18.7 cm to attainment of maturity but also added that no spawning takes place at this size. He was of the opinion that the second and third peaks at 28.7 and 33.7 cm were due to ripening for spawning. Studying the fisheries of Chilka lake, Jhingran and Natarajan (1966) observed that mature females measure 20-30 cm and mature males 17.5-30 cm but it is not clear why they added that the females of 20-30 cm length may not spawn.

In Bangladesh waters (Meghna), Shafi, Quddus and Islam (1978) observed a size of 21 cm in the case of males and 32cm in the case of females, as the size at first maturity. Dunn (1982b), on the other hand, observed the absence of significant numbers of adult fish of sizes in the 4+ age group and suggested that there is little spawning below this size. This age group roughly corresponds to a length of about 40 cm.

Spawning season

Hora (1938 & 1941) and Hora and Nair (1940a) were of the opinion that in the Hooghly the fish probably breeds throughout the year with a major peak in July-August and a minor peak in May. The peak periods were found to be correlated with the flooding of the rivers owing to the south-west monsoon and the nor'westers respectively. Bhanot (1973) is the only other author who has indicated, with collection of larvae in the Hooghly river, that the hilsa spawns throughout the year, peaking in February-March, July-August, and October-November.

On the other hand, a restricted spawning period, as well as two distinct spawning periods, have been recorded by other workers. Jones and Menon (1950 & 1951) have stated that the breeding of hilsa is very restricted, if not at a standstill, during the winter months of December and January. They have, however, indicated the possibility of winter breeding lower down in the estuary where temperatures may be higher. Pillay (1958a) has shown that there are two distinct spawning seasons in the river Hooghly, one starting in the monsoon season and extending up to November, and the other during winter from January to February. After studying the early growth pattern of hilsa in the Hooghly, Sujansingani (1957) inferred that the spawning of hilsa cannot be demonstrated to cease by about January and hinted at the possibility of restricted spawning during January and February. From his studies on the distribution and abundance of fish larvae in the Hooghly estuary, Chandra (1962) concluded that there is no winter spawning for hilsa and that the fish breeds during the monsoon months with one peak in August and another in October. On the contrary, Bhanot (1973), as mentioned earlier, has collected eggs and larvae in the same region throughout the year.

Motwani, Jhingran and Karamchandani (1957) have reported that the breeding of hilsa in the Ganga would appear to commence with the onset of the monsoon in July, with peak breeding from September to December. Nair (1958) was of the opinion that although spermatogenesis and oogenesis start by the end of January, reach a peak in March and again start in June attaining a peak by August, during the first period of peaking the ova undergo atresia and resorption even though the spermatozoa are shed. He even indicated that it is only during the second peaking that actual spawning takes place.

Pillay and Rao (1962) observed that there is only one spawning season, which lasts from July to November, for the Godavari hilsa and that there is no winter spawning. But records of juveniles available in the studies of Rao (1969) and Rajyalakshmi (1973) appear to indicate that spawning could have taken place in winter.

Jones and Sujansingani (1951) stated that in the Chilka lake the breeding season is much shorter than in the Hooghly. They have observed ripe fish in the lake from August to October with September-October as the peak period, and concluded that Chilka hilsa breed in the lower regions of the Daya river. Their observations appear to indicate absence of any winter spawning, whereas the records of Sahoo(Ms.) indicate spawning in March.

Observations which support two spawnings, one during monsoon and the other during winter-spring, come from the investigations of Mathur (1964) in respect of the Ganga, Kowtal (1967 & 1976) with reference to Chilka lake, Shafi, Quddus and Islam (1978) in Meghna, and Quereshi (1968) in respect of both Meghna and Padma in Bangladesh. Records of only one spawning are also available in the works of Swarup (1961) who inferred the spawning to be restricted to August-November in the Ganga, of Rao and Pathak (1972) who collected larvae and post-larvae in the Brahmaputra in May-July, of Rajyalakshmi (1973) in respect of the Godavari where no spawning after October could be established, and of Ramakrishnaiah (1972) for the Chilka lake where evidence of spawning was available only in September with all fish after October being spent.

There is some evidence to suggest that there are two different and distinct spawning stocks or varieties. Ghosh and Nangpal (1970) found that winter spawning is restricted to the resident 'slender' variety in the freshwater sector of lower Ganga. Quddus (1982) was of the opinion that the stocks responsible for the two spawnings are different—the 'broad' variety taking part in monsoon spawning and the 'slender' variety in the winter spawning.

As for the factors influencing spawning, it is generally held that the upstream migration of the fish during the monsoon period is largely dependent on the flooding of the rivers. The second spawning migration was attributed by Jones (1957) to the general rise in temperature of the water in the estuaries after the close of winter. Nair (1958) stated that the temperature probably exercises some influence on the ripening of the gonads and rainfall provides favourable conditions for spawning. He concluded that very low and very high temperatures perhaps inhibit gonadal activity. He was also of the view that the rainy season, which floods the rivers and makes the water turbid and the current flow faster, is the condition most favourable for spawning.

Quddus (1982) observed that the onset of monsoon with heavy rain, high turbidity, high temperature and low production of plankton, may have activated and influenced the gonadal activities of the 'broad' type of hilsa which breeds in the monsoon season. On the other hand, a rise in the rainfall amount and temperature, and availability of plankton in the river system from February onwards, may offer favourable conditions for breeding of the 'slender' type of hilsa.

Spawning frequency

Virtually, all the studies on ova diameter measurements indicate that only one group of ova get differentiated from the general stock of oocytes. However, the inferences have been different. Pillay (1958a) inferred that in Hooghly the fish breed intermittently during the breeding season because if there is only one spawning in a season, the spent fish could be expected to be available throughout the seasons, whereas in Hooghly they were obtained only at the end of the spawning season. From the differentiated stock of ova, he presumed that several spawnings take place with only a small proportion of the ova being shed at each time. The author has also stated that the same fish does not spawn twice during the year. This is at variance with his earlier observations (Pillay, 1957b) and the opinion of Pillay *et al.* (1963). De (1980), on the other hand, concluded from his studies of Hooghty hilsa that there is only one spawning for individual fish, thus disagreeing with the above view of Pillay (1958a). At Allahabad (Ganga/Jamuna), Swarup (1959b) concluded that the fish spawn several times during the breeding season. The illustrations of ova diameter measurements given by Mathur (1964) for the specimens collected from the same area indicate multiplicity of modes among the already differentiated ova in the advanced stages of maturity. He has inferred that these modal groups are shed in batches. He also did not rule out the possibility of resorption of some of the well-advanced ova. It is also seen in the diagrammatic representation that the partly spent ovaries have a large percentage of advanced ova left behind. The author has also ruled out the possibility of unshed ova being carried over to the next spawning season. Thus, although it would appear that there is fractional spawning in hilsa, the conclusion that there is multiple spawning within the season for the same fish has to be taken with a certain amount of reservation since the data are not that convincing.

For the Chilka lake, Ramakrishnaiah (1972) concluded that the hilsa spawn only once in the season. In the Godavari, the observations of Pillay and Rao (1963) indicate one modal group of eggs ripening towards maturity, but occurrence of partly spent ovaries is evidence of fractional spawning.

For Bangladesh waters (river Meghna), Shafi, Quddus and Islam (1978) in spite of recording only one group of ova differentiating from the general egg stock, concluded that the individual fish spawn intermittently throughout the year.

Spawning grounds

Southwell and Prasad (1918) expressed the opinion that there are no fixed breeding grounds for the fish in the generally accepted sense of the term and that they probably breed during the rains when conditions such as weather, temperature and other undetermined factors are suitable. Hora (1938) inferred that the stretch of Hooghly river near Pulta Waterworks forms one of the spawning grounds of the fish. This was confirmed by further observations made by Hora and Nair (1940a) and Jones and Menon (1951). Pillay (1958a) inferred that the lower limit of the spawning ground of hilsa in the river Hooghly is Bagh Bazar in Calcutta. Chandra (1962) has also recorded the freshwater zone of Hooghly river as the spawning grounds for hilsa; this was later confirmed by Bhanot (1973). Both Chandra (*loc. Cit.*) and Bhanot (*loc cit.*) could not find any larvae in the tidal or gradient regions of the Hooghly. The hilsa of Chilka lake spawns in the lower regions of the Daya river (Jones and Sujansingani, 1951). Kowtal (1967 & 1976) observed from collection of eggs and larvae that the Daya river mouth and the region close to it in the eastern shore of the northern sector are the breeding grounds of the fish. Motwani *et al.* (1957) have described the spawning ground of hilsa in the Ganga as the stretch of the river between Patna and Allahabad. Ghosh and Nangpal (1970) have recorded the lower Ganga and Bagalpur areas to be the spawning grounds for the 'slender' variety of hilsa in the winter period. The presence of larvae in the neighbourhood of Lalgola in the Padma indicates the probability of the fish spawning in that area also. In the Godavari, Pillay and Rao (1963) inferred that hilsa breeds below the anicut at Dowlaiswaram to a distance of nearly 35 to 40 miles downstream in two of the three branches of the Godavari; these areas are about 20 to 25 miles from the sea. The authors observed that the fish may breed above the anicut also during years of very high floods when the fish are able to migrate above Dowlaiswaram, as evidenced by the presence of young fish in the upper stretches after the subsidence of flood. In the Brahmaputra, Rao and Pathak (1972) have recorded evidence of spawning through collection of larvae and post-larvae of 8-25 mm. In Bangladesh, Quereshi (1968) has recorded that the breeding grounds are predominant in Meghna and its tributaries.

Fecundity

Pillay (1958a) and Pillay and Rao (1963) found that the relationship between fecundity and body weight of hilsa is linear, and that between fecundity and length, curvilinear. However, there are also records of a linear relationship between length and fecundity (Mathur, 1964; Swarup 1961; Doha and Hye 1970; Shafi, Quddus and Islam, 1977). The estimates of fecundity in relation to fish size by different authors for different places are presented in Table I. These indicate that the fecundity of hilsa increases with increasing size of the fish; the estimates range from 0.1 to 2.0 million eggs for fish ranging in length from 25 to 55 cm. Generally, it is seen that for fish in the size range of 25 to 40 cm the fecundity estimate is about 0.25 to 0.40 million; for fish in the size range of 40 to 50 cm the estimate is 0.4 to 1.6 million and for fish above 50 cm, it is 1.3 to 2.0 million. All these findings suggest that the hilsa is a highly fecund fish. As the fish does not show parental care, the high fecundity enables it to compensate for any great loss of progeny which may occur due to predation and unfavourable hydro-ecological conditions. Comparative studies by Quddus (1982) of the 'broad' and 'slender' types of hilsa indicate a highly significant difference between the two types in the fecundity estimates. In the 'broad' type, the fecundity estimates range from 0.6 to 1.5 million for the fish in the size range of 33 to 51 cm, and for the 'slender' type from 0.4 to 0.6 million for fish ranging in size from 32 to 49 cm.

There is a close correspondence in the records of the number of ova per gram body weight; it is found to be 848 by Shafi, Quddus and Islam (1977) and 828 by De (1980).

The diameter of the fully ripe ovarian egg has been found to range generally between 0.70 and 0.90 mm. According to Southwell and Prashad (1951) the ripe eggs are 0.8 mm in size. Jones and Menon (1951) recorded the diameter as 0.70 to 0.75 mm. Pillay (1958a) observed 0.89 mm as the diameter of the ripe ovarian egg. The range given by Swarup (1961) is 0.6 to 0.9 mm. Quereshi (1968) recorded 0.7 mm as the diameter of the fully ripe egg. He further stated that the eggs are of oily transparency, pale yellow in colour and demersal in character. Mathur (1964) recorded the range as 0.76 to 0.86 mm with a modal size of 0.83 mm. De(1980) recorded the maximum as 1.0 mm with the mode at 0.34 mm. In Bangladesh waters, Shafi, Quddus and Islam (1977) have recorded 0.735 mm as the modal size of the fully ripe eggs.

The egg when laid in water and fertilized, swells to 2.1 mm to 2.3 mm in diameter and is demersal in still water, but its density being very close to that of water, it is easily buoyed up and drifted by slight currents (Kulkarni, 1950). Earlier, Southwell and Prashad (1918) recorded the size of the fertilized egg as 1.8 mm. The egg membrane is elastic and the vitelline space is wide. The yolk is segmented and has numerous oil globules of varying sizes which coalesce later to form a large and conspicuous globule (Jones and Menon, 1951). Kulkarni (*loc. cit.*) and Motwani *et al.* (1957) stated that the hilsa egg has a double-layered membrane, but Jones and Menon (1951) observed that the double layering takes place as a result of post mortem changes.

Larval history

Nair (1939) has given a description of larvae of 14-32 mm length which were obtained in November in the river Hooghly. A detailed account of the embryonic and larval development is available in Jones and Menon (1951). Contemporary works from other areas are those of Kulkarni (1950) and Karamchandani (1961) which relate to Narbada river on the West coast of India.

The length of the newly hatched larvae is recorded as 2.3 mm by Jones and Menon (1951); 3.1 mm by Kulkarni (1950); 2.50 to 2.55 mm by Motwani *et al.*, (1957); and 2.4 to 3.0 mm by Karamchandani (1961).

The rate of development of hilsa embryos is reported to be influenced by temperature conditions. Hatching takes place in about 23 to 26 hours at an average temperature of 23°C (Jones and Menon, 1951); 18 to 26 hours at 28.0°C to 28.5°C (Kulkarni, 1950); and at about 24 to 28 hours (Motwani *et al.*, 1957). Ghosh and Nangpal (1970) recorded in March/April in the lower Ganga region that the larval concentration was more on a day with lower water temperature at 22°C to 24°C; the concentration was less when the temperature rose from 26°C to 28°C and there was a total disappearance of the larvae on a further rise in the temperature to 29°C.

Juvenile history

In the Hooghly, according to Hora (1938), the brood of July-August may attain a length of 140-150 mm by the third week of November, indicating a growth during the first four months. Hora and Nair (1940a) recorded a length of 40-50 mm, 80-89 mm, 100 mm, 130 mm, and 160 mm during the first successive five-month period; they also estimated an average increase of 30 mm per month during the first five months, and 20 mm per month for the next seven months. They also recorded a slower growth rate of 35 mm a month during November and a higher rate of 50 mm per month during the summer months. From the rivers of Bangladesh, they have recorded juveniles of 50-79 mm and 110-129 mm in February and have remarked that *jatka* (juvenile of hilsa) come up the rivers in that region towards the end of March. Hora and Nair (1940b) confirmed the identity of *jatka* as juveniles of hilsa and recorded from February to May, a size range of 85-164 mm, which according to them corresponded to an age of two to five months. They also observed that the juveniles migrated from the estuaries into the fresh-

water region for feeding, and that during April-May feeding is stopped and growth inhibited. Jones and Menon (1951) found that in the Chilka lake, the July-August brood grows to about 110-133 mm by the first week of December. This would indicate a slower rate of growth as compared to that recorded by Hora (1938). Sujansingani (1957) concluded from the records taken from the river Hooghly that in the first month after hatching the fish grow to about 28 mm and in the subsequent 2 to 3 months, the growth rate was 15 to 20 mm per month: thereafter, a slower rate of growth, averaging 10 mm per month, was observed. Pillay and Rao (1963) registered a modal size of 65 mm in the river Godavari in January which they traced to 95 mm in February, 125 mm in March, and 155 mm in May. Another modal group at 75 mm in March was traced to 115 mm in May. Pillay (1958a) has recorded a growth of 110 to 120 mm in three months in respect of Hooghly stocks. In Chilka lake, Jhingran and Natarajan (1969) assigned the age of the juvenile hilsa measuring 50 to 74 mm, abundant in December-January, to $3\frac{1}{2}$ to $5\frac{1}{2}$ months. Ramakrishnaiah (1972) indicated the modal size of 62 mm found in December to be the progeny from late monsoon breeding in November which progressed to 137mm after 5 months: he estimated an average growth of 20cm during the first year. He was of the opinion that juveniles of 31 to 90mm recruited during November-January remain in the lake. Sahoo(Ms.) recorded waves of juveniles of 4 to 5 cm in length in late April in the mouth of the Chilka lake.

In the studies of Rao (1969) on the Godavari hilsa, it is seen that the 110-120 mm modal sizes occur from January through May and the 70-90mm group from February to June. The author explains that occurrence of the same length group in different months indicates that the spawning season is somewhat extended.

Rajyalakshmi (1973) was of the opinion that the winter recruits added 100 mm during a period of 4 months (February to June). She also traced the growth of the monsoon recruits from 88.5 mm in November to 213.5 mm in June, spanning a period of 7 months.

These records appear to indicate that the Juveniles remain in the rivers/estuaries till they probably reach a length of '150-160 mm which is believed to be attained in about 5 months' time. It is possible that the seaward migration is undertaken at this size/age. No information is available at present on the rate of survival of the early stages of fish, but it has been observed that the operation of small-mesh nets in the period immediately succeeding the breeding season in the river Hooghly results in large-scale destruction of young fish (Pillay and Rosa, 1963). Similar observations have also been made in respect of Bangladesh waters by Quereshi (1968).

Jhingran and Natarajan (1969) have indicated the strength of the juveniles recruited annually from 1958 to 1965 for successive size classes of 50-74 mm, 75-339 mm, Frd 499 mm and above.

Adult history

The lack of a suitable method for determining age and growth has been one of the major handicaps in the study of hilsa populations. Hard parts like scales and otoliths have been tried, but the results have either not been encouraging or would require confirmation. Since the stocks are mostly exploited by selective gear, length frequency studies also have their limitations. This has led to the expression of conflicting views on the subject.

Hora and Nair (1940a), Prashad, Hora and Nair (1940), Chacko, Zobairi and Krishnamurthy (1948), Chacko and Krishnamurthy (1950), Jones and Menon (1951) and Pillay (1958a), among others, have tried to interpret growth or spawning marks found on the scales, but the results have not been encouraging. Pillay (1958a) has concluded that the number of radii on the scales is not related to the age of the fish and is therefore of no use in determining either age or growth rate of the species.

Quddus (1982) found otolith quite suitable for age and growth studies. He noticed that the annulus formation in otolith takes place once a year both in the 'broad' variety of monsoon

season and in the 'slender' variety of winter season. The seasons of annulus formation were found to generally coincide with the spawning seasons of the respective varieties. The time and cause of annulus formation was assumed to be growth cessation associated with maturation, spawning, and partly starvation. The maximum number of annuli in both the types was observed to be 5 and the back-calculated total lengths at annulus formation were observed to be as follows:

Broad type:	158.8,	245.7,	309.1,	369.2,	and 417.5 mm
Slender type:	142.8,	224.6,	288.9,	348.4,	and 398.3 mm

Employing the length frequency method, Sarkar (1957), studying the size composition of hilsa catches from the lower Sunderbans, observed that the class interval having a mid-point of 304.5 mm grew to a class interval with a mid-point of 384.5 mm during December to March (3 months), adding 40 mm in January and 20 mm each in February and March. In the next season, the increment was only 60 mm in 3 months from 324.5 mm to 384.5 mm. Pillay (1958a) has concluded that male hilsa in the Hooghly attain modal lengths of 247, 343 and 393 mm and females 265, 391, and 436 mm in $1\frac{1}{2}$, $2\frac{1}{2}$ and $3\frac{1}{2}$ years, respectively. Pillay and Rao (1963) designated the length of Godavari hilsa at modal lengths of 355, 415, 455, 485, 505 and 525 mm as +1, +2, +3, +3, +5 and +6 age groups, respectively. In respect of Chilka lake, Jhingran and Natarajan (1969) estimated the age of 275-399 mm sized fish as $15\frac{1}{2}$ - $27\frac{1}{2}$ months. They also estimated that the fish grows to 217 mm in one year and 357 mm in 2 years. The observations of Ramakrishnaiah (1972), viz., that the fish grows to 237 mm in 1 yr and 387 mm in 2 years, closely correspond to the above estimation. In Bangladesh, Dunn (1982b) assigned an age of 5 or 6 months for 150 mm fish; yet he preferred to assign an age of 4 to 5 years to fish of 350-400 mm.

Food and feeding habits

Southwell and Prashad (1918) inferred from the large number of empty stomachs, that adult hilsa do not feed while ascending the river. Hora (1938 & 1940) recorded that the young hilsa between 20 mm and 40 mm in length feed mostly on diatoms and sparingly on crustaceans, and that slightly larger specimens up to 100 mm were found to feed on smaller crustaceans and also on insects and polyzoa. He also inferred that the young hilsa feed at the bottom as well. Hora and Nair (1940a) found that algae constituted the bulk of the food eaten during February-March, while diatoms formed the main item during the nor' westers (March-April).

Hilsa is essentially a plankton feeder and does not show any selectivity in feeding with its closely-set sieve-like gill rakers (Hora, 1938 & 1940; Jones and Sujansingani, 1951). Generally, the items which are preponderant are crustaceans (particularly copepods), diatoms, green and blue algae; organic detritus, mud and sand have also been recorded (Hora, 1938 & 1940; Hora and Nair 1940a; Chacko and Ganapati, 1949; Pillay and Rao, 1962; Halder, 1968 & 1971; Quereshi, 1968; Shafi, Quddus and Hossain, 1977a, to mention a few). Pillay (1958a) has reported that he did not find any evidence of cessation or appreciable decrease in the feeding activity during the spawning period, but some workers have observed that during spawning migration the intensity of feeding decreases or ceases altogether (Pillay and Rosa, 1963). Pillay (*loc. cit.*) has further observed that the stomach of spawning hilsa contained considerable quantities of mud and sand, showing that they feed at the bottom and that the intensity of feeding during the post-spawning period appeared to be very high. Pillay and Rao (*loc. cit.*) noted that both young and adult hilsa feed at the bottom in the Godavari. Marked variations in the intensity of feeding were recorded by Halder (1968). He later observed that the fish feed at all depths and that in the juveniles up to 120 mm, crustaceans dominated, and in the size range 120-160 mm diatoms dominated, but the situation was the reverse in the 180-200 mm group (Halder, 1971).

Quereshi (1968) was of the opinion that in Bangladesh waters, the fish appears to feed only in the sea and stops feeding while ascending the rivers and that the fish is probably sustained by the fat accumulated during the feeding phase in the sea which gets gradually reduced during the upstream journey. He has also noticed the presence of sand grains and mud, indicating

bottom feeding. Shafi, Quddus and Hossain (1977a) recorded that the juveniles were voracious eaters and bottom feeders and that the food and feeding habits change with increase in the size of the fish and with changes in the season.

Length-weight relationship and condition factor

A number of workers have studied the length-weight relationships, and some of them the fluctuations in the condition factor also. Pillay (1958a) found that the equation of exponential growth, $W = Ae^{bL}$ is superior to the equation $W = CL^n$ in describing the length-weight relationship in the case of hilsa. Swarup (1965) also adopted the former equation. Otherwise, the latter equation has been employed by other workers such as Rao (1969), Ramakrishnaiah (1972), Rajyalakshmi (1973), Shafi and Quddus (1974), and Quddus (1982). Shall and Quddus (1974) and Shafi, Quddus and Hossain (1978) found the length-girth relationship to be linear.

Regarding studies on the condition factor, Pillay (1958a) found that the ratio between gonad weight and body weight showed high values during and just after the monsoon (July-November) and in late winter (January-February), with a major peak in November and a minor peak in February. This trend is reflected in the relative condition factor, K_n , in both the males and the females. He also observed inflection in the curve of the variation in the K_n values at a mean length of 28.5 cm in the case of males and 30.5 cm in the case of females for the size range 19.5 cm to 48.5 cm. Since another inflection was seen among the immature fish at a mean length of 8.0 cm, and in the absence of data for the intermediate size between 12.5 cm and 19.5 cm, the author found it not possible to detect the actual point of inflection after the first peak of relative condition in the immature fish. The other workers who have studied the condition factor in terms of the relative condition factor, K_n , are Swarup (1967) and Shafi and Quddus (1974). The data of the latter authors show two peaks, one at 30 cm and the other at 45 cm. The authors attribute the first peak to recovery in freshwater after migration of the fish from salt water, and the second peak to the recovery after spawning, and the trough in between, to the spawning of the fish. It is also possible to argue that these two peaks refer to condition just before spawning at the respective sizes. The authors have not examined fish smaller than 30 cm.

Quddus (1982) examined the values of condition factor, K , and found slight differences in the values between the sexes and between monsoon and late winter which are the spawning seasons respectively of 'broad' and 'slender' types of hilsa. The mean condition factor in the 'broad' type showed peak values in the months of June, October and March in the case of males, and July, November and February in the case of females. With regard to the 'slender' type, the peak values were obtained in July and January for the males and September, January and March for the females.

V. FISHERY

Fishing methods

The riverine/estuarine stocks are exploited by a variety of gears, the most common of which are the clap net, gillnet, drift net, seine net, barrier net, and fixed bag net; the largest contribution, however, comes from gill/drift net. Mechanised fishing with gillnets accounts for the bulk of the landings from the sea, both in India and Bangladesh. The fishermen's choice of nets for operation in different areas and different seasons depends on the velocity of the current, the nature of the catch, and to a large extent, on their financial condition. Hornell (1924 & 1950), Naidu (1939), Ahmed (1954) and Jones (1959 a & b) have described hilsa fishing gear and its operation in the Indo-Bangladesh regions. The information contained in these

reports has been summarized and tabulated by Pillay and Rosa (1963). Saxena and Chandra (1968) have given a description of a new gillnet introduced in the Ganga. It is characterised by the absence of bottom ropes and sinkers and is reported to be comparable to certain other types of net in the region, including Burma.

The traditional boats, by and large, are plank-built, undecked or partly decked. A description of the types of fishing boats is given by Pillay and Rosa (1963).

The traditional boats in West Bengal vary in length from 6 m to 15 m. They are characterized by raised and pointed ends and oval midship section, usually without a keel. They are carvel-built, with planks butted together by "staples". They are partly decked with loose planks and have a tunnel-formed bamboo cover placed amidships as protection against sun and rain. They are driven by sails and oars. The gillnetting is done within a 15 km range from the coast by individual boats, but as far as 70-90 km offshore by a fleet of 5 to 6 units supported by a launch which transports them to and from the fishing area. The total length of a set of gillnets, made up of 120 pieces of 10 cm mesh size is about 1500 m. The usual depth of the net is 10 to 12 m, but nets of twice that depth have recently been employed in the fishery. **Some of the traditional boats have been mechanized and** are of 14 m length, equipped with 12 hp marine diesel engines. There are also mechanized gillnetters of 30 ft in length equipped with 37 hp engines. The launches which operate as mother ships for the traditional craft are 16-18 m in length and are equipped with 120 to 220 hp engines (Anon, 1977a).

In Orissa, the traditional craft is a plank-built displacement type, using sails and paddles/oars for propulsion. The typical length of these boats is 7 m. They have vertical and pointed stem and stern with a full midship section. They are built of planks with frames and there is one carvel and one clinker type of construction. They carry drift gillnets of about 12 cm mesh size measuring 600-900 m in length and **5 m in depth**. A set of gillnets is 1500-2500 m in length and about 9 m deep (Anon., 1977b). The mechanized gillnetters are of two types: 30-32 ft and 35-36 ft and are equipped with engines of 18 to 45 hp. The larger boats have been fitted with reconditioned old truck engines. Hilsa fishing is carried out in the northern district of Balasore. The area of operation during monsoon is about 10 to 15 km from shore where the depth is about 20 m, and during October to March it is 20 to 25 km from shore where the depth is about 40 m. At present, the mesh size of the drift net operated during July to September is 10-11 cm and during October to March, 6-9 cm. North of Balasore, on the Subernarekha side, the Orissa fishermen operate encircling nets for hilsa, a kind of mini purse-seine, in deeper waters in winter. Five or six country boats encircle the school. Both medium and small sizes of fish are caught and are sold to the mechanised boats coming from West Bengal.

According to a census report of the Central Marine Fisheries Research Institute (Anon., 1981 d), there were, as of mid-1980, 740 mechanized gillnetters owned by fishermen in West Bengal and 119 in Orissa. The non-mechanized plank-built boats were estimated at nearly 4000 in West Bengal and a little over 3000 in Orissa. The number of drift/gillnets is about 2500 in West Bengal and 10,500 in Orissa; however, Balasore district is credited with only 1700 drift/gillnets.

In Bangladesh, there are three types of fishing craft: *Dinyhi*, *Chandi* and *Baiam*. The *Dinghi* is a plank-built shallow boat about 6 to 8 m long with pointed bow and stern. There are ribs and cross-beams to strengthen the hull. The decking consists of detachable and half-split bamboo. They are propelled by long oars and/or by sail. The *Chandi* is also a plank-built boat and its length varies from 5 m to 26 m. It has a stern slightly higher than the bow. Part of the vessel is decked with planks; the rest may be decked with split bamboo. The mast is far forward and usually carries a square sail. In the *Ba'am* the hull is a dug-out and the bow and stern are slightly raised. The sides are built up by fitting planks to the dug-out. These planks are tied with 'rattan' and made watertight by plugging the joints with weeds. A small *Balam* has no deck or hood. A large *Ba'am* is 15 m to 20 m long, the medium ones are 10 m to 15 m long. The motorized traditional boats are 12 m to 14 m long and are equipped with 15 to 23 hp engines. They carry 100 pieces of gillnets of total length 1400 m on an average (Mohiuddin *et al.*, 1980). The present day mechanized gillnetters are 38 to 50 ft in length fitted with 22 to 33 hp Yanmar

engine. The mesh size of the drift gillnet, whether in the traditional or mechanized boat, ranges from 7.5 to 13.5 cm, the most common being 8-11 cm.

In Cox's Bazar region, the fishery is exploited mainly by the gillnet from September to December; during January to March a very large encircling gillnet is used; in June and July the clap net is employed. About 2000 mechanized boats are believed to be in operation in Cox's Bazar division, and about 400 in the Chittagong division. The fishing grounds are generally between 160 km south of Cox's Bazar (St Martin Island) and about 50 km northwest of Cox's Bazar (Kutubdia). Of this coastal stretch, the fishing grounds are reported to be between 3-5 km and 32 km due west, the concentration being more in the area 24 to 32 km due west of the coast and 32 to 40 km due south of Cox's Bazar.

Fishing season

The fishing for hilsa takes place mainly during the monsoon season when adult fish migrate up the rivers for spawning and is centered in the estuaries and rivers. A less important fishery takes place during the later part of winter, when there is a minor run of mature fish up river for spawning. Fishery also takes place during the winter season for young fish from estuaries and river mouths (Pillay and Rosa, 1963). In the sea off Cox's Bazar, the fishery extends almost throughout the year, but the activity is much reduced during the monsoon months of June to August. There are two peaks of catches, a major peak during September-October and a minor peak during February-March. On the other hand, off Chandipur, Orissa, monsoon fishery is now reported to be more intense than during the other months; earlier Pillay and Rosa (1963) recorded that on the Digha and Chandipur coasts of India, fishing is carried out throughout the winter months. Now the sea fishery extends from July to March.

The duration of the fishing season varies in different areas. Fishing in the rivers generally starts after the commencement of the south-west monsoon and lasts till 2 to 3 months after the monsoon. The winter fishing is limited, generally starting around December in the lower reaches and January-February in the upper reaches of the Hooghly. In Chilka lake, and in the river Ganga there is year-round fishing activity, though the peak periods are during the monsoon and winter (Pillay and Rosa, 1963).

As the fishery for hilsa is largely dependent on its migratory movements, the time and duration **of the fishing season also varies with the time and duration** of the migrations. The fishing season generally lasts as long as the catches are satisfactory. Mojumdar (1939b) and Hora and Nair (1940a) have observed that better catches are obtained during the spring tides.

There have been some changes in recent years from the general trend indicated above by Pillay and Rosa (1963). In the Hooghly-Matlah estuarine system, the winter season (November-December) has brought in a richer fishery than the monsoon season (July to October) according to Mitra and Ghosh (1979); the authors have also recorded that the summer season (March-June) is the lean season. The marine zone has contributed largely to the winter season's catch, while the upper estuaries have contributed mostly to the monsoon catch. A somewhat similar picture with regard to seasonal abundance comes from river Jamuna from where Ghosh (1967) has reported that the winter season extending from November-February marks a most productive season followed by July-October with peak catches in October; the summer months of March to June represent a lean period.

In Orissa, practically all the marine catch of hilsa comes from the Balasore coast. The importance of hilsa at Chandipur is reported to be largely due to influx of fresh water from the river Budhabelang where there is heavy flood during the monsoon from the mountain range of Maurighanj District. Similarly, good fishing exists at Kasafal where the river Panchapara meets the sea. The next important place is Chowmukh where the river Subernarekha joins the sea. In the south, there are two places Cheudamani near the river mouth of Gomei, and Chandnipal, the southernmost point near the mouth of river Damra.

Earlier, there was a regular fishery in the Mahanadi river, but now there is practically none; nor is there any fishery in any other river mentioned above. Even though Mahanadi opens into

the sea at Paradeep, there is no recorded fishery there, probably because the sea is much deeper in that area. With regard to the marine fishery, in former years, during 1962-70, the fishery used to start after the Pooja in October and extend up to March. However since 1970, the monsoon fishery has also picked up due to the increase in mechanized gillnetters. Both mechanized and traditional gillnetters operate during the season. There is year-round activity but catches are poor during April/May. The bulk of the catch generally comes during October to December; the June to August period accounts for the next highest production.

With regard to Bangladesh, Ahsanullah (1964) has reported that in the northern region (upper reaches of the rivers), hilsa is mostly caught in summer months. In the eastern region (coastal stretch of Chittagong and Cox's Bazar), the winter months of December-March represent the lucrative fishery with a peak in January; in the southern regions (lower reaches and estuaries), it is almost throughout the year, having two peaks—one in September, and the other in January or February. In this area the catches pick up in June, reach a peak in September and decline by November-December, only to attain another peak in January-February followed by a decline thereafter till June. Quereshi (1968) has confirmed that the fishery lasts almost throughout the year, the summer run starting in May and lasting till October-November, and the winter run from January to March. Shafi, Quddus and Hossain (1978) have also indicated that in Padma the fishery is throughout the year with two peaks in October and January. According to Dunn (1982b) there are three distinct peaks of production, a winter peak around February, a peak in June, and a major peak in September. While this is the result of a combination of information from different parts of the fishery, it does not necessarily represent the complete picture at any one location. With regard to sea fishery, the peak catches are obtained in October and in March.

In Burma, the main season for sea fishery is September to February, with a peak in November-December; the main fish supply to Rangoon market comes during November to April (FAO, 1970 Er 1971).

Age/size composition in the fishery

The commercial catches of adult hilsa in the river systems of India are reported to be composed of age groups 1+ to 5+ years, the dominant age classes being the 2+ and 3+ year groups. The monsoon fisheries are contributed mainly by the larger sized fish, the small sized groups forming the fishery during the winter months. This general pattern has been found to hold good in the Hooghly, Padma, Ganga and Godavari where there are distinct monsoon and winter fisheries for the species (Pillay and Rosa, 1963).

Pillay (1957a) attributed the success of the fishery in 1954 and 1955 to the contributions made by the 3+ and 4+ year old classes, which he traced to successful spawning in the monsoon of 1950.

Pillay and Ghosh (1958) recorded that the commercial catches in the Brahmaputra and the Barak consist mainly of 3 year old fish. Pillay (1958a) recognised five size groups in the commercial catches from the Hooghly—62 mm (undetermined juveniles), 169 mm (immature), 253 mm (mature; 1½ years), 364 mm (mature; 2½ years), and 446 mm (mature; 3½ years). He also found that the modal lengths of mature male and female hilsa of the three age groups differed significantly, the differences being 18, 47 and 43 mm, respectively, in the three successive age groups. He further observed that larger sized hilsa were more predominant in the catches in the lower Sunderbans during the winter months than higher up the river.

Difference in sizes between sexes was also noticed by Jhingran (1957) in the Ganga fishery at Buxar; the males ranged in length from 221 mm to 465 mm and the females from 325 to 485 mm. Jones and Sujansingani (1951) recorded a length range of 84 mm (December-January) to 520 mm in the case of Chika hilsa. From the studies of Ramakrishnaiah (1972) in the Chilka lake, it appears that the fishery is supported by the 1 and 2 year groups comprising modal sizes of 240-260 mm and 340-390 mm, respectively. From the account of Jhingran and Natarajan (1969) also, it would appear that the 270-400 mm group is the backbone of the fishery

in the lake. In the Sunderbans, the commercial fishery is supported by the 300-380 mm group (Sarkar, 1957).

Ghosh (1967) has analysed the size distribution in the commercial catches of river Jamuna. He classified the size groups as small, medium, large, and very large, with the respective size ranges of 96-228 mm, 229-381 mm, 382-500 mm, and above 500 mm. From the tabulated statement showing the distribution of dominant size groups, it is seen that the medium sized fish, i.e., of size range 229-381 mm, has been more frequently represented than the other size groups, while the success of the fishery depends upon additional contributions from the third group.

Off the Orissa coast, from June to September the fishery is for the larger fish of 250 to 500 mm which are reported to be gravid, and from October to March, it is for the smaller fish in the size range 200 to 250 mm. During December/January, the sudden appearance of juveniles in 120 to 150 mm size range is often reported. This is followed by the continuance of the earlier size group, 200 to 250 mm. This fishery is exploited by small-mesh gillnets, 24- to 31/4 inches mesh size. Dunn (1982b) is of the opinion that the fishery in Bangladesh is accounted for by hilsa that are four to five years old.

Population

The size and density of any of the hilsa stock have not yet been determined except for one reference wherein Ghosh (1976) has mentioned that the production of the fishery above the Farakka Barrage has dropped from 116.1 kg/km pre-construction to less than 1 kg/km post-construction. Wide fluctuations have been observed in the abundance of the fish in different river systems and a five year cycle in the abundance of the fish suggested (Hora, 1940; Hora and Nair, 1940a; Biswas, 1954; Varma, 1954). Hora and Nair (*loc. cit.*) have indicated that the variations in the monsoon are probably responsible for the usual fluctuations in the annual crop of the species.

According to Pillay and Rosa (1963), recruitment to the fishable stocks in most areas takes place when the fishes are 1 to 1½ years old and have attained sexual maturity. The recruitment rates appear to fluctuate very greatly from year to year and this fact appears to be largely responsible for the fluctuations in the fisheries. There is a general belief, according to the above authors, that the hilsa fisheries of the Indian region are fast becoming depleted. This belief is largely based on the inadequacy of supplies to markets and the increase in consumer prices. Detailed information on the dynamics of the population is not available.

Jhingran and Natarajan (1969) estimated the mortality from age 1 to age 2 as 70%, which they attributed to over exploitation.

Some catch and effort data are available in the works of Pillay and Rao (1963) and Rajyalakshmi (1973) for the Godavari (Table X & XI). Pillay and Rao (*loc. cit.*) have observed that the improvement in catches during the 1960 monsoon was reflected in the catch per unit effort. From the studies of Rajyalakshmi (*loc. cit.*) it is seen that in the years 1963 to 1967, the catch and the effort were the highest in 1964. The best catch per effort was obtained in the following year, perhaps due to a reduction in effort by 50%. The subsequent two years saw reduction in both catch and catch per effort. The trend does not appear to indicate that the decline is fishery-induced.

Some catch and effort data are available in the experimental fishing trials conducted by the FAO/IDA project for "Development of Small-Scale Fisheries in the Bay of Bengal", under activities undertaken on "Mechanisation of Country Craft", and "Large-mesh Driftnets", and "Small-mesh Driftnets", in Bangladesh. Dunn (1982b) has reproduced some data; Pajot and Das (1981 & 1984) have published some; other data remain unprocessed or unpublished.

Catch

The highly dispersed nature of the fisheries, the physical terrain and the difficulties in approaching the landing centres, and the diversity of fishing gear employed, and the system of transfer

of catches to collector/carrier boats at the fishing grounds are the major handicaps to the collection of reliable catch statistics. Lack of precise and comparable data, with reference to space and time, precludes analysis of the fluctuations in the catches. The catch records have a continuity only for a few places and for a few years. Considerable fluctuations have been reported in the catches from different areas.

Pillay and Rosa (1963) have reported that in the erstwhile East Pakistan (Bangladesh) the catches ranged between 13,608 tonnes and 18,144 tonnes. They have placed the total catch of hilsa in India at an average figure of 16,000 tonnes. They have also given production figures of some selected areas where sampling surveys have been undertaken during the period 1958-1961. These figures indicate an average catch of 766 tonnes for the Padma, 303 tonnes for the Hooghly, and 110 tonnes for the Ganga.

Ghosh (1967) mentions that of an estimated landing of 460,000 tonnes of fish from the inland waters of India, hilsa accounted for about 14,000 tonnes. Since the present inland fish catches in India are estimated to be of the order of 1,000,000 tonnes, proportionately the hilsa catch may amount to about 30,000 tonnes, provided that there has been no marked decline in the yield. The rivers Hooghly, Jamuna, Ganga, and Brahmaputra and their tributaries may contribute to about 70% of the total hilsa production in India. On this basis, it may be estimated that the hilsa production from the inland waters of the region adjoining upper Bay of Bengal may be around 21,000 tonnes. With regard to marine catch of West Bengal and Orissa areas, probably some improved statistics, as collected by the Central Marine Fisheries Research Institute (CMFRI), are available from 1974. These records (Table II) indicate a catch ranging from 3,044 to 10,629 tonnes in this coastal stretch. Of this, the Orissa coast accounts for the bulk, ranging from 60% to 90%, averaging mainly around 80%. The low landings on the West Bengal coast are probably due to the fact that fishing is carried out only from the short Contai coast and the catches are often taken by water transport to the deltaic area for disposal, thus not being reflected in the coastal catch. The data available with the Directorate of Fisheries, Orissa (Table II), on the other hand, indicate much lower figures. For the comparable period, 1976-1981, the average annual estimate of the State Government is only 16% that of the CMFRI.

Some regular catch statistics are available for the Hooghly-Matlah estuarine system. The tabulated figures (Table III) indicate that from a very low catch of 100 to 200 tonnes before 1960, the average figure rose to 1,085 tonnes during the 1960s and to 2,670 tonnes during the 1970s. There have been two bumper harvests, in 1971-72 and in 1981-82, when more than 6,000 tonnes were landed.

Some landing figures at Allahabad from the rivers Jamuna and Ganga are given by Ghosh (1967) (Table IV). At Allahabad, the average catch from 1955 to 1962 was 72 tonnes from the river Jamuna and about 120 tonnes from the river Ganga. It is further seen that while violent fluctuations in the landings have been a characteristic feature of both the riverine stocks in that period, the Ganga stock seems to have staged a revival whereas the Jamuna stock appears to have dwindled considerably.

A time-series of catch data is also available for the Chilka lake (Table V). It is seen from these records that during the phase 1957 to 1965 the average catch was 142 tonnes, whereas since 1970 the average catch has improved slightly to 165 tonnes. The fluctuations have been more moderate and within a limited range since the 1970s, whereas the fluctuations were rather violent during the earlier period. Jhingran and Natarajan (1966 Er 1969) have reported that the northern sector of the lake contributes about 78% of the total catch. This area is characterized by low salinity as compared to the central and southern sectors of the lake.

For Bangladesh, we have some data from Ahmed (1954) and Ahsanullah (1964) (Table VI). The data given by Ahmed (1954) relate to the quantity of hilsa exported to India during the years 1948-1949 to 1951-1952. Among these four seasons, the year 1951-1952 was the best with an export of nearly 4,000 tonnes. In the investigations carried out subsequent to the recommendations of the Hilsa Sub-Committee of the IPFC, the production from Bangladesh waters was estimated by Ahsanullah (1964) for the period 1956-1957 to 1961-1962 when

the annual catch ranged from 95,255 tonnes to 147,065 tonnes, with an average of 122,688 tonnes. This includes a catch of about 7,000 tonnes from the marine sector. A decline in trend was seen from the beginning of the 1960s. Probably this trend continued almost till the end 1960s when the catches seem to have improved considerably, as can be seen from the data compiled by Dunn (1982b) for the period starting mid-sixties. The latter has estimated the Bangladesh catch to be of the order of 90,000 to 100,000 tonnes. This was based on an assessment of all the available series of data for 1981 which suggested that the commercial catch of that year was between 45,000 and 50,000 tonnes; presuming an equal quantity is traded at the smaller landings and consumed in the fishing communities, the total estimated figure was arrived at. Melvin (1984) has placed the landing figure at 125,000-150,000 tonnes for 1982 and 1983.

Shahidullah (Ms.) has estimated the production from the mechanized boats operating along the coast of Bangladesh, at about 54,000 tonnes in 1982-83. The data collected at Chiflagong show an average of 1.33 tonnes of all fish for each trip. On the basis of three trips in a month for each boat and for a period of 8 months in a year, he estimated a total catch of 80,000 tonnes for 2,500 mechanised boats. Of this catch, the hilsa was credited with 67.5%. In 1983-84, the estimated yield is reported still higher not only due to increase in the number of boats to about 3400, but also due to a better average catch of 1.68 tonne per boat per trip (Shahidullah, personal communication). On this basis the estimated catch of hilsa is about 95,400 tonnes, forming 69.6% of the total fish catch.

In the early years of mechanization, the hilsa was found contributing a small percentage to the catches of the mechanized boats operating from Cox's Bazar, as seen in the status paper by Mohiuddin et al. (1980). However, during the years 1967-68 to 1971-72 the percentage of hilsa was found to increase from about 13% to about 32% of the total catch of the mechanized boats, the quantity of hilsa catch increasing from 60 tonnes to 181 tonnes. There has been further improvement and the estimated catch in the recent years is over 1000 tonnes at one particular landing centre in the Cox's Bazar region (Table VII). The estimates are based on six observation days in a month, once every 5 days.

At the same landing centre, according to the records of the BFDC, the hilsa landings were 428, 828 and 1147 tonnes respectively during the successive seasons, 1981-82 to 1983-84. Although this increasing trend conforms to the general trend in the coastal fishery, it is suspected that the above figures are underestimates, because the weight is evaluated on the basis of the value of the catch declared by the auctioneers who have to pay a levy of 6% of the value as landing charges to the BFDC. A comparison with Table VII for the corresponding years lends support to this suspicion.

The Marine Fisheries Department of the Directorate of Fisheries at Chittagong has a programme of collection of data on major species-wise landings at the three landing places in Chittagong, since January 1982. Mr. T. F. White, Team Leader of the FAO/UNDP project on "Marine Fisheries Research, Management and Development" has analysed the hilsa data and has provided the following information.

The total landings were 7730 tonnes in 1982 (average of 644 t/month) and 11,905 tonnes in 1983 (average of 992 t/m). In general the landings show the usual two peaks, one between January and March and the second in September-October. The normal lean period for landings and effort is April to August. Practically all the landings are reportedly caught along the eastern coastline between Cox's Bazar and Kutubdia Island, and hence may be considered as purely of marine origin. The catch per effort—landings per vessel and landings per vessel per fishing day—also appear to exhibit a pattern similar to the landings—two peaks, one in February-March and the other in September-October.

Whether these peaks faithfully reflect changes in abundance or are artefacts reflecting changes in catchability (due to the effect of weather upon gear efficiencies, amount of net used, ability to sight fish for encircling net fishing, seasonal changes in mean fish size, etc.) is not known. The fishery is exploited by gillnets of different mesh sizes and encircling nets, according to the season and the size of the fish. Of the gillnets, the 4" mesh net caught the majority of the fish, though the 3.5" mesh gillnet replaced the larger net during the latter part of the year. The mean size of the fish probably decreased during the second half of the year.

In a 1985 study, the Fishery Resources Survey System of the Directorate of Fisheries, Bangladesh, estimated that 70 per cent of the 80,000 t landed in 1983-84 by gillnets and seine nets was hilsa.

Dunn (1982b) has painstakingly compiled all the available records in Bangladesh. The sources of records were the freight offices of the Bangladesh Railways on transshipment from four principal railway stations, the Barisal Fish Merchants' Association, and the wholesale fish markets at Dhaka and Narayanganj. His records indicate that during the first half of the 1970s there were very good landings representing a revival phase from the earlier phase of less production during the late 1960s. There was a fall in production in 1976 and 1977, followed by a partial recovery and stabilisation during the subsequent period till date. For the five landing centres considered, the average figure for the first half of the 1970s was 25,000 tonnes and for the subsequent years up to 1981 the average was about 21,000 tonnes. The earlier period represents a rich riverine fishery which seems to have declined during the latter period. However, the fall has been compensated to a large extent by increase in the marine catch in Chittagong from an average of about 700 tonnes during the former period to an average of 6,000 tonnes during the most recent three-year period. His data in respect of each of these centres for the period 1972 to 1981, as corrected for some years by Melvin (1984), have been summarized in Table VIII.

For the period 1956-1957 to 1961-1962, Ahsanullah (1964) recorded that in Bangladesh, Chandpur accounted for the largest share (31%) of the total hilsa catch. This centre was followed in importance by Barisal, Khulna and Goalunda. Recently, the reports of Dunn (1982b) and Melvin (1984) indicate a major departure from this sequence; the order of importance is Chandpur and Chittagong competing for dominance followed by Barisal, Goalunda, and Khulna. Dunn further indicated that according to anecdotal information, the location of the major hilsa fishing grounds has been moving downstream and at present the major activities are in the lower reaches of the main rivers and estuarine areas. Melvin (1984) has gone a step further to draw attention to the growing importance of hilsa landings from the marine sector. His analysis of marine landings as depicted by landings at Chittagong show the usual peaks in February and October, with a large depression occurring during the May-September monsoon season when increased catches are reported in the riverine and estuarine systems. In the latter regime, as evidenced by the landings at Chandpur, peaking occurs in June and September; between November and April the catches are extremely low. This trend is brought about by the spawning migration into the estuaries and rivers. The index of landings at Goalunda, which receives catches from both marine and inland waters, thus shows a combined picture of three peaks in March, June and September.

Earlier Ahsanullah (1964) credited Meghna and its tributaries with 65% of the total hilsa catch, the Padma and the Pasur contributing 15% and 13%, respectively. The share of the marine sector was 6%. On the whole, 9% of the total landings came from the northern region of Bangladesh, the eastern region accounting for only 6%, and the remaining 85% came from the southern region. Quereshi (1968) has recorded that the hilsa formed a small fishery in river Karnaphully, near Chittagong, but that this is not of much importance. It may be significant to record here that at present there is no fishery in river Karnaphully.

Information available from Burma (FAO, 1970 & 1971) is given in Table IX. During the period 1966-1969 the hilsa catch was found to increase from about 2,600 tonnes to nearly 5,000.

Factors affecting the fishery

It has been reported by several workers that variability of the monsoons causes considerable fluctuations in the catches of hilsa. The intensity of the monsoon and the time of its arrival and the consequent flooding of the rivers, and high turbidity of the waters have been included as causal factors.

Hora and Nair (1940a) and Hora (1941) have recorded that besides the annual fluctuations, there is a five-year cycle in the hilsa fishery. This view was supported by Biswas (1954) on

the basis of the trend in prices, and by Varma (1954) with regard to hilsa fisheries of Bihar. Hora and Nair (*loc. cit.*) have also observed that the long range fluctuations are due to large populations attaining maturity at particular periods. They have inferred that a majority of the fish attain maturity when they are five years old and hence every five years the bulk of the stock on becoming mature swarms up the river and provides bumper catches. Noticing the absence of the reputed five-year cycle in the data compiled by him, Dunn (1982b) has observed that the five-year cycle can be easily accommodated with the five-year generation cycle and that the effect of a successful recruitment year may be felt for several subsequent generations of the fish stock.

Jones and Sujansingani (1951) have presumed that the migration of hilsa, and consequently the abundance of the fish in the estuaries, are correlated with the floods in respect of the fishery in Chilka lake and the Mahanadi. However, Mitra and Devasundaram (1954) have disputed this, adducing additional data on flood levels in the Mahanadi. They were of the opinion that the fluctuations are probably influenced by the intensity of fishing and not by the flood levels.

Ghosh (1967) is of the opinion that the decline in the catches in the Jamuna is due to the change in year classes and higher representation from the younger classes resulting in reduction in the total quantity of the landings. Gopalakrishnan and Ghosh (1971), while examining the incidence of a bumper crop in the Hooghly estuary in 1971, have observed that the principal factors contributing to the bumper crop are due to essential discriminative factors in the lower zones favouring large-scale spawning migrations of the fish. These factors, like water velocity, volume of discharge, suitable physico-chemical factors like salinity and temperature, have been the direct result of unusually early floods in the river, well before the normal monsoon rains.

Dunn (1982b) has listed the following as the ecological factors which have important effects on the fishery: rainfall pattern, flow rates and water turbidity, sediment and nutrition load, extent of flooding, levels of primary production and availability of planktonic food, and fishing pressures especially on juveniles. He has examined the rainfall records, the water level fluctuation and turbidity values. He has suggested a direct correlation between intensity of monsoon and recruitment which is reflected after five years in the fishery. He has also related the two peaks of monsoon rainfall during June to September with the two peaks in the catches in the months of June and September. Finding it difficult to suggest which environmental parameter is the stimulus for this synchrony, he is of the view that the stimulus to migration and conditions for reproductive success must be an environmental factor or a combination of environmental factors associated with waters of many channels, such as flow, silt load, primary and secondary production. These environmental factors are dependent upon conditions throughout the whole of the vast watershed of the Ganga-Brahmaputra system and not only on local rainfall and drainage. The author has also considered water level fluctuations in the Padma and the turbidity values, expressed as index of sediment load compared with water-flow, as causal factors in the fluctuations in the fishery, but could not arrive at any definite conclusion. However, Melvin (1984) did not agree with Dunn's observations on a positive correlation with the index of monsoon severity or with the five-year cycle.

VI. RACIAL INVESTIGATIONS

The possibility of there being different races of hilsa was conceived at a very early stage of hilsa investigations. Day (1873a) has mentioned two classes which ascend the rivers: those below one year of age and which do not appear to breed, or if they do, it is at the very end of the year or commencement of the succeeding one; and those which breed at the commencement of or during the monsoon. This is comparable to what in the present day, is called the winter and the monsoon runs, respectively. His observations are thus suggestive of two physiological races.

On more or less similar lines, Jenkins (1938) has raised the question whether there are two, or more, races or varieties of hilsa with different spawning grounds and habits. Following this, J.T.J. (1940) wondered whether the fish which spawn in the Sunderbans and those which spawn up the Ganga beyond Monghyr represent distinct races, and if so, whether they could be distinguished apart. He referred to the samples received from Allahabad which were marked with black spots, a characteristic feature of the young. Naidu (1939) has also pointed out the variations in the number of lateral blotches and the absence of them in some, and has raised the question whether these variations distinguish distinct races or species, or whether the feature is only a variation of colouration in the same species. He was also of the opinion that there is not sufficient evidence to prove that the fish known *asjatka* in East Bengal is really the young of hilsa and that the likelihood of their being different stocks has to be investigated. Mojumdar (1939a) has indicated that there are differences between hilsa occurring in different rivers of East Bengal and also of the sea. He recognised three types of hilsa: (i) those of the saline water of the seas, (ii) those from the muddy freshwater of rivers like Padma or Hooghly, and (iii) those from the clear freshwaters like Meghna, though some may migrate from place to place with the rise of water. According to him, the Padma hilsa is thicker in structure and of a bright silvery colour, while the Meghna hilsa is thinner, a bit darker and a bit elongated. He has also suggested that turbidity and the degree of salinity are factors separating the stocks. That there is a possibility of three eco-types was shared by Dutt (1966) also.

Hora (1940) has suggested that the hilsa of the Hooghly and East Bengal (Bangladesh) might represent separate stocks. Hora and Nair (1940a) found no evidence in support of the possibility of two or more races as far as the stocks of the Hooghly and those obtained from the Ganga at Allahabad were concerned. However, they indicated that the specimens from East Bengal are somewhat deeper and it is quite possible that different races of the species occur in other rivers.

In the proposal for the investigation of the hilsa stocks of India, Pakistan and Burma, the Hilsa Sub-Committee of the I.P.F.C. observed that whilst it is most likely that the western populations of the Persian Gulf and of the Indus remained quite distinct from those of the Bay of Bengal, the status of the Bay of Bengal stocks cannot be considered with the same assurance; there is a possibility that each separate river system has its own stock and that even each of these is further fragmented into spawning or ecological groups; there is also the possibility of communication between at least the stocks of the rivers flowing into the Bay of Bengal (Hora, 1952). In view of the interest thus generated, the subject engaged detailed study in the subsequent years. (Pillay, 1952, 1954 & 1957b; Pillay, Pillay and Ghosh, 1963; Ghosh, Bhattacharya and Rao, 1968; Rao, 1969; Ramakrishnaiah, 1972; Quddus, 1982).

Pillay (1952 and 1954) made a preliminary biometric study comparing the data relating to body size and length of head of samples drawn from what was East Pakistan (Bangladesh), West Bengal, Uttar Pradesh and Orissa, and indicated the possibility of there being at least three stocks of hilsa distinguishable by the relative size of the body, one stock co-extensive from East Pakistan through West Bengal to Orissa coast, another from East Pakistan and Orissa, and a third from Uttar Pradesh.

Pillay (1957a), noticing that the hilsa caught during September and October 1955 in the Hooghly have a relatively deeper body, compared the relevant data on body height of fish collected in 1952 and 1953 and concluded, on the basis of significant differences, that the fish caught in 1955 probably represent a stock different from the one that usually ascends the river. Similarly, the monsoon samples of 1955 were different from the winter (December) samples of 1955, whereas the latter was similar to the winter samples of 1952-53. The author also concluded that the hilsa which ascended the river during September-October 1955 had migrated back to its original habitat by the end of the monsoon season.

Pillay (1957b) in his morphometric study of the hilsa population of the Hooghly and the Chilka lake, considered the number of scutes, number of lateral line scales and the number of vertebrae from the meristic side, and among the non-meristic characters, fork length, standard length, height of body, length of head, diameter of eye, length, height and thickness of caudal peduncle, and thickness of body. The study was undertaken to determine whether the monsoon and

winter runs of hilsa in the Hooghly bear on two different stocks. He concluded that they constituted a single stock and the only distinguishable difference is in the age composition of fish in the runs. These observations are at variance with those expressed by him earlier (Pillay, 1957a). His study also indicated that the hilsa of the Chilka lake belongs to a stock separate from that of the Hooghly.

Pillay, Pillay and Ghosh (1963) made a comparison of regression and D^2 analysis of body measurements as well as comparison of vertebral counts of the samples from the rivers Hooghly, Ganga, Padma, Brahmaputra, Barak, Godavari, Krishna, Cauvery and Nerbada, the Chilka lake, and the Saurashtra coast. The non-meristic characters included the total length, standard length, fork length, height of body, length of head, diameter of eye, length, height and thickness of caudal peduncle, and thickness of body. The results indicated that the different major river systems, the Chilka lake, and the Saurashtra coast have their own stocks of hilsa and there is very little, if any, intermingling among them. The river Ganga has at least two populations represented by samples studied from Allahabad and Buxar. The stocks of Ganga, Padma, Chilka lake, Godavari and Saurashtra coast could be distinguished from the hilsa of the Hooghly by the regression of one or the other body measurements on total length. The height of body, length of head, length, height and thickness of caudal peduncle, thickness of body, and diameter of eye, were found to be relatively more useful in the identification of stocks. With regard to the vertebral count, some samples could be distinguished on the basis of average total number of vertebrae, some on the basis of average number of trunk vertebrae, some by the average number of caudal vertebrae and some by the average number of the vertebrae with duplicate neural spines.

Ghosh (1967), while examining the fishery at Allahabad, suggested that the stocks of hilsa at Allahabad are heterogeneous in nature and that the Jamuna stock is endemic, probably also heterogeneous, and is supplemented by a migratory stock. He also indicated that the different stock in the upper Ganga identified by Pillay *et al.* (1963) may perhaps be the Jamuna stock with a small range of migration within the local waters.

Ghosh *et al.* (1968) examined samples from six centres in the Gangetic system covering the rivers Ganga and Padma. Samples were drawn from non-selective gear and their study was based on statistical analysis of the head length, height at the origin of dorsal fin and at the origin of the anal fin in relation to the total length. They could distinguish on the basis of height of body, three forms 'slender', 'broad', and 'broader'. Employing the method of discriminant score, the distribution of individual sub-populations in the Gangetic system was studied. They concluded that all the three sub-populations are widely distributed in the entire stretch from Allahabad on the Ganga, to Lalgola on the Padma in the downstream. However, the limited number of observations did not permit the authors an understanding of the pattern and the rate of intermingling of the sub-populations between different sectors. They were also of the opinion that it is likely that each sub-population may occupy a separate spawning ground and, therefore, at the spawning season the intermingling would be negligible, or absent. That the population at a centre need not be homogeneous was also brought to light by their investigations and in this context they had pointed out that the heterogeneity of the hilsa population at a centre was overlooked in the investigations of Pillay *et al.* (1963). The authors' data on distribution of individual sub-populations also indicate an interesting sequence of the importance shifting from one variety to the other, from west to east of the investigation area. It is seen that the dominant 'broad' forms of Allahabad are replaced by the 'broader' forms at Varanasi and Buxar, which are localities located east of Allahabad. The 'slender' form dominates at Bagalpur, and is replaced by the 'broad' forms at Rajmehal, which in turn, is replaced by the 'broader' type at Lalgola on river Padma. The significance of such a distribution is not clear. Another interesting feature is that between Bagalpur and Lalgola—a distance of about 100 km along the river—each of the three varieties has dominated at each of the three centres in the same monsoon season of 1964. This would probably support the authors' contention that each sub-population may occupy a separate spawning ground and the intermingling during the spawning season could be negligible or absent.

With regard to the Chilka population, Jhingran and Natarajan (1966) observed that winter/spring and monsoon samples did not indicate any significant differences between these two

migrant populations, suggesting thereby their homogeneity. Ramakrishnaiah (1972) who subjected his data on the number of scutes and vertebrae to statistical test, came to the same conclusion that the monsoon and winter/spring stocks of the lake are homogeneous.

Rao (1969) examined the juveniles of different centres on the Godavari estuary and took into consideration the meristic data on pectoral fin rays, ventral scutes, and vertebrae and morphometric data on standard length, height of the body and head length. He found significant differences between the year classes in respect of the number of pectoral fin rays and number of vertebrae. Significant differences were also seen in height as well as head length.

Quereshi (1968) has briefly mentioned, without the support of any data, that the biometric study conducted in East Pakistan indicated homogeneity of stocks. Biometric analysis carried out by Shafi, Quddus and Hossain (1977b) confirmed the identity of *jatka* as the juveniles of hilsa. Quddus (1982) examined samples from the rivers Padma, Meghna, Jamuna and Dhaleswari of Bangladesh. Because of their distinctive differences in the body height, he bifurcated the samples as 'broad' type and 'slender' type. He employed, for comparison, 15 meristic and 8 morphometric characters to find out the racial characteristics of hilsa from these rivers. Of the meristic characters, significant differences were observed between the two types in six—number of ventral scutes, post-pelvic scutes, pectoral fin rays, abdominal vertebrae with haemal arch, caudal vertebrae, and number of vertebrae from the tip of vertebral column to the vertebrae with enlarged haemal arch. Among the morphometric characters, seven out of eight characters showed significant differences.

Besides the morphometric study, Quddus (*loc. cit.*) also examined the two types for differences in biological features. He found that the two types have different spawning seasons—the broad ones spawning during monsoon and the slender ones during winter. The broad type grew faster and attained greater length at each age as compared to the slender type. Fecundity estimate was considerably lower in the case of the slender variety. He also observed that the broad type was characterised by silvery body, the lateral blotches disappearing in larger specimens, fins, particularly dorsal and caudal, comparatively short, inter-muscular bones few in number, head tapering, head skin soft, eyes small, length of pyloric caecum short, and fat content high. In the slender type, the colour is greenish, blotches remain in older specimens, the dorsal and caudal fins are comparatively larger, inter-muscular bones more numerous, head big in size and in shape, head skin hard, eyes large, length of pyloric caecum larger, and fat content low. In the light of these observations he suggested that the populations consist of two subspecies of *Hilsa ilisha*, but recommended studies of biochemical composition, electrophoretic analysis, blood characteristics and genetics of these two types, before coming to any conclusion regarding the specific identity of the species.

Referring to the total lack of knowledge on the migration of hilsa at sea, Melvin (1984) was of the opinion that the large concentration of hilsa in the Bay of Bengal may be indigenous to the rivers of Bangladesh or that they may represent a heterogeneous stock of fish from many rivers of India, Bangladesh and Burma. In the latter case, the respective stocks may be returning to their natal rivers for spawning.

To examine the possibility of using the blood characteristics for differentiation of stocks, Pillay (1954 & 1958b) conducted studies on the extent of individual variation in the hilsa of the Hooghly. He recognised three blood groups and established the pattern of their distribution (Pillay, 1954). The erythrocyte counts, haemoglobin content, coagulation period, and erythrocyte cell size and nuclei size of the blood of Hooghly hilsa were determined and it was shown that the characteristics of the blood taken from the heart of live fish were not significantly different from those of dead fish preserved in ice; it was further indicated that the coefficient of variation of the different characters was normal for purposes of comparison with blood samples of other stocks of hilsa (Pillay, 1958b).

From the tagging experiments, Pillay *at al.*, (1963) concluded that among the populations of Hooghly, Padma and Ganga, there is little or no movement between the rivers and little intermingling of the three populations. They were also of the opinion that the hilsa stock in the upper Ganga is probably different from that of the lower Ganga and Padma, the upstream movement of the latter stock extending perhaps up to about Bhagalpur.

VII. MANAGEMENT

Fisheries management and regulations

In spite of marked fluctuations in the fisheries of hilsa and the depletion of the fisheries upstream, no proper management or regulatory measures are followed in any of the countries now. Free fishing is permitted in all areas except in the Brahmaputra, where fishing rights are auctioned out (Pillay and Rosa, 1963). A general ban on capture of hilsa within the one mile limit below anicuts and dams is in existence in some states of India. In Bangladesh, the operation of gillnets of less than 100 mm (4") mesh size is legally prohibited; but the fishermen are still using smaller mesh sizes.

The fisheries in Indian rivers have undoubtedly been adversely affected by the construction of anicuts and dams. The fish that gather below these obstructions are caught indiscriminately in very large numbers by fishermen. With a view to controlling this, the concerned states have enacted legislation to prevent the capture of hilsa within one mile of such obstructions. Even though there is no law in the region at present to ensure the provision of fish facilities in dams or other obstructions built across rivers, the need for such facilities was recognised long ago. However, a suitable fishway for hilsa has yet to be constructed.

It is reported that an experimental fishway designed by Day was constructed in the lower anicut at Coleroon in the Cauvery. His object was to employ under-sluices and vents in place of the usual kind of fish pass, and so to convert the anicut or part of it into a lock through which fish could easily pass. This fishway did not work successfully (Nair, 1954). The enquiries of the Madras Fisheries Department in 1909 revealed that the fish pass did not ensure hilsa migration because of various practical and technical difficulties; in the first place, the expenses for the construction of a fish pass were not commensurate with the expected results and secondly, sufficient water could not be provided for the efficient working of the pass (Nair, *loc. cit.*). In 1916, a fish pass was constructed in the weir across the Mahanadi at Cuttack but just as in Coleroon, this was also found to be ineffective (Southwell and Prasad, 1918). Other references on this subject outside the Bay of Bengal region are those of Talbot (1959) and Hossain and Sufi (1962). Examining past efforts on fish pass and drawing attention to the migratory habits of the fish, Nair (*loc. cit.*) observed that it is of fundamental importance to make a detailed study of the bionomics of the different stocks, their magnitude and composition before building up a programme for the conservation of the fishery. He was also of the view that considering the delicate nature of the fish, and also that the high cost of construction and maintenance of fish pass is not commensurate with the results, it may not be advisable to insist on the provision of fish passes. It is reported that the fish pass constructed across the Farakka Barrage has also proved a failure (Malhotra and Shah, 1979).

The establishment of hatcheries for the artificial propagation of hilsa for stocking the rivers, to counteract the effect of dams across rivers was advocated a long time ago (Raj, 1917) and a hatchery was established near the lower anicut on the river Godavari. The results were far from encouraging and it was soon realised that it will neither be economical nor feasible to have sufficiently large hatcheries to compensate for the adverse effect of dams. Hora (1938) suggested that the brood and young fish should be better protected instead of constructing hatcheries or fish passes. Devanesan (1942) has also suggested that the brood fish should be protected below the anicuts of rivers by legislative measures. Jones and Sujansingani (1951) have advocated the restriction of fishing in the Chilka lake from the mouth of the Makra to the mouth of the Daya in a narrow belt of 3.2 km to 4.8 km for the protection of brood fish that ascend the rivers for spawning.

The large-scale capture of small-sized hilsa, known as */atka* in East Pakistan (Bangladesh) and hilsa khoira in West Bengal, as well as fry and larvae has been considered highly destructive by Hora and Nair (1940a) and Jones and Menon (1951), as such fish do not get an opportunity to breed even once. Referring to the legislation of the State Government of Andhra Pradesh prohibiting fishing within one mile below the anicuts in Godavari, Pillay and Rao (1963) were of the view that this regulation requires further consideration and clarification

since the breeding grounds of hilsa in the river are more extensive than hitherto believed. They recommended instead, consideration of **reducing or even stopping** the capture of juvenile hilsa by prohibiting those nets which are used **exclusively for the purpose**. This view was shared by Rajyalakshmi (1973) also.

Hora (1954) has referred to the socio-religious injunction that was observed in West Bengal (India) of not eating hilsa from Bijoya Dasami (September-October) to Shri Panchami (January-February). This discouraged fishing for spent and immature hilsa during the winter season, which he thought had a highly conservational value for the fishery. This practice is no more followed and large-scale hilsa fishing is now carried on in winter also.

Dunn (1982b) is of the opinion that at present there is no danger to the hilsa stock of Bangladesh, but it is possible that a large increase in fishing efficiency, particularly by use of purse seine, will lead to a level of exploitation that cannot be sustained. He has suggested protection of the brood fish and young ones for which the spawning grounds in the rivers should be closed for fishing during the spawning time, the fishing gears should not be allowed to cover the whole stretch of the river, and the small-mesh nets should be totally banned.

Fish farming

Attempts to artificially propagate hilsa for stocking rivers have been already referred to. The first attempt was made in 1907 and was repeated thereafter in 1917, 1918, 1924, 1952, and 1962, but in no case could the resultant hatchlings be kept alive beyond three days (Malhotra and Shah, 1979). That the hilsa thrives well in stagnant or semi-stagnant waters has been shown by their occurrence and rate of growth in the settling tanks connected with irrigation canals of the south Indian rivers Godavari, Krishna and Cauvery. Collection of fry and fingerlings as well as rearing in cement cisterns have been done successfully by Pillay (1958a) for experimental purposes. Large-scale culture of hilsa in ponds was advocated by Mojumdar (1939b) and Hora (1940).

The only known instance of an attempt to transplant hilsa was that of Wilson (Nicholson, 1915) who planted eyed ova of this fish from the hatchery at the Lower Anicut in the Cauvery in the Ponnani river in Malabar (India-west coast), but there is no evidence of the fish having become established there.

Quddus (1983) has suggested that experiments may be conducted in Bangladesh on the culture of this fish by transplanting the fry and juveniles to ponds and artificial fertilisation carried out to liberate the fry into the rivers to supplement the natural stocks.

In India, artificial fertilisation has been conducted successfully. The Central Inland Fisheries Research Institute has developed the complete technology for the successful artificial fecundation, hatching of the fertilised eggs, rearing of the hatchlings thus produced, transport of 'live' fertilised eggs and hatchlings, culture of hilsa in confined fresh water, preparation of pond for rearing hilsa spawn, etc. An account of efforts and results achieved in this sphere has been summarized by Malhotra and Shah (1979); further details are available in the works of Malhotra *et al.* (1969 & 1970) and Mathur *et al.* (1974). The hatchlings could be reared for a maximum of 2 years and 4 months when they attained an average size of 345 mm within a range of 325 to 360 mm (Malhotra and Shah, *loc. cit.*).

It has also been reported that there has been natural breeding of hilsa in the Ukai Reservoir of Gujarat. The self-propagating stock was introduced into the reservoir after artificial breeding and stocking of the fry of 20-25 mm (Anon., 1981 c). Hilsa has also been cultured to marketable size in pond environment. Hilsa fry of 4-6 cm size stocked and reared in 0.1 ha pond have recorded a growth of about 240-250 g in 448 days. A higher level of dissolved oxygen and a feeble current in pond water was maintained by mechanical splashing of water under pressure. Only periodic manuring of pond water was done and no artificial feeding was resorted to. No significant mortality was encountered. The culture of hilsa in confined waters is, therefore, no longer considered a remote possibility (Anon., 1981 a).

VIII. CURRENT INVESTIGATIONS IN INDIA AND BANGLADESH

India

The Central Inland Fisheries Research Institute (CIFRI) used to collect catch data at selected places like the stretch of river Ganga between Allahabad and Buxar, and in the Hooghly estuary. These have been discontinued at present. Recently, the Government of India has sanctioned a scheme for collection of catch statistics from the inland waters on an all-India level, for implementation by the CIFRI; this scheme will cover all fisheries, not hilsa exclusively. At present, hilsa research is not being given that much priority as in the past. The Institute's efforts in the 1970s were largely oriented towards perfecting the methodology of artificial propagation. This line of investigation is being continued now. In the past three years, the following lines of investigation have been emphasised:

- (i) Culture of hilsa in confined waters involving artificial fecundation by wet stripping method, fertilisation, hatching, transportation, stocking in reservoirs and culture. The reservoirs chosen are Farakka (river Ganga) and Ukai (river Narbada).
- (ii) Research and development technology for commercial-scale production of hilsa seed. This also involves artificial fecundation and is carried out at Barrackpore (Calcutta).
- (iii) Fluctuations in the hilsa fisheries of the Hooghly estuary. These studies largely relate to aspects of maturity, fecundity and spawning.

The following aspects have been contemplated according to the Institute's *Annual Report, 1981*:

- (a) Impact of Farakka Barrage on the spawning of hilsa in the middle stretch of river Ganga,
- (b) Standardisation of transport techniques for fry and fingerlings,
- (c) Evolving efficient feed from non-traditional plant and animal sources for hilsa and other cultivable species,
- (d) Genetic characterisation of hilsa.

The hilsa team at CIFRI consists of 10 scientists who handle the three sub-projects mentioned earlier; they also handle projects other than those on hilsa.

The Central Marine Fisheries Research Institute (CMFRI) collects catch data on the marine landings of hilsa in their regular programme of collection of catch statistics of marine fish landings in India. The current design of data collection by the CMFRI is one of stratified multi-stage random sampling, the stratification being over space and time. A zone is a stratum over space and a calendar month over time. The West Bengal coast is considered as two zones, and data are collected by three assistants from three centres, Contai, Frazerganj and Diamond Harbour. In Orissa, three assistants are deployed, one for complete coverage of Paradeep Port and the other two with Gopalpur and Pun as bases. Each month is divided into three clusters of 10 days each, of which 6 consecutive days form the period of observations. In each cluster, three landing centres are sampled; at each landing centre the coverage extends from 12 noon to 6 pm on the first day, and from 6 am to 12 noon on the following day. Any night landings from 6 pm of the first day to 6 am of the next day are recorded from oral enquiry. On the day of observation at the selected centre, sampling is done in a predesigned manner. Data on species-wise catch, effort, types of crafts and gears operated, and nature of fishing ground are collected.

Samples of commercially important species are also taken for biological observations. Based on the information from selected fishing units, the total landings for the landing centre day are estimated and from these the monthly estimates for the zone/state are made.

As may be seen from Table II, there is a big difference in the catch figures of CMFRI and the Directorate of Fisheries, Government of Orissa. No biological studies of marine stocks have ever been undertaken by either of the central institutes or by the State Government's Department of Fisheries. Since 1982, at Chandipur, the collection of length data has been initiated by the staff of the Department of Fisheries.

Bangladesh

A Hilsa Fishery Investigation and Management Unit was established in mid-i 981 in the Freshwater Fisheries Research Station at Chandpur. This unit is engaged in: compilation of bibliography on hilsa; collection of catch data from different centres; determination of age and growth through study of otoliths and scales; study of morphometric characters from different areas; experimental fishing at Chandpur; study of environmental factors; and re-analysis of data given in Dunn's report.

The staff available at this Unit at present consists of the Deputy Director in-charge of the Station, a Research Officer, a Scientific Officer and a Farm Manager; the latter two officials have joined the University of British Columbia in Canada for their Master's Degree, basing their work on hilsa material from Bangladesh. The Laboratory facilities at Chandpur are limited to the barest needs of the investigations on hand.

The International Development Research Centre (IDRC) has come forward to extend financial support for hilsa investigations. It is informally learnt that the IDRC input would be of the order of about US \$300,000 for a duration of 2 to 2½ years, starting mid-1984. The IDRC input would be in the form of supply of equipment, material and also a fulltime consultant. There is some time lag in the commencement of this project; it is now expected to take off not before mid-i 985.

The proposed areas of investigation under the IDRC project are learnt to be along the following lines (subject to official finalisation)

1. Biological sampling at Chandpur and other selected centres for studies on size distribution, age, growth and maturity,
2. Collection of catch and effort data at selected centres and monitoring of catch trends in the country,
3. Establishment of a programme to understand stock abundance and their movement in the river system and coastal waters,
4. Collection of environmental data to correlate them with the biological activities of the fish and the fluctuations in the fishery,
5. Conduct of experimental fishing with netting of graded mesh sizes,
6. Identification of spawning grounds, eggs, larvae and the early stages,
7. Racial investigations through biometrics and protein polymorphism,
8. A tagging programme, if found justifiable,
9. Economic evaluation of the fishery at various stages from harvesting to marketing; of the commercial gear, its efficiency and improvements if required,
10. Investigations on the support for the fishery in terms of infrastructure, gear and finance.

For the marine sector, at present, the Freshwater Fisheries Research Station at Chandpur has one Field Assistant at Cox's Bazar to collect the marine hilsa landings data at the BFDC's landing centre. This Field Assistant has been collecting data for the past 5 or 6 years and transmits these data to his headquarters at Chandpur. (Comparison of the two sets of data collected by this Field Assistant and the BFDC shows wide disparities.) Estimations of landings at Chittagong are also being undertaken since 1982. However, no biological information is being collected from the marine catch.

IX. GENERAL APPRAISAL

The main reason for the conflicting/confusing views on some of the basic biological features of the fish such as age, growth, and reproduction, is largely on account of different interpretations by different workers viewing different stocks at different points of time from different places and also due to the selectivity of the commercial gear. It is understandable that when investigations were simultaneously carried out in the early years at different places, there could be different interpretations by different authors; a comparative study of all the data in the later years could have helped crystallize definite opinions on such of those features on which divergent views had been expressed.

With regard to the size and age at first maturity of the fish, there is an unbelievably wide range from 16 cm to over 40 cm, aged at one to five years! Obviously there is some error in the interpretation, even granting that deductions are made from different riverine/estuarine systems. It would appear that the fish generally mature for first spawning at 25-30 cm at the end of the first year and that the second spawning takes place at the end of the second year at 35-40 cm; perhaps they may be even somewhat longer at the respective spawnings. There are repeated references in the literature that the age at first maturity is 1+ or 2+ years. For this odd designation of age at first maturity, and also for divergent views, there are various reasons; one reason could be that recruitment is believed to take place at the height of monsoon in July-August with maturity being attained at the end of monsoon or in winter. It may be also due to mixing up of the recruits of monsoon and winter runs which are separate year-classes/stocks. It is also possible that the mix-up could be between two heights of reproductive activity as revealed by abundance of larvae within the so-called monsoon run, namely, at the height of the monsoon in July-August and after the monsoon in October-November. Another reason could be related to the differential intensity of recruitment between the two peaks and differential rate of growth of the respective recruits. It is possible that one of the two broods may manifest itself strongly and register a faster rate of growth than the other. There is yet another possibility that the purely freshwater stock and the anadromous stock wandering between the foreshore and the freshwater habitats may spawn at different times within the main spawning season. Then again, the spawning grounds may be different for the different ecotypes. There may be also differences in the spawning grounds/months for the different age groups. Perhaps, the anadromous stock may mature earlier than the purely freshwater stock or vice-versa. Jenkins (1938) cites the instances of the two species of the European shad, of which the Allis shad goes a long way up the rivers as far as Switzerland to spawn, whereas the Twaite shad hardly wanders beyond the tidal influence where it spawns. He has also reported that the herring spawns in widely different conditions—in freshwater of the River Schlei in Schleswig (Germany) and even in an arm cut off from the bay in which the water has become almost fresh, and also spawns—perhaps a different race—in deep and very salty water off the coast of the British Isles. Thus, with so many possibilities in view, it is very necessary that the reproductive biology of the fish is studied in detail.

Regarding the spawning season, in spite of differences of opinion, it would appear that in the Ganga-Hooghly stretch there may be three spawning peaks, within the two spawning seasons, namely, monsoon and winter—one at the height of monsoon in July-August, one after the monsoon in October-November, and the third towards the end of winter in February-March. In the other rivers, Godavari, Padma and Meghna, the evidence supports two spawning seasons, a monsoon and a winter, but the timing of peak activity appears to be slightly different at different places. It is possible that the stocks that participate in these spawning seasons are mutually different, the same stock spawning once or more than once during the year. There is also another possibility that the monsoon stock of Ganga/Hooghly may have different spawning peaks or spawn twice with an interval of one month. Regarding factors influencing spawning, since the two major spawning seasons are characterised by different ecological conditions, the respective stocks appear to have developed over a period of time certain specific requirements for spawning.

On the question of spawning frequency, there is no dispute that only one group of ova differentiates from the general stock of oocytes as the spawning season approaches. Some tend

to believe that from this differentiated stock of advanced eggs, small batches are shed intermittently during the spawning season, hence the individual fish has a protracted spawning season. The other view is that there is only one spawning act when all the eggs are shed. Malhotra and Shah (1979) have stated that during artificial fecundation, hilsa of the size range 265 to 505 mm yielded an estimated total of 0.32 to 2.22 million eggs which roughly correspond to fecundity estimates in the literature. It would thus appear that at the time of spawning, all the differentiated ova are ready for release in one act of spawning. Malhotra and Shah (*loc. cit.*) have also stated that most males released their gonadial contents immediately after capture by nets. There could be also a third interpretation that if the environmental conditions are not ideal for spawning, the fish may experience fractional spawning with subsequent resorption of ova. That there is resorption of sexual products in the fish, especially among the adult hilsa of the winter run at the end of the winter and before the summer, has been shown by Nair (1958) and supported by Ramakrishnaiah (1972). In another clupeid, the Indian oil-sardine (*Sardine//a long/caps*), Raja (1973) examined the possibility of adult non-spawners and concluded that such a feature cannot be ruled out under adverse ecological conditions. With the incidence of partly spent ovaries as the supporting evidence, perhaps fractional spawning and resorption can take place even when conditions are not adverse (Pillay and Rao, 1963).

With regard to winter spawning, while this has been recognised in the estuarine stocks and freshwater stocks of the Gangetic system, the opinion is that there is no winter spawning with regard to the stock in the Chilka; but the unpublished records (Sahoo, Ms.) of very small juveniles of 4-5 cm at the mouth of the lake in late April would appear to indicate the possibility of spawning towards the end of winter in Chilka lake also. Similarly, in the river Godavari, although an opinion was earlier expressed that there is no evidence for winter spawning, the data of subsequent workers prove beyond doubt, that there is one in the lower reaches of the Godavari estuary.

It is seen that while some of the workers have subjected their data on sex ratio to statistical analysis before expressing their conclusion, others have based their views on the picture of numerical dominance of one sex over the other. It has been observed already that males attain a comparatively smaller size as a result of slower rate of growth. It is also possible that there is a bathymetric difference among the sexes in their distribution as was noticed by Pillay (1958a). There are also possibilities of different populations occurring in particular areas during different seasons. There are, thus, bound to be differences in the sex ratio. Unless large samples are subjected to statistical analysis and factors like growth, behaviour, and races are taken into consideration, it would not be possible to come to a definite conclusion.

On the subject of age and growth, the differences in interpretation of the data collected on length frequency studies appear to be the reason for conflicting views on the subject. Like in most of the tropical fishes, the difficulty lies in determining the growth during the first year and also the age at first maturity. It is very well known that in the tropics, due to the high rate of metabolic activity, the fishes like other organisms, grow fast, attain maturity early, and have a short span of life. From a study of literature it would appear that the winter recruits have a slower rate of growth as compared to the recruits of the monsoon season. Even among the monsoon season recruits, there appears to be differential rate of growth between those recruited during the height of the monsoon and those recruited after the end of the monsoon. There may also be differences in the rate of growth between the year-classes, such as a slower rate of growth among the recruits of abundant year-classes and faster rate of growth among those of poor recruitment year. Then, there are differences between the sexes, the females growing faster than the males. Some of the differences in interpretations appear to be due to differences in fixing the recruitment time. Generally it would appear that the fish attain a length of about 25-30 cm, 35-40 cm and 45-50 cm at the end of the first, second, and third year, respectively. The early monsoon recruits may have a faster rate of growth, probably reaching 30 cm or more at the end of the first year.

The records from the settling tanks of Pulta Waterworks (Hora and Nair, 1940a) demonstrate that the fish grow to about 30 cm at the end of one year and attain maturity. This is under favourable conditions of food and water flow. Raj (1937) has reported that in confined waters, the fish grow to a size of 163-225 mm in 8 to 9 months. In the pond culture experiments at

CIFRI, where no artificial feeding was resorted to, a growth of 240-250 g has been recorded in 448 days (Anon., 1981a). This would correspond to about 30cm length. Perhaps this could be considered as a condition in-between normal environment and the conditions obtained in the settling tanks of Pulta waterworks. In Ukai Reservoir (Anon., 1981c), the stocked fry grew to a weight of 500 g in 17 months and 600 g in 19 months, and before 21 months were found to have bred in confined waters for the first time. The corresponding lengths for the weights given would be 36-38 cm and 38-40 cm respectively. The 38-40 cm fish was reported to be gravid. The delay in becoming sexually mature may be because of captive conditions. In this case, the fish seem to have grown to about 38 cm in 1 1/2 years and attained maturity. This may probably represent a faster rate of growth than in normal conditions because the fish started converting its energy for sexual maturation late.

The occurrence of two runs of hilsa in the major river systems—one during the south-west monsoon and the other during late winter—has been recognised both in Bangladesh and in India; it is not so certain in Burma. The monsoon run is of comparatively greater magnitude and longer duration. It has also been seen that in these two runs there is a distinct difference in the size composition of the fish. The monsoon run is dominated by larger-sized fish and the winter run by smaller-sized fish. These runs also result in two principal spawning seasons.

A new dimension that has been added to this picture is the segregation of stocks into at least two variants, a broad and a slender form. The occurrence of these two types was recognised very early in the investigations, but the observations made earlier were rather qualitative and casual, and only recently has this been established well (Ghosh *et al.*, 1968; Quddus, 1982). The records from the Burmese coast (FAO, 1970 and 1971) appear to indicate that the fishery of Arakan coast consists of the slender-bodied forms, whereas in the central and southern parts, the fishery is for the broad type. It is also learnt that the winter fishery off Cox's Bazar, especially from January onwards, is largely for the smaller slender variant of hilsa. On the other hand, the identity of the variety which contributes to the fishery off the Balasore-Digha coast, is not known. Interestingly, it has also been pointed out that it is the slender form that is responsible for winter spawning, at least in two definite pockets—one in the lower Ganga (Ghosh and Nangpal, 1970) and the other in Bangladesh rivers (Quddus, 1982). Ghosh *at al.* (*loc. cit.*) distinguished, within the broad forms, one broader than the other, whereas in Bangladesh, Quddus' (1982) records indicate the absence of the 'broader' variety. Perhaps examination of more samples in both these areas would provide additional evidence to confirm whether there could be three types or only two with some overlapping of the two. Looking at the background of three spawning peaks, it is tempting to wonder whether the three different bodied forms are responsible for the three spawning peaks.

On the subject of occurrence of broad and slender forms of hilsa, Melvin (1984) is inclined to relate the morphological difference to the state of maturity, the maturing and mature specimens are broad and the spent ones slender. This opinion, is however, based on examination of only fifteen specimens. There is quite some evidence in literature to warrant a much more serious consideration of the subject.

The three peaks, both in the production and in the spawning intensity, take place at those times when ecological conditions are different from one another. The monsoon run is believed to be influenced by the rainfall and the consequent flooding of the rivers. At this time the waters are highly turbid and are characterised by high temperature and low production of plankton. During the second peak, the monsoonal conditions have disappeared, there is a planktonic bloom, turbidity is low and there is a fall in temperature and salinity. When the third peak occurs in February, the water temperature and salinity tend to rise, there is no rainfall and planktonic production is low. It would thus appear that there are independent hilsa stocks which have got naturalized to a certain set of conditions and breed on arrival of those optimum conditions.

For the difference in the timing of the spawning runs and for the occurrence of two spawning seasons, Melvin (1984) considered the water temperature which may operate in conjunction with or result from rising water level in the rivers. In the absence of records of water temperature, he examined ten year records of monthly air temperature at Barisal and Faridpur which

he expected to result in a similar trend in water temperature, which may be approximately 2-3 degrees below mean monthly air temperature. He mentioned that there is a marked decrease in air temperature in May-June and again in October, reaching the lowest level in January. He was inclined to correlate the two periods of decline in air temperature to the two major peaks in the hilsa run in the river systems. He was, therefore, of the opinion that the movement of hilsa into individual rivers may well be in response to a temperature stimulus and that the rising temperatures might also serve to trigger the young hilsa to leave the rivers.

The data presented by him, on the other hand, offer a rather weak basis for this argument because the decline in temperature in May-June is negligible and that in October is only 0.7°C. In fact, the average temperature during April to September is almost steady in the narrow range of 28.1°C to 28.8°C.

On the subject of the role of temperature on spawning, Melvin (1984) attributes a fall in temperature for the spawning in October-November (from 28°C to a range of 24°C to 27°C) whereas the warming up of the waters in February-March (from 18°C to a range of 21°C to 26°C) has been assigned as the reason for the second spawning intensity. However, there are no comments with regard to yet another spawning peak in July-August, in the height of monsoon, when the temperature is stationary at 28°C. While it is admitted that a particular water temperature regime may act as a stimulus for spawning and anything outside this regime may produce an inhibitory effect, more direct evidence is necessary, besides an examination of other factors.

With regard to races/stocks, it is possible that the stock which is exploited off the Balasore-Digha coast may consist of the broad variety and it may represent the anadromous stock entering the estuaries of West Bengal and possibly Bangladesh. There may be another anadromous stock off Chittagong which may contribute to the inshore fishery and the estuarine fishery of Bangladesh. A third stock may possibly be a marine stock contributing to the fishery off Cox's Bazar coast of Bangladesh and the Arakan coast of Burma. A fourth stock may again be an anadromous one contributing to the fishery in the rivers Irrawady, Rangoon and Sittang, and frequenting the inshore waters of the Mergui coast of Burma. If all the information, both published and unpublished, is put together, one could perhaps hazard an opinion on the possibility of four major stocks in the upper Bay of Bengal region. These are exclusive of purely fluviatile stocks in the major river systems of India and Bangladesh and perhaps of Burma.

In the wake of the finding of maturing, mature and spent hilsa off Veraval coast by Pillay (1964), Dutt (1966), on the lines of Mojumdar (1939a), indicated the possibility of three ecotypes: (i) fluvial anadromous stock that feed and grow in coastal waters and spawn in middle and lower reaches of rivers within the level of tidal influence, (ii) fluvial potamodromous stock that inhabit the middle reaches of rivers, and (iii) marine stock. He pointed out that one major reason for our limited knowledge on the behaviour of hilsa is that studies to date have been based on commercial catches which are neither satisfactory nor adequate, the commercial gear being selective and seasonal in its operation. He was of the view that the problem of the extent of migration of the hilsa could be solved by undertaking experimental fishing with suitable least selective type of gear and by large-scale tagging in all the three habitats.

Regarding the marine phase of the fish, right from Day (1873 a Er b), several workers have recorded its appearance in the sea. Prashad *et al.* (1940) have brought under one roof all the historical marine records of hilsa. There is a record of a regular sea fishery five decades ago in the Palk Bay (Raj, 1932). Elsewhere, off Gujarat on the west coast of India, existence of a marine stock has been established (Pillay, 1964). Regular exploitation of the marine phase of the fish is carried out on the Balasore-Digha coast on the upper east coast of India, in Bangladesh off Chittagong, and Cox's Bazar coast, and in Burma off Arakan coast of Bay of Bengal and the Mergui coast of the Andaman Sea.

Some brief remarks made in two recent studies on hilsa of Bangladesh are of significance. Dunn (1982b) observed: 'At present, the population of hilsa in the sea is ill-defined as to size, make-up, location, movements through the year, etc.' Melvin (1984) recorded: 'the hilsa fishery has evolved from what was considered a riverine fishery. ... to a rapidly expanding

coastal and marine concentrated fishery. ... The migration of hilsa at sea is simply unknown.' These observations are symbolic of our present knowledge, or more precisely, the lack of it on the marine phase of this fish.

It is surprising how the need for investigations on the marine stocks has not been felt while conducting studies on the inland stocks. Due to lack of information on the marine phase of the species, no link can be established with the observations on the inland counterparts of the species. The catch data, except for certain restricted pockets, by and large, do not appear to have been estimated scientifically. Even from the inland sector, practically no information is available on effort expended. The question of studies on population parameters and stock assessment has been ignored. The stocks have thus been allowed to be exploited with no concern for management.

Enjoying a wide distribution, it goes without saying that the species should be quite adaptable to changing conditions. In spite of the construction of weirs, dams, anicuts across the rivers, although the upstream migration of the fish has been curtailed to a large extent, records indicate that the fishery is able to revive and stabilise itself. The records of bumper crop in the Hooghly estuary in 1981 appear to set at rest the fears expressed by some quarters that the hilsa fishery of Hooghly was over-exploited or facing depletion. There are certainly some factors which are responsible for such abundant fishery once in a while, but so far the causal factors have eluded detection.

Two major factors emerge from the opinion of earlier workers on the factors influencing the fishery. One is that there is a five-year cycle in the fishery, and the second is the direct correlation between the monsoon and the resultant rainfall with the abundance of hilsa. With regard to the five-year cycle, the basic assumption made by the earlier workers is that the fish mature at the end of five years, hence this is reflected in the rich fishery once in five years. The catch records for different periods of time at different places given in Tables II to IX, were looked into to find how far this five-year theory could explain the fluctuations. In none of the records is there any indication in support of this theory.

The authors who believed in the fish attaining maturity after five years were probably influenced by the fact that the European herring shows a five-year maturity period and like hilsa, it spawns under widely different conditions of salinity. It is very well-known that in tropical waters, the fishes attain maturity at a very young age. In the case of hilsa also, it would appear that the fish mature at the end of first year and probably spawn at annual intervals. There are also records to suggest that there is more than one sub-population of the species. It is also well-known that there are two spawning seasons; the conditions of one spawning season (monsoon) are entirely different from those of the second spawning season (winter). Besides, the monsoon spawning is reportedly prolonged—one peak at the height of the monsoon and the other at the end of the monsoon. The concept of five-year cycle should, therefore, no longer be tenable and the instances on record should be treated more as an exceptionally rare repetition than a rule.

With regard to the positive correlation between rainfall and the catch, a perusal of data given by Dunn (1982b) would show that while there is positive correlation in respect of production years upto 1975, it fails to show during the subsequent years. With regard to 1970, although the catches were very good, the relative rainfall of 1965 was poor. For 1976, which registered a very low catch, the corresponding rainfall for 1971 was found to be good, in fact, better than 1968, which is believed to have influenced the success of the 1973 catch. Again, in 1980, while the corresponding rainfall of 1975 was good, the catch was poor. In addition, as per the rainfall data, the fishery should have been a failure in 1982, but the data given by Dunn (1982b) for the first half of 1982 is in fact better than the corresponding period in 1981, which itself was a good year; oral enquiry by the author indicated that 1982 was better than 1981.

Any opinion on the state of art on the level of exploitation and fishery situation can be only qualitative in view of absence of reliable information on the time-series of catch and effort statistics. From the landing data available, it appears that the exploitation is at a fairly high level in Bangladesh.

While Dunn (1982b) is of the opinion that at present there is no danger to the hilsa stock of Bangladesh, provided there is no large increase in fishing efficiency, Melvin (1984) holds an opposite view. Analysing the long term trend in the index of landings at two stations, Chandpur and Goalunda (after making certain corrections to the estimated landings made by Dunn (1982b) and employing a method of indexing the annual landings somewhat different from that of Dunn), Melvin (1984) has reported that after a period of stabilization during 1958-68, there were bumper catches in 1969 and 1970, only to decline to pre-1969 level immediately thereafter. Between 1974 and 1980, there have been a number of peak years in landings but none is comparable in magnitude to 1969, 1970 and 1973. After 1977, there is a gradual increase until the present. Although one might suspect that this trend, in some way, may represent variations in stock abundance, he tried to trace the reason to the impact of input of quantities of nylon twine, marine diesel engines and boats distributed by the BFDC and BJMSS. He found that almost every sudden increase in the landing index is matched by a similar increase in the index for the number of motors and boats and/or weight of twine distributed during the corresponding previous year of the peak landing. He also detected a disturbing feature that unlike the earlier period, after 1973 although there have been a number of peak years of distribution of both types of equipment, they have in no way resulted in proportionate increments in landings. He, therefore, concluded that the hilsa fishery has reached the point of diminishing return, that the hilsa stocks are under a great deal of fishing pressure and that the increase in landings can be interpreted as a decrease in stock abundance. He was also inclined to advise that the rate of expansion be controlled in the near future. He, however, cautiously added that there is no truly reliable data available to prove or disprove his conclusion; it may well be a misrepresentation of the true stock level.

It may be worthwhile to add in this connection a small note on the quantity of nylon twine imported and that distributed. In Table XII are given the quantity of nylon twine imported during 1977-78 to 1980-81 (most of which is utilized by the fishing industry) and the quantity distributed by the BJMSS/BFDC as reported by Melvin. It may be seen that only a very small percentage of imported twine is distributed through these agencies, and this percentage is highly variable. How far this input could influence the landing index is a point worth further consideration. It is also not clear why Melvin has limited this analysis only to Chandpur and Goalunda and has not extended it to the landing records of Chittagong, especially when Chittagong landings have been registering phenomenal increases in recent years.

Both in India and in Bangladesh, the stocks in the upper reaches of the rivers seem to have thinned down or even disappeared. In the estuarine sector, as far as the Hooghly is concerned, the position seems to be stable with an occasional bumper yield; in Bangladesh, the trend is one of increasing yield. As far as the sea fishery is concerned, probably there are data both in India and Bangladesh which will have to be analysed to understand better the present level of exploitation.

As long as the exploitation is in the hands of the traditional sector and is carried out by traditional methods, there may not be any danger to the stocks in general. However, with increasing pressure on the stocks through mechanization programmes, the exploitation in the inshore waters in recent years has increased in the upper Bay of Bengal. All these years the research efforts have been isolated in the respective countries necessarily because the studies were confined to the inland waters of the respective countries. Now that there is some evidence, though limited, that there can be a common stock in the inshore waters from which migrations take place in different directions, both along the coast as well as into the estuaries, a cooperative endeavour is called for, for mutual benefit of all the three countries of the region, so that a fresh and fuller picture of this important fishery resource can emerge.

More than 30 years have elapsed since the scientists concerned and administrators sat together and discussed the hilsa problem at a symposium held in India in 1952. Now that the marine sector appears to contribute about 40 to 45% of the total production, the time has come to sit together once again to chalk out an all-embracing programme for both marine and inland sectors. Perhaps a definite framework of investigations would be necessary only to cover the estuaries and the sea. In any case, future investigations should certainly take up studies on fishery and biology of the exploited stocks in the sea, conduct experimental fishing in the sea

with non-selective gear, and undertake racial investigations from biometrics, biochemical and cytogenetic aspects and migration studies through tagging programmes.

X. RECOMMENDATIONS

The following is only indicative of the lines of investigation which may provide useful information from the point of view of studies on shared stocks:

1. Studies on fishery and biology of the marine stocks

To understand the hilsa population in all its dimensions, it is essential to initiate studies on the hitherto neglected aspect,—fishery and biology of the marine stocks in relation to their environment.

Bangladesh

The studies are principally to be carried out with Cox's Bazar and Chittagong as the bases. They may be undertaken by the existing Hilsa Unit by further strengthening it or separately by the Marine Fisheries Department in collaboration with the Freshwater Fisheries Research Station. (Incidentally, it may be mentioned that in the provisional programme envisaged for the Hilsa Unit under the IDRC project, there is no provision for full time study of marine stocks.) In this connection, collaboration with the on-going FAO/UNDP project on "Marine Fisheries Research, Management and Development" at Chittagong and "Fisheries Resources Survey System Project" at Dhaka may also be considered. The FAO's Bay of Bengal Programme which is engaged in development of fishing craft and gear technology, could also play a useful role in this effort, chiefly on fishing trials.

Fishery: To put the existing catch records straight, data collected at Cox's Bazar and Chittagong by the BFDC and the Directorate of Fisheries may be examined carefully and discrepancies reconciled.

A sampling programme for commercial catches may be launched. The landings at the BFDC landing centre at Cox's Bazar may be sampled for three days a week and across the Bakhali river at Chofuldandi, twice a week. At Chittagong each landing ghat may be sampled on alternate days. Craft-wise, gear-wise (with mesh size, length and depth of net) data on catch, effort, location of fishing grounds (distance and direction from the base and depth) shall be the major parameters recorded. An identification sheet to distinguish between *H. ilisha*, *H. to/i* and *H. kelee* may be prepared on the basis of FAO Species Identification Sheets and sent as guidance material for the data collectors. As soon as they become familiar enough to distinguish *H. ilisha* of distinctly different body depth, the data collectors should separate the landings at least for the two types, 'slender' and 'broad.' This item of work on the commercial catch could be taken up by the existing three assistants, two at Chittagong and one at Cox's Bazar. The processing of the data should be the responsibility of a statistician at the officer's level.

Since the commercial catch is predominantly contributed by selective gears, experimental fishing with non-selective gear has to be undertaken for stock assessment and growth studies. Since hilsa has not been recorded in any of the bottom trawl surveys in the upper Bay of Bengal and in the two-boat high opening bottom trawling trials conducted in Bangladesh, perhaps the pelagic trawl/purse seine could be experimented with. It is possible that these gears may not yield satisfactory results. In that case, gillnets of varying mesh sizes, up to 12-13 cm could be employed. (Such a gear is proposed to be experimented within the inland waters by

the Hilsa Unit.) Once the type of fishing has been decided, it is desirable to have sampling done at least twice a month, with each cruise covering the entire seaboard from north of Chittagong to St. Martin Island. The work plan includes collection of data on catch, effort, biological parameters on length, depth, weight, sex, maturity and environmental features such as temperature, salinity, dissolved oxygen, collection of plankton samples, records of speed of the boat and length of head rope and swept area if the trawling method is adopted, and preservation of material, fish/ovaries, whenever necessary. Catch and biological data should be kept separately for the 'slender' and 'broad' bodied forms. Arranging vessel time could be explored in consultation with the on-going international projects. The personnel requirement for the local inputs, would be one officer and three assistants; a team of two officials would participate in each cruise by turn. To begin with, perhaps locally available commercial mechanized gillnetters could be hired for experimental fishing with multi-panelled gillnet of graded mesh sizes.

Biology: The biological sampling from commercial catches which should include total length, fork length, depth, weight, sex, stage of maturity (stages to be clearly defined), weight of gonads, and remarks of any significant observations, would consist of 25 fish per sample. It is advisable to have as many samples as possible for recording length frequency data in the field. The sampling is to be carried out twice a week at Cox's Bazar and Chittagong and once a week in the neighbourhood of Cox's Bazar. On the days of sampling, gear-wise particulars of catch and effort have to be collected and estimation made for the day. The length frequency data for the day should be also raised to the day's catch of the relevant gear. Scales and otoliths are to be collected at a later stage on the basis of results obtained from the present investigations of the Hilsa Unit.

Data on environmental features (temperature, salinity, dissolved oxygen, plankton) may be collected once a week from the area of fishing.

The requirement of personnel would be a team of one officer and one assistant each at Cox's Bazar and Chittagong.

India

The studies may be initiated by CIFRI or CMFRI or the Orissa State Directorate of Fisheries by opening a field centre for the purpose at Chandipur.

Fishery: Data collected by the CM FRI and the state Directorates of Fisheries of Orissa and West Bengal may be gone into for reconciliation at the earliest for as many years as possible and the trend of production indicated. The data on catch, effort, and other features so far collected may be analysed and published.

The catch data from the commercial landings may be collected at Chandipur and Digha for 3 days a week at each place, while other centres could be covered by rotation, twice a week. Two assistants would be required for this work and the processing should be done by a statistics officer. Details of the sampling programme both for commercial catch and experimental fishing would be the same as indicated for Bangladesh. The experimental fishing with pelagic trawl/purse seine/gillnet of different mesh sizes, may be conducted to cover Balasore and Digha coasts. It is also worthwhile to have the experiments extended to the Hooghly-Matlah estuary. One scientific officer and three assistants would be required for experimental fishing studies.

Biology: Biological sampling is to be done twice a week at Chandipur and once in alternate weeks at Digha and one of the other centres by rotation. The biological and environmental data are to be collected as per the programme listed for Bangladesh. One scientific officer and one assistant would be the personnel required.

2. Racial Investigations

Biometric Studies: Past studies on morphometric and meristic characters were confined to estuarine and riverine stocks. These are now to be extended to marine stocks and renewed

concurrently for estuarine stocks also. It is now certain that there is more than one morphologically different type and these types are present among the marine stocks also. They may probably differ in biological and anatomical features also. With this background, the whole problem could have a very rewarding conclusion, if simultaneous studies are undertaken in the region, choosing only a very few characters already reported as significantly variable so that a large number of specimens could be covered under the study. The recommended sampling places are Chilka lake, Chandipur, Sunderbans, Hooghly, Khulna, Patuakhali, Barisal, Chandpur, Chittagong and Cox's Bazar. To eliminate individual bias in taking counts/measurements, it is suggested that the study is undertaken by one fishery biologist having a sound statistical background to cover all the centres. Especially, the samples are to be drawn from (i) monsoon period (July to August), (ii) post-monsoon period (October to November), (iii) winter (January to February) and (iv) summer (April-May). It should be possible to complete this study in one year.

Biochemical/cytogenetic studies: As a part of racial investigations, electrophoretic analysis, serological studies and karyotype investigations may be conducted on the already established different body forms of hilsa. Some studies have earlier been attempted on the estuarine stocks. These are to be reviewed and carried out in conjunction with studies on marine stocks. Biochemical/cytogenetic studies could be carried out in collaboration with nearby medical colleges/hospitals so that the hardware available is used and their expertise utilised for analysis and interpretation of data. Some international input for software and for engaging scientists for this study may be necessary. This aspect could be conducted by one senior scientist with a team of post-graduate students to cover the region as a whole or could be split into two teams, one for Bangladesh and one for India. If there are two teams, they may meet at frequent intervals for comparison of data and exchange of views so that, if necessary, mid-course corrections in the approach could be adopted. The samples could be taken from the same places where samples are drawn for biometric studies, or if there are constraints on having so many places, they could then be reduced to Chilka lake, Chandipur, Hooghly, Chandpur, Chittagong and Cox's Bazar.

Migration Studies: Bangladesh has a programme of undertaking extensive tagging in the nearshore waters and in the rivers. It would be ideal if simultaneously a work plan is drawn by Bangladesh and India to cover (i) the marine stocks off Cox's Bazar, Chandipur and Digha, and (ii) the estuarine stocks in the Hooghly-Matlah system, in the Chilka lake and in the Padma-Meghna system.

To ensure dependable results and successful experimentation on a fish having such a wide distribution, tagging techniques should be perfected and a uniform methodology adopted throughout the area of study. Besides, a great amount of coordination and cooperation is necessary from all the three countries of the region. It is also desirable to have a central point for reporting and return of tagged fish. Extensive publicity in all the concerned languages and through all the mass media is essential. This publicity should not be a one-time effort but should be sustained for a long period. An attractive reward for return of tag/tagged fish is another necessity. All these would mean that it is an expensive undertaking and requires considerable financial support. It also requires launching of a cooperative programme and mobilisation of vessel time and personnel. A committee with technical representatives from Bangladesh and India and funding agencies could be set up for framing a detailed work plan on this subject.

3. Academic studies

It is worthwhile to have academic institutions also involved on hilsa research for undertaking fundamental/academic research. Examples: the Institute of Marine Sciences at Chittagong, the Department of Zoology at the University of Dhaka, the Agricultural University of Mymensingh, the Central Institute of Fisheries Education, Bombay. Some of the topics that could be assigned for post graduate dissertation work are:

– subject-oriented bibliography and synopsis of data,

- relationship between gillraker count and length/depth of fish,
- occurrence of parasites,
- seasonal variations in fat content,
- histochemical studies on gonads,
- morphological and physiological properties of hilsa blood,
- anatomical differences in different body types.

4. Other studies

Besides the above suggestions, it is considered necessary to catalogue the different craft and gear, both in the inland and marine sectors, during different seasons so as to update the information. Efforts have also to be made to standardise the effort in one country with that of the other countries so that there would be compatibility of data for joint stock assessment studies in future.

The areas of investigation suggested in the preceding paragraphs rightly deserve a cooperative effort among the countries of upper Bay of Bengal to form a composite *Operation H/Isa*. Although the recommendations pertain to Bangladesh and India, it is highly desirable to have Burma coopted in this endeavour for mutual benefit of all the three countries of the region so that a fresh and fuller understanding of an important fishery resource could emerge from such an operation.

In 1951 the Indo-Pacific Fisheries Council at its Third Meeting observed “having considered the extent and importance of the fisheries for hilsa in Burma, India and Pakistan, and being aware of the severe fluctuations which take place in the catches of the species and of the intensity of the fishing operations which have been brought to bear upon it, we believe that urgent action should be taken to secure the fullest possible information on the species and on the fishery which bears upon it.” These observations are no less relevant today than they were in 1951.

XI. SUMMARY

1. The paper reviews our current knowledge on the hilsa shad, *H/Isa i//sha*, of the upper Bay of Bengal region relating to aspects such as environment, distribution, migration, behaviour, reproduction, larval, juvenile and adult history, fishery, races, and management. After a brief appraisal of the existing information on important features of the hilsa biology and fishery, a set of recommendations is given for future studies, both in Bangladesh and in India, at the national, bilateral and multilateral levels. A bibliography on the subject is appended.
2. The existing literature, rather more exhaustive in the Indian region than elsewhere, relates, however, almost solely to the riverine and estuarine stocks; there is practically no scientific information on the marine segment of the population in spite of the fact that its importance was stressed more than four decades ago, and it has been subjected to increasing exploitation recently. A more intensive investigation than hitherto accorded has been launched in Bangladesh. In India, studies are now more oriented towards artificial propagation, commercial-scale seed production and genetic characterisation of hilsa. Information from Burma is very scanty.

3. There are at least two distinct eco-types, the potamodromous stocks which appear to remain in the middle reaches of the rivers throughout the year and breed therein, and the anadromous stocks whose normal habitat is the lower region of the estuaries and the foreshore areas, ascending the rivers during the breeding season and returning to the original habitat after spawning. Besides these, there is some doubt whether a purely marine type also exists.
4. Although hilsa was earlier credited with long migration of even over 1000 km. it would appear that the range of migration is not that great as was originally believed. Tagging experiments conducted showed a recovery rate of about 8%; 30% of the recoveries were made within 10 days and 80% within a month. The maximum time at liberty was 770 days and the longest distance of recovery about 340 km. It was concluded that the same fish comes up the river more than once during successive spawning seasons; that the downstream migration does not necessarily follow soon after spawning but is rather pronounced during end of the season after winter spawning and that the hilsa stock in the upper Ganga is different from that of the lower Ganga and Padma.
5. The construction of dams, anicuts and weirs has definitely affected the fisheries, but attempts to provide fish passes have proved futile. In spite of man-made obstructions, however, the hilsa appears to have established itself below the barriers and has reached a stage of stabilisation.
6. There are some conflicting/confusing views on some of the basic biological features of the fish, such as age, growth and reproduction, perhaps because of different interpretations by different workers who have been looking at different stocks at different points of time from different places; the selective nature of the commercial gear has also contributed to this. On reproduction, it may generally be concluded that the fish attain their first maturity at the end of one year when they are 25-30 cm in length. Two principal breeding runs have been reported, one during the south-west monsoon, and the other during late winter; the latter is of a smaller magnitude. Regarding spawning, although two seasons, monsoon and winter, have been recognised within the June to March period, it is not clear where one season stops and the other begins. Insofar as the Ganga-Hooghly system is concerned, there appear to be three peaks of activity, one at the height of the south-west monsoon in July-August, the second after the monsoon in October-November, and the third towards the end of winter in February-March. In the other river systems, the timing of the peak activity appears to be different at different places. Available evidence seems to indicate that the two spawning runs are mutually different, the same stock spawning only once during the year, although the conclusion drawn from tagging experiments was that the same fish comes up the river during successive spawning seasons. On the question of spawning frequency, opinions differ whether the clearly differentiated single stock of ova is shed in one batch or in more than one batch, whether spawning in individual fish is short or prolonged. The records may indicate fractional spawning, but they are not convincing enough to suggest multiple spawning. As regards factors influencing spawning, although the intensity of monsoon and the flooding of rivers appear to be the stimulus for the monsoon run, the fact that the two major spawning runs are characterised by two different sets of ecological conditions appears to indicate that the two runs are governed by different sets of requirements.
7. Hilsa is a highly fecund fish, the estimate ranging from 0.1 to 2.0 million eggs, increasing with size of the fish. Generally, for the fish in the size range of 25 to 40 cm length, the fecundity estimate is about 0.25 to 0.40 million, for those in the 40-50 cm range, 0.4 to 1.6 million, and for those above 50 cm, 1.3 to **2.0 million**. **The diameter of the fully ripe ovum** ranges from 0.7 to 0.9 mm. The length of newly hatched larvae ranges from 2.3 to 3.1 mm.
8. The juvenile history appears to indicate that the fish may attain a length of about 15-16 cm in about 5 months when the anadromous stock undertakes the seaward migration. Although interpretations on growth increments from the length frequency data have been

different, it would appear that the fish attain a length of about 25-30 cm, 35-40 cm and 45-50 cm at the end of first, second and third years, respectively.

9. Hilsa is a plankton feeder, feeding both on phytoplankton and zooplankton, resorting to bottom feeding at times. The items found in dominance are copepods, diatoms, and green and blue algae.
10. The fishery belongs to the artisanal sector, both the traditional non-mechanized and the modern small mechanized; it is exploited by a variety of gears but the major contribution comes from gillnet/drift net. The traditional boats, by and large, are plank-built, undecked or partly decked. Fishing for the marine segment of the population by small mechanized gillnetters is on the increase. The fishery in the upper and middle reaches of the rivers have either thinned down considerably or disappeared. The anadromous stocks in the estuaries and lower reaches of rivers seem to have reached a stabilised state, while the returns from the sea are increasing.
11. The fishing season extends from June to March; however, the duration varies in different areas. From the anadromous/potamodromous stocks, peak catches are obtained in September-October and in January-February; there may be a minor peak in June. In the sea, while fishing activity is very much reduced during the south-west monsoon on the Bangladesh coast, it is reported to be intense on the opposite side of Bay of Bengal, viz., on the upper east coast of India. On the Bangladesh coast, there are two peaks, as in the case of estuarine/riverine stocks, a major peak in September-October and a minor one in February-March. On the Indian coast, in addition to the lucrative fishery during the monsoon, the winter months of November-February witness a good harvest.
12. Although there is difference of opinion on the age/size composition in the fishery, it could be generally concluded that the 25-40 cm group, belonging to two successive year-classes, forms the backbone of the fishery.
13. **There is a general lack of precise and comparable catch data** with reference to space and time. The catch records have a continuity only for a few years. Bangladesh nets the largest catch of about 1 50,000 tonnes, about half or 60% of which may be harvested from the sea. From the Indian region adjacent to upper Bay of Bengal region, the total catch may be of the order of 27,000 tonnes, the inland waters contributing to about 21 ,000 tonnes and the coastal belt to about 6,000 tonnes. In Burma, the yield may be 4000-5000 tonnes.
14. The recruitment rates appear to fluctuate very greatly from year to year which is largely responsible for the annual oscillations in the fishery. There is, however, practically no work on population dynamics/stock assessment, no adequate data on effort and the corresponding catch, and no proper management or regulatory measures except for some local prohibitory orders on fishing within one mile below the anicuts in some of the states in India. In Bangladesh, although there is a ban on the use of gillnets with mesh sizes less than 100 mm, the fishermen continue to employ smaller meshed gillnets.
15. On factors affecting the fishery, the time of arrival and intensity of monsoon, the consequent level of flooding of the rivers and the degree of turbidity of the waters have been included as major causal factors. Some workers have projected a five-year cycle in the fishery as related to the five-year biological cycle or as related to rainfall amount of the fifth preceding year, but the evidence is not convincing.
16. The subject of racial composition has received a good amount of attention, mainly tackled through biometric studies; some serological investigations and tagging experiments have also been conducted. The existence of individually different stocks in each of the major river systems of the Indo-Bangladesh region has been established. A new dimension that has been added recently is the segregation of the stocks further into at least two varieties, a broad and a slender one, in all the three countries. However, no studies have been made on the composition, continuity, independence or interdependence of the

stocks of the marine sector. It has been provisionally suggested that there may be at least four stocks, if not more, in the region, three anadromous and one marine. The three anadromous stocks may be distributed as: one in the Indo-Bangladesh area, one on the eastern Bangladesh, and one in the central and southern regions of Burma. The marine stock may be contributing to the fishery of south-eastern Bangladesh coast contiguous with the Arakan coast of Burma. These are besides the purely fluviatile stocks in the upper reaches of the major river systems in India and Bangladesh and perhaps in Burma.

17. Farming of hilsa has been successfully developed in India and self-propagating stock established in confined waters of Ukai Reservoir. Standardisation of technology for commercial seed production and transport is the aspect now engaging the main attention in India.
18. A general appraisal of existing information, especially on the bionomics of the fish, racial structure and factors influencing the fishery/reproduction has been attempted. In view of the increasing importance of the marine sector and its influence on the whole hilsa population, it has been suggested that a well designed cooperative programme be undertaken by the countries concerned for a fresh and fuller understanding of this important fishery resource. Future efforts should certainly take up studies on fishery and biology of the exploited stocks in the sea, conduct experimental fishing the sea with least selective gears, and undertake racial investigations from biometrics, biochemical and cytogenetic aspects and migration studies through tagging experiments.

XII. BIBLIOGRAPHY

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