Factors Affecting Timing and Size of Runs of *Hilsa* Shad (*Hilsa ilisha*) in Bangladesh and Pakistan

by

Nitya Nanda Das

A thesis submitted in partial fulfillment of
the requirements for the degree of

Master of Science

in

The Faculty of Graduate Studies
(Department of Zoology)

We accept this thesis as conforming to the
required standard

The University of British Columbia

April 1985

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Nitya Nanda Das

Department of Zoology

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date 22 April 1985

ABSTRACT

Data were gathered in 1983 and 1984 on the Hilsa fishery in the Meghna River in Bangladesh, and on factors related to its seasonal variation, including effort as estimated by weekly counts of fishing boats, and landings as estimated by counts of fish offloaded at Chandpur. Historical data were also analyzed concerning factors influencing annual variations in Hilsa landings from the Padma River of the Ganges (1967-1974) and from the Indus River of Pakistan (1968-1982). Rail shipments were good indicators of landings. No significant relationship was observed between riverine Hilsa landings and fishing intensity. Rainfall, mean water level and maximum air temperature had no obvious influence on annual variations in seasonal timing of Hilsa runs in the Padma river of the Ganges. Rainfall two years earlier had a significant negative relationship with annual variation of Hilsa landings, in both the Padma River and in the Indus River. Mechanisms regulating this negative association between landings and rainfall may be that Hilsa are 1^+ year old when they are first recruited to the fishery, and the survival of eggs and fry is minimum in years when there is a very high rainfall. In the Ganges and Indus rivers, annual landings were not closely correlated, and appear to be dependent in part on earlier rainfall conditions within each region. This dependency offers a means of rough forecast of annual harvest on the basis of previous rainfall data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

It gives me much pleasure to record here my deep sense of gratitude, sincere appreciation and profound regard to my research supervisor, Dr. C.C. Lindsey, for his constant and untiring help, scholarly guidance and constructive criticism in all phases of this research work.

I am grateful to Dr. T.G. Northcote for his invaluable counsel and comments, and Dr. N.R. Liley for his constructive criticism.

I have also benefitted considerably from discussions with Drs. N.J. Wilimovsky, J.D. McPhail and C.J. Walters.

Much of the field work would not have been completed without the hard work, enthusiasm and perseverance of Dr. Melvin, Md. M. Hossain, Md. Sanaullah, Mr. Bibhuti Das, Md. Sattar, Mr. Indra Mohan, Md. Nurul Islam and of Md. Abbas Patwari.

Eric Taylor and Michael Lapointe provided patient assistance with computer handling, programming and their open-door policy regarding my frequent queries on the nuances of various statistical analyses. Eric Taylor also read the first draft of this thesis and provided many constructive comments.

Deepest and most sincere gratitude are also due to my parents, wife, brothers and sisters for their blessings. I received utmost encouragement and appreciation from my wife in completing this work.

I am grateful to the International Development Research Centre for awarding me a pre-project fellowship during the tenure of which this work was carried out.

Last but not least, I would like to thank Linda Duncan for her considerable secretarial assistance.

I dedicate this thesis to my dearest people.

1. INTRODUCTION

The Hilsa shad Hilsa ilisha (Hamilton) is the most important single species of food fish caught in Bangladesh and is a major source of protein in the people's diet. The Hilsa catch comprises about 22% of the total catch in Bangladesh, while no other single species contributes more than 5%. Employing 50,000 to 100,000 fishing boats, the fishery for Hilsa is also a major source of employment. The importance of Hilsa as a food source is such that the demand for Hilsa far exceeds its supply, and may necessitate management of the harvest to prevent overexploitation. Unfortunately, the fishery is as yet almost totally uncontrolled and undocumented. Currently, the Hilsa fishery resource is threatened by the construction of Farakka Barrage in India which diverts water from entering Bangladesh, and by irrigation, flood control measures and industrial effluents in Bangladesh.

Basic life history knowledge of Hilsa is so rudimentary that measures to protect or expand the catch cannot yet be formulated. Successful stock management requires a good understanding of the major factors affecting survival and subsequent run size. Although studies have been published on several aspects of the biology of Hilsa ilisha (Day 1873, Hora 1938, 1940, 1941, 1942, Hora and Nair 1940, Jones 1957, Jones and Menon 1951, Pillay 1952, 1954, 1955, 1957a, 1957b, 1958, Pillay and Rosa 1963, Quddus et al. 1984a, 1984b, 1984c), little is known of the impact of environmental parameters such as rainfall on timing of runs, or on annual variations in this important commercial fishery. Nor has an attempt been made previously to correlate this information from different countries where Hilsa occurs (extending from the Persian Gulf to the Bay of Bengal).

The primary goals of the present research were:

(1) to establish to what extent records of rail transhipments of Hilsa reflected changes of abundance of Hilsa in the rivers, independent of varying fishing effort;

(2) to study seasonal variations in abundance of Hilsa in the Padma and Meghna Rivers in Bangladesh, and their relationship to rainfall or other environmental factors, and

(3) to study annual variations in Hilsa in the Padma and Meghna Rivers of Bangladesh and in the Indus River of Pakistan.

An attempt is made, using this information to develop a run prediction model.

2. STUDY AREAS

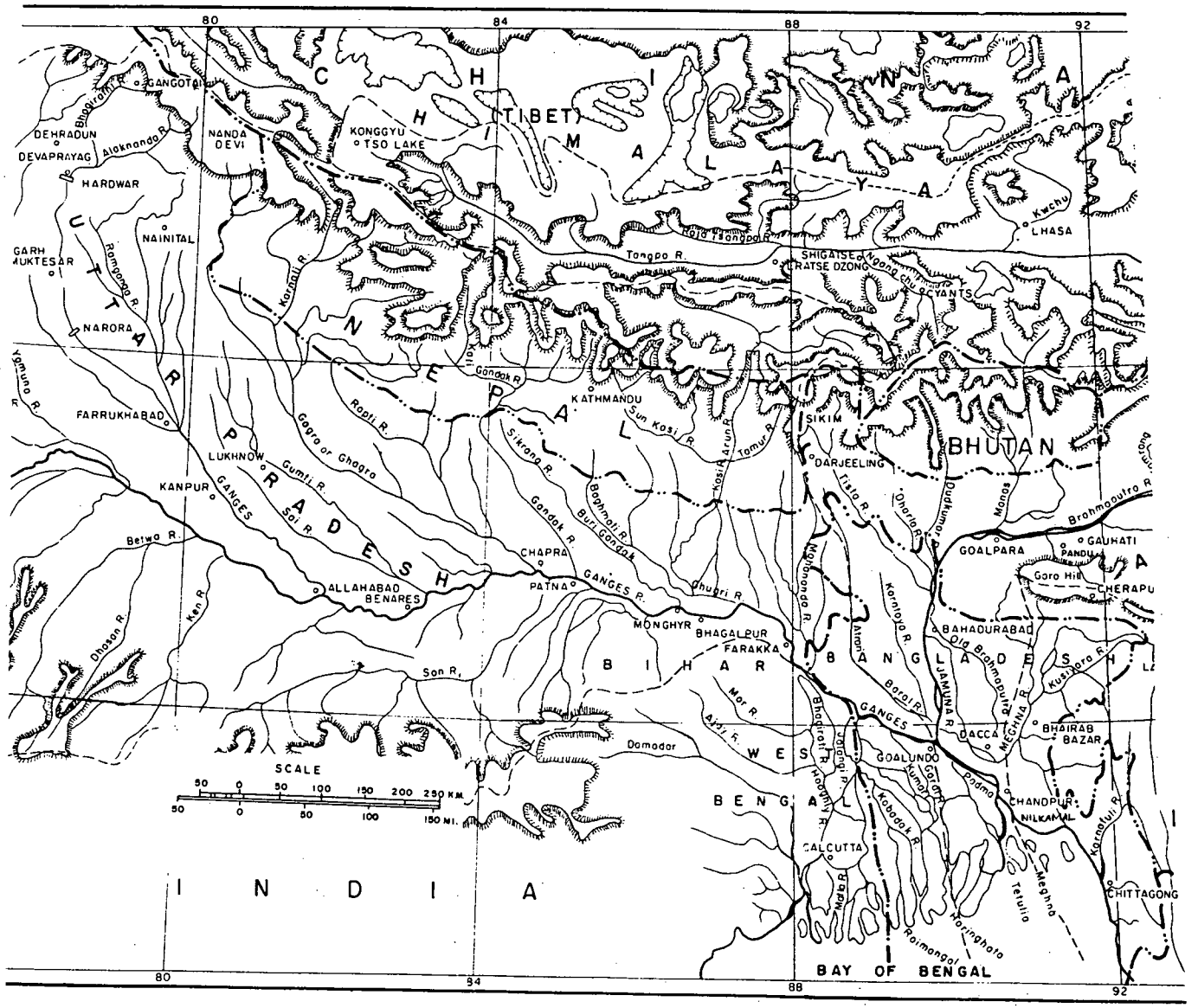
2.1 Ganges River

The Ganges-Brahmaputra River system forms in the Bengal Basin a delta of 25,000 square miles extent. It is the life line and main source of supply in Bangladesh. The river serves as a source of irrigation, navigation and fish protein for urban and rural settlements. The Ganges River basin supports a concentration of 300 million people.

The Ganges, one of the major rivers of the world, has a length of 1570 miles down to the mouth of the Meghna River (Rashid 1977). It rises at an elevation of about 23,000 feet in Gangotri on the southern slope of the Himalayan range. Along this boundary are located the three highest mountain peaks: Mt. Everest, Kanchanjangha and Makalu. From its headwaters, the Ganges flows in a south-easterly direction and, further downstream, in an easterly direction through India to the border of Bangladesh (Fig. 1).

Amongst the major tributaries which feed the Ganges, three viz. the Karnali (Ghaghara), the Gandak and the Kosi, flow down from Nepal and together contribute about 41% to the annual flow and about 71% to the dry season flow of the Ganges (Abbas, 1982). The river Bhagirathi-Hooghly, on which the Port of Calcutta is situated, branches off from the south bank of the Ganges at Farakka a short distance above the point where the Ganges enters Bangladesh (Fig. 1). It is at Farakka that a barrage was constructed across the river by the end of 1974 which diverted a large portion of the Ganges water into

FIGURE 1. Map of the Ganges.


80
84
88
92
C H I N A
(TIBET)
H I M A L A Y A
KONGGYU TSO LAKE
NANDA DEVI
GANGOTRI
Bhagirathi R.
DEHRADUN
DEVAPRAYAG
Alaknanda R.
HARDWAR
NAINITAL
GARH MUKTESAR
Ramganga R.
NARORA
Karnali R.
Tsangpo R.
Kwchu
LHASA
SHIGATSE
GYANTSE
Gandak R.
KATHMANDU
Sun Kosi R.
Kosi R.
Arun R.
Tamur R.
SIKIM
DARJEELING
BHUTAN
Rapti R.
Gogra or Ghagra
Sikrong R.
Bagmati R.
Burri Gandak
Gandak R.
Tista R.
Dharla R.
Brahmaputra R.
Manas
GOALPARA
GAUHATI
Goro Hill
CHERAPUNJI
FARRUKHABAD
LUKHNOW
Gumti R.
KANPUR
GANGES
Sai R.
Belwa R.
ALLAHABAD
BENARES
CHAPRA
PATNA
GANGES R.
Ghughri R.
MONGHYR
BHAGALPUR
FARAKKA
Mahananda R.
Karatoya R.
BAHADURABAD
Old Brahmaputra R.
Kusiyara R.
Dhasan R.
Ken R.
Son R.
Mor R.
Ajay R.
Bagati R.
JAMUNA R.
MEGHNA R.
DACCA
BHAIRAB BAZAR
Damodar
Bhagirathi R.
Jalangi R.
Hooghly R.
GOALUNDO
Garai
Kumar
Kobadak R.
Padma
CHANDPUR
NILKAMAL
Karnafuli R.
CHITTAGONG
CALCUTTA
Matla R.
Meghna
Tetulia
Horinghata
Raimangal
SCALE
50 0 50 100 150 200 250 KM.
50 0 50 100 150 MI.
I N D I A
BAY OF BENGAL
U T T A R P R A D E S H
N E P A L
B I H A R
W E S T B E N G A L
B A N G L A D E S H

the Bhagirati-Hooghly Channel. After reaching the Indo-Bangladesh border, the Ganges forms the boundary of the two countries for a distance of about eight miles, whereupon it diverges completely into Bangladesh. At this point, it flows for another 70 miles before joining the river Brahmaputra-Jamuna (which flows southwest through Assam) at Goalundo. The combined course of the Ganges and Brahmaputra-Jamuna, taking the name of Padma, is joined from the east by another river, the Meghna off Chandpur. The Meghna receives the old Brahmaputra on its right bank at Bhairab Bazar. A little above the confluence, the Meghna has a width of half a mile. The mean discharge at this point, from late May to mid-October, is about 250,000 cusecs with a recorded maximum of 431,500 c.f.s. in 1960. Average annual discharge is estimated to be 92 million acre-feet. Ten miles from Shaitnol, where the combined Ganges and Brahmaputra-Jamuna, as the Padma River, meets the Meghna, the confluence is seven miles wide in the rainy season. From this point, the combined course of the three rivers continues as the Lower Meghna into the Bay of Bengal.

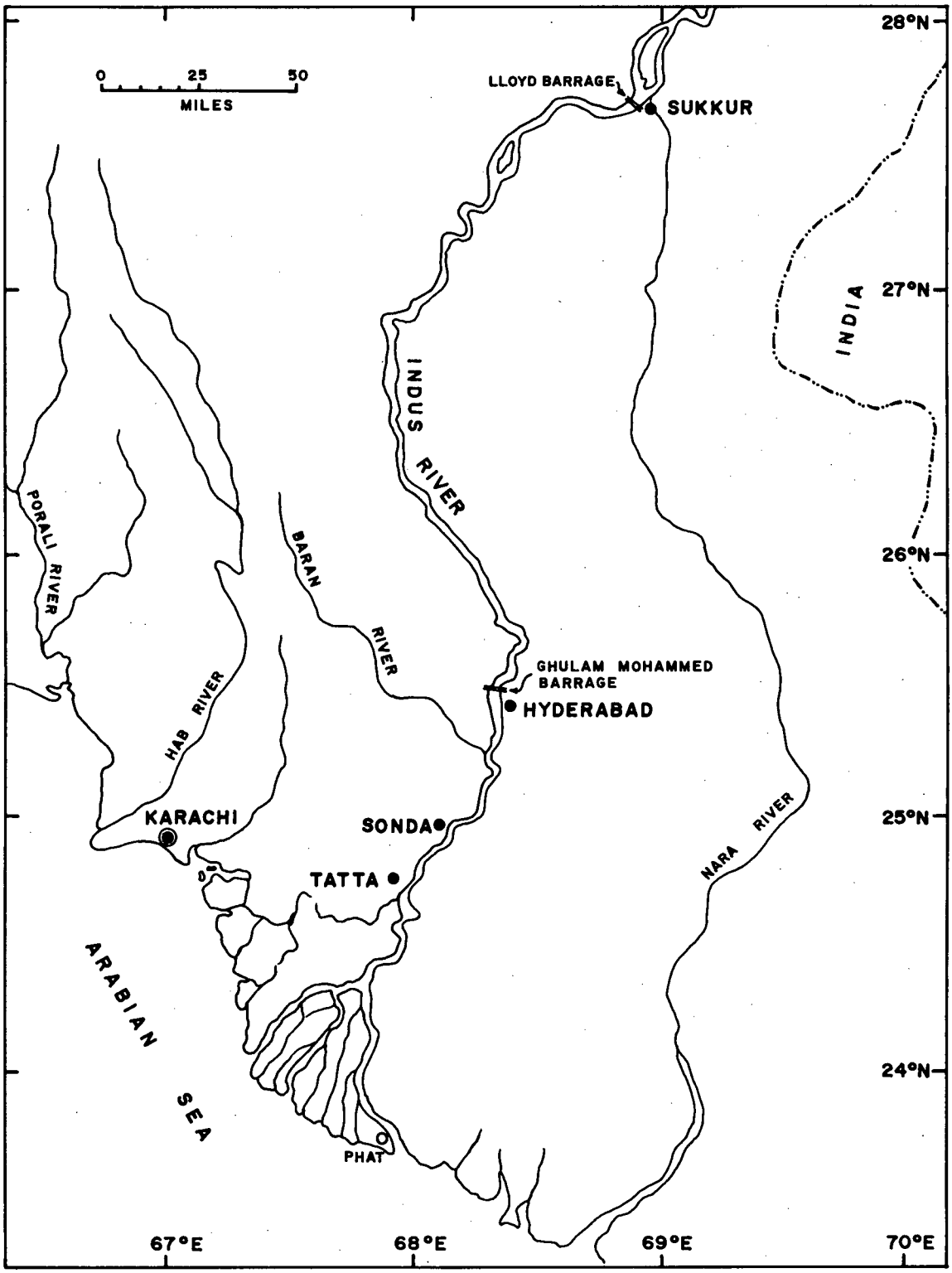
The estuary of the Lower Meghna is usually taken to stretch from the Rabnabad Islands to the Kumira Coast, a distance of 95 miles. The water is, however, saline from half the year as far north as a line drawn from the middle of Bhola to the north of Shondip. Tidal influence extends as far upstream as Chandpur, but there is no tidal influence at Goalundo. The estuary of the Lower Meghna may be considered to be the Ilsa (or Tetulia) and Shahbazpur Rivers, which together have a width of twenty miles at the sea-face. The estuarine discharge is not known, but at Chandpur the mean discharge from June

to October is around 2.5 million c.f.s. (cubic feet per second). The mean maximum in this period of the year is about 4 million c.f.s. In winter, the flow is about one-eighth as much, but the river even then is several miles wide. In maximum flood, the Lower Meghna's flow is not less than five million c.f.s. It is also estimated that from May to October, its daily load of sediments is nearly four million tons. The annual load of sediments carried by it is about 1,500 million tons and annual water discharge about 875 million acre-feet.

2.2 Indus River

In Pakistan, only the River Indus supports a run of Hilsa. About 5000-7000 fishermen catch about 8000 metric tonnes of Hilsa annually. The Indus is the longest Himalayan river, about 2000 miles in length. The Indus arises in Tibet, flows northwest for about 800 miles between ranges of the Himalayan Mountains, and then abruptly turns southwest, flowing for almost 1000 miles through Pakistan before emptying into the Arabian Sea about 65 miles southeast of the major seaport city of Karachi. At Sukkur (about 475 miles upstream from the mouth, Fig. 2), the volume of water flowing into this river varies from a low of about 30,000 c.f.s. during the winter to about 410,000 c.f.s. during its peak flow in August. The river is navigable in only its lower 750 miles. In most of this lower area, the river flows through arid country where irrigation is necessary to support farming, the major land use of the region.

FIGURE 2. Map of lower Indus River.


0 25 50
MILES
LLOYD BARRAGE
SUKKUR
INDIA
INDUS RIVER
PORALI RIVER
BARAN RIVER
HAB RIVER
GHULAM MOHAMMED BARRAGE
HYDERABAD
KARACHI
SONDA
TATTA
NARA RIVER
ARABIAN SEA
PHAT
28°N
27°N
26°N
25°N
24°N
67°E
68°E
69°E
70°E

3. KNOWN FEATURES OF BIOLOGY OF *Hilsa ilisha*

Owing to its high consumer preference and high tonnage landed, the Hilsa shad (*Hilsa ilisha*) ranks as a valuable commercial fish in the western division of the Indo-Pacific faunistic region. *Hilsa ilisha* belongs to the subfamily Alosinae of the family Clupeidae and is generally thought to be anadromous. Geographically, this species ranges from the Arabian Sea to the Bay of Bengal (Fig. 3), but is concentrated in the waters of Bangladesh, India, Pakistan and Burma (Pillay and Rosa, 1963).

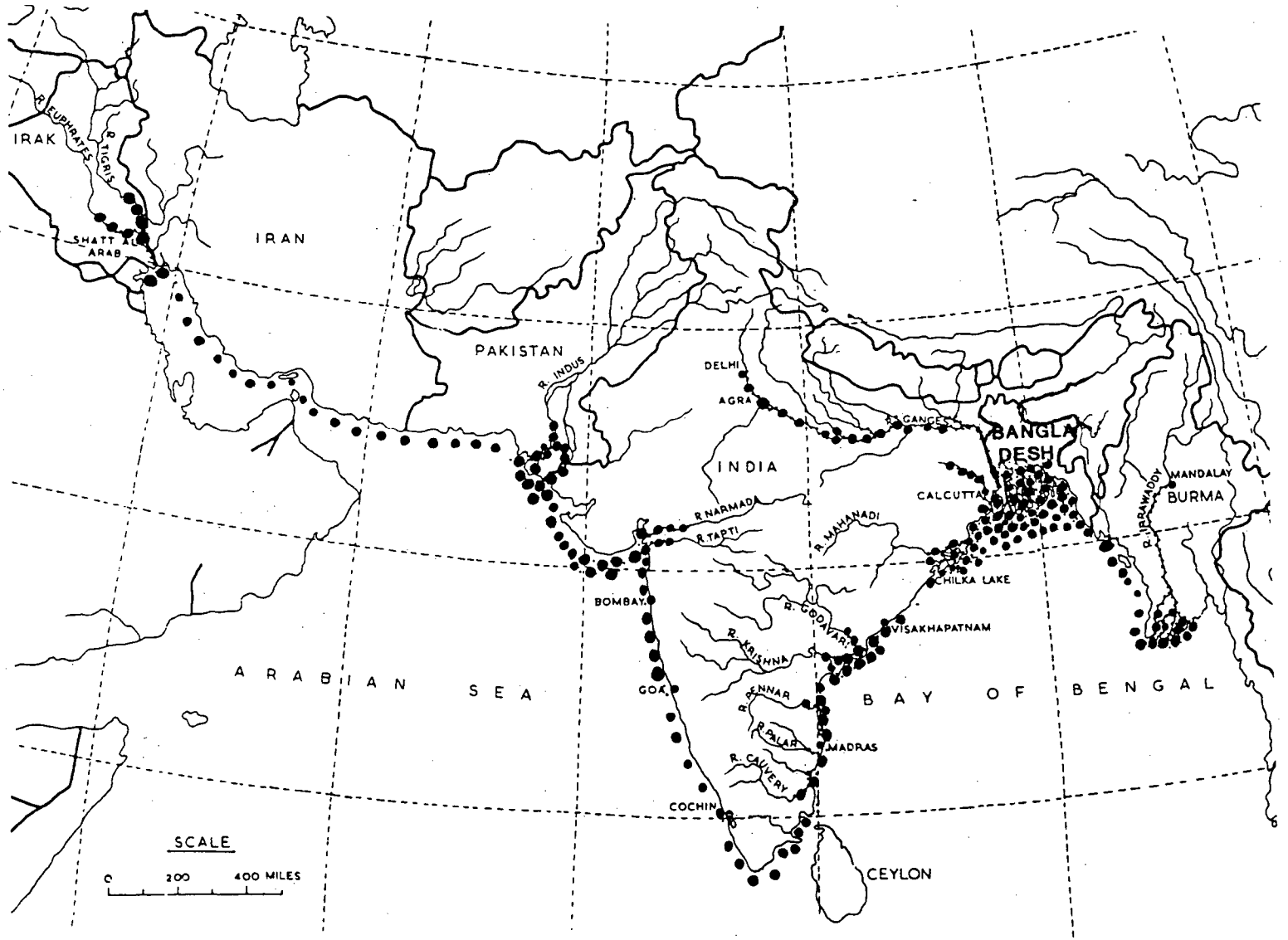
The fishery for *Hilsa ilisha* and its biology have been under investigation for over one hundred years. The existing knowledge about this species stems largely from observations of commercial fishing operations. Although these observations offer only a limited data set for deductions, they nevertheless form a basis on which to build further research. A clear knowledge of the life history of this fish is an essential prerequisite in any programme of its fishery research and management.

3.1 Migration

Hilsa ilisha are reported to be largely anadromous; adults migrate into freshwater from the sea for spawning; the young upon hatching rear in the river channels and estuaries before descending to the sea for further feeding and growth. Thus, there are three phases for potential exploitation: during the breeding migration, the freshwater rearing stage, and the marine phase (Raja 1984).

Generally, it is believed that there are three ecotypes: i) fluvial anadromous stocks which move between coastal waters and the lower reaches of rivers and breed in the area above the level of tidal influence; ii) fluvial resident stocks that live and breed only in the

FIGURE 3. Area of distribution of *Hilsa* indicated by heavy dots.


IRAK
R. EUPHRATES
R. TIGRIS
SHATT AL ARAB
IRAN
PAKISTAN
R. INDUS
DELHI
AGRA
R. GANGES
BANGLA DESH
INDIA
CALCUTTA
MANDALAY
BURMA
R. IRRAWADDY
R. NARMADA
R. TAPTI
R. MAHANADI
CHILKA LAKE
BOMBAY
R. GODAVARI
VISAKHAPATNAM
R. KRISHNA
ARABIAN SEA
GOA
R. PENNAR
BAY OF BENGAL
R. PALAR
MADRAS
R. CAUVERY
COCHIN
CEYLON
SCALE
0 200 400 MILES

middle and upper reaches of rivers, and iii) purely marine stocks. In addition to these three types, a recent development is the establishment of a self-generating stock in the confined waters of Ukai reservoir in Gujrat, India (Raja, 1984).

The descriptions by many workers of the migratory behaviour of Hilsa ilisha are based almost entirely on its occurrence in commercial catches. The only studies on the migration of Hilsa, through tagging experiments, are those of Pillay et al. (1962) in the Ganges. Their findings, although not conclusive, indicate that Hilsa marked in the lower Ganges descended to estuarine areas through the main Padma River that lies in Bangladesh.

The movement of adult Hilsa from the sea to freshwater is characterized by a rapid increase in freshwater catch of sexually mature fish. In the Ganges Delta System, this increase in landings corresponds to the commencement of the south-west monsoon rains (May) and consequent flooding of all rivers of Bangladesh and India. The variations in the intensity of the monsoon during the breeding season appear to be related to the considerable fluctuations in abundance of the fish and catches in different areas. According to Day (1873), the breeding migration in the Indus and the upper Irrawady takes place when rivers are flooded by melting snow, not by monsoon rains. In the Indus River of Pakistan, Hilsa begin to enter freshwater in January, and in some years remain in the river as late as November. Peak landings occur during June, July and August. Although increased stream flow does not appear to be the stimulus that attracts Hilsa into the Indus, as reported for other streams, the peak of the run does occur during peak flows (Islam and Talbot, 1968).

Water temperature has been given little attention as an environmental stimulus for Hilsa migration, yet this factor is known to play a critical role in many aspects of clupeid life history, including anadromous species. The influence of temperature on the movement of Hilsa ilisha is not known, but observation of catches at CIFRI, India suggest some associations with temperature variation; Hilsa show very restricted migratory movements during the cold season (Jones and Sujansinghani, 1951). Jones (1957) observed that from November to February, Hilsa move in large shoals at the mouths of estuaries and along the foreshore areas of the Bengal-Orissa Coast and as far south as the Mergui Archipelago on the Burma Coast (Kyaw 1953). The general rise in temperature in the rivers occurs during the latter part of winter when Hilsa migration also takes place, suggesting that temperature is a contributory factor to initiation of the run. Jones (1957) suggested that the upstream migration of Hilsa in the latter part of winter in the Hooghly River is stimulated by increasing water temperature.

Hora (1940) and Hora and Nair (1940) have surmised that there is a five-year periodicity in the Hilsa fisheries of the Gangetic Rivers. In Bangladesh waters, Dunn (1982) observed the suggestion of a five-year periodicity in the Hilsa catch which corresponds to the index of monsoon severity.

Upstream migration of Hilsa may be extensive. In Bangladesh rivers, they ascend the entire length of the Gangetic Delta System; i.e., about 500 km (Pillay and Rasa 1963). In the Irrawady River of Burma, Hilsa are known to ascend into upper Burma to Mandalay, a distance of about 724 km from the sea. On the Ganges in India, prior to

the commission of the Farakka Barrage in 1975, Hilsa were captured inland as far upriver as Delhi, about 1287 km (Pillay and Rosa 1963). In the Indus River of Pakistan, the migration extends to the Ghulam Mohammad Barrage, about 161 km from the sea.

It has often been observed that during years of great abundance of Hilsa the usual limits of upstream migration may be extended. Such instances have been recorded in the Brahmaputra River where Hilsa catches were made even in areas above Tezpur during 1955 (Pillay and Ghosh 1958) and in the small tributaries of the Ganges, through which the fish ascended into Lake Mahasratal during 1954 (Banerji 1955).

Day (1873) considered it essential to provide fish passes to facilitate the migration of Hilsa to the upper reaches of rivers in which artificial obstructions have been constructed. However, the fish passes constructed across the Coleroon and Mahanadi Rivers (Southwell and Prashad 1918) were found not suitable for Hilsa. Devanesan (1942) observed that migrating fish gather below the obstructions and fishermen take large catches, greatly reducing the spawning escapement. Later investigators have all concluded that it is not feasible to erect suitable fish passes in Indian rivers (Nair 1954).

Ghosh(1976) estimates that the production of the fishery above the Farakka Barrage dropped from 176.1 kg/km pre-construction to less than 1 kg/km post-construction. Bilgrami and Munshi (1982) also reported the deleterious effect of the Farakka Barrage on the Hilsa fishery.

In the Ganges River system in Bangladesh, the major fishing activity is now in the lower reaches of the main rivers and estuarine

areas. There is little fishing in upstream areas of Bangladesh such as Goalundo, Paksey and Rajshahi, once considered to be centres of the industry. Ganapati (1973) associates the reduced migrations of Hilsa up Indian rivers with the lack of high discharges to the sea, caused by dams or irrigation diversions.

In Pakistan, the Ghulam Mohammed Barrage was constructed in 1954, the fish ladders provided in the Barrage were ineffective also (Hossain and Sufi 1962).

3.2 Maturity and reproduction

Conflicting views have been expressed on the minimum size of Hilsa at first maturity. Day (1873) observed that Hilsa may attain first maturity at the end of the first year, or at the beginning of the second year. Jones and Menon (1951) reached a similar conclusion based on their observations in the Hooghly, the Mahanadi and Chilka Lakes. They have recorded that males become mature when 21.6-25.4 cm in length and suggested they were over one year old, while females became mature in the second year when 26.7-30.5 cm long. However, Pillay (1958) found still smaller sizes in the Hooghly River at first maturity; some males mature at 16-17 cm and females at 19-20 cm in total length when they are both about 1 1/2 years old. Some workers have expressed the view that males mature earlier than females, but critical evidence is not available (Pillay and Rosa 1963).

For the Ganges at Allahabad/Varanasi, Mathur (1964) reported that 50% of the females mature at 35 cm, while the smallest size at maturity were 33 cm in Allahabad and 31 cm at Varanasi. He also

recorded that males mature at a length of about 20 cm. In the upper stretches of the Hooghly, De (1980) observed that females first reach maturity at a size of 34.1 cm. Raja (1984) reported that female Hilsa attain first maturity at the size of 32 cm. The smallest mature male Hilsa observed in the Godavari by Pillay and Rao (1962) was 25.6 cm, and the smallest mature female 37.0 cm long. They concluded that the modal size of 35.5 cm in the length frequency studies represents the group at first maturity. This mode was suggested to represent fish aged 1^+ year. In all other cases, the age of the first maturity was placed at 2 years.

In contrast to the foregoing, Hora (1940) and Hora and Nair (1940) suggested that Hilsa must be 5 years old before attaining maturity. Dunn (1982) reported that almost all reproductive Hilsa were at least 4^+ in age and thus he concluded that there is little spawning below this age. This age group corresponds to a length of about 40 cm (refer to age and growth section).

3.3 Spawning season

The spawning season of Hilsa ilisha has been reported to vary from a few months to year-round, depending on the river. Hora and Nair (1940) and Hora (1940) suggested that in the Hooghly River, Hilsa probably breed year round with a major peak in July-August and a minor peak in May. On the other hand, Jones and Menon (1951) contended that the breeding in the Hooghly is very restricted, if not suspended during the winter months of December and January. Their contention was based on the low density of pre- and post-larvae of the species in routine plankton hauls during winter. This indicated, however, that

some winter breeding may occur lower down in the estuary where temperatures are higher. Bhanot (1973) confirmed by collection of larvae in the Hooghly River that Hilsa spawns throughout the year with peak activity in February-March, July-August, and October-November. Pillay (1958) suggested that there may be two distinct spawning seasons: one which begins at the start of the southwest monsoon and continues through to November, and a second peak occurs from January to March. Based on gonadosomatic indices, Quddus et al. (1984a) described two types of Hilsa from Bangladesh waters; type "A" breeds from July to October and type "B" from January to March. They claimed that the two types of shad are also characterized by differences in morphology; type A is "deep-bodied" and type B is "slender".

Motwani et al. (1957) reported that the breeding of Hilsa in the Ganges appears to commence with the onset of the monsoon season in July, with peak breeding from September to December. Ghosh and Nangpal (1970) found that winter spawning is restricted to the resident slender variety in the freshwater section of the Ganges, while Nair (1958) observed that oogenesis reached its peak in March and the ova undergo atresia and resorption. Nair's observations appear to indicate that there is no winter spawning of Hilsa in the freshwater section of the Ganges.

Ahmed (1954) observed that some gravid Hilsa have been found throughout the year in Bangladesh waters, but the majority of individuals with well developed gonads are available during monsoon months. It appears from Ahmed's study that Hilsa spawn throughout the year, but the peak season comes during the rainy season. On the basis of ova maturation studies, Pillay (1958) concluded that Hilsa breeds

intermittently during the breeding season in the Hooghly River. The ova that were likely to be spawned during the season had a size range of 252 to 882 microns. Since no distinct size grouping could be observed among the samples, spawning throughout the year was suggested.

In summary, observations which support two spawnings, one during monsoon and the other during winter-spring, come from the investigations of Mathur (1964) with respect to the Ganges, and Quareshi (1968) and Quddus et al. (1984a) from the Padma and Meghna Rivers.

3.4 Factors influencing spawning

On the basis of observations on development stages collected from the spawning grounds, Jones and Menon (1951) suggested that the spawning time of Hilsa is towards the afternoon and evening.

Very little is known about the factors that induce spawning in Hilsa. Southwell (1914) suggested that the changes involved in the transition from the sea to freshwater induce spawning. Nair (1958) studied the variation in water temperature of the Ganges near Banaras and the gonadial activity throughout the year, and suggested that very high temperatures have perhaps an inhibitory effect on maturation of the ovaries. The floods during the rainy season, which make the water turbid and the current flow faster, were considered by Nair to be most favourable for spawning.

3.5 Spawning grounds

Southwell and Prashad (1918) expressed the opinion that there are no fixed spawning grounds for Hilsa in the generally accepted use of the term, and that they probably breed during the rains whenever conditions such as weather, temperature and other undetermined factors are suitable.

The first positive evidence of the location of spawning grounds was discovered by Hora (1938) when he identified the young of the species from the Pulta Water Works tanks, into which they would have gained access only in the form of eggs or early larvae, because of the very narrow suction space in the centrifugal pumps at the intakes. He inferred that the stretch of Hooghly River near Pulta Water Works formed one of the spawning grounds of Hilsa. This was confirmed by further observations made by Hora and Nair (1940) and Jones and Menon (1951). Pillay (1958), on the basis of ova studies, inferred that the lower limit of the spawning grounds of Hilsa in Hooghly River is Bagh Bazar in Calcutta. There is evidence to show that they breed upstream up to Medgachi, a distance of about 251 km from the sea. The Hilsa of Chilka Lake spawn in the lower reaches of the Daya River (Jones and Sujansinghani 1951).

Karamchandani (1961) concluded that Hilsa breeds also in the freshwater regions of the river, below the most upstream limit of its migration (about 161 km from the sea) in a stretch of about 29 to 32 km. From obvervations on the size composition of catches, he observed that only older Hilsa (males 31.5 cm to 48.5 cm and females 41.5 cm to 55.5 cm) migrate to the freshwater zones for breeding and that the younger Hilsa breed in the tidal zone. Southwell (1914) has

also suggested such a possibility in the rivers of eastern India. Motwani, Jhingran and Karamchandani (1957) have described the spawning grounds of Hilsa in the Ganges as the stretch of the river between Patna (Bihar) and Allahabad (Uttar Pradesh). The presence of larvae in the stretch of Lalgola of the Ganges indicates the probability of Hilsa spawning in that area. The presence of spent Hilsa in the sea off the Saurashtra Coast, where there are no large rivers up which Hilsa might ascend, has indicated the possibility of the stock in the area breeding in the sea (Pillay 1963).

Ahmed (1952) has recorded that Hilsa breed in the Indus River near Nawabshah and in the stretch of the river immediately below the Sukkur Barrage. The spawning grounds have been restricted by the construction of the Ghulam Mohammed Barrage in 1954, below which Hilsa now spawn.

In Bangladesh, Qureshi (1968) observed Hilsa spawning grounds in the Padma and Meghna Rivers and their tributaries.

3.6 Eggs

The diameter of the fully-ripe ovarian egg has been recorded as 0.70 mm to 0.75 mm by Jones and Menon (1951), 0.89 mm by Pillay (1958) and 0.76 mm to 0.87 mm by De (1980). 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 as its density is very close to that of water, it is easily buoyed up and drifted by slight curents (Kulkarni 1950). 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 (1950) and Motwani, Jhingran, and Karamchandani (1957) stated that the Hilsa egg has a double-layered membrane, but Jones and Menon (1951) observed that the double-layering takes places as a result of post-mortem changes. There is no information available on the parasites and predators of Hilsa eggs in nature.

3.7 Larval history

Kulkarni (1950) has given the following account of the development of artificially fertilized eggs of Hilsa (Appendix Table 1). The temperature of the water in which the eggs were hatched was between 28°C and 28.5°C. The hatching time varied from 18 hours to 26 hours, depending on the temperature and oxygenation of the water. Observations by Jones and Menon (1951) on developing eggs, collected from the Hooghly River, showed a longer incubation period which might have been due to the low water temperature (23°C) in which they were reared. They suggested considerable retarding of growth with drop in water temperature. Motwani, Jhingran and Karamchandani (1957) recorded the incubation time to be 24 to 28 hours.

The newly hatched larva is 3.1 mm according to Kulkarni (1950) and 2.3 mm according to Jones and Menon (1951). Motwani, Jhingran and Karamchandani (1957) found the length of newly hatched larvae to be 2.5 mm to 2.55 mm and Karamchandani (1961) observed it varying between 2.4 mm and 3.0 mm.

3.8 Age and growth

One of the major limitations in the study of Hilsa populations is the lack of a suitable method for age and growth determination. Aging from hard parts, such as scales and otoliths, has been attempted, but the results have not been encouraging. The most promising structures for aging are the otoliths, which are under investigation by Md. Mokammel Hossain (pers. comm.).

Since the stocks of Hilsa are exploited mostly by size selective gear, aging by length frequency analysis is of limited use. The lack of reliable aging techniques has led to many different views of age and growth in Hilsa. Hilsa is thought to live a maximum of 5 to 7 years, although age groups 2 to 4 appear to contribute most to the fishery.

3.9 Food

Hilsa ilisha is a planktivore exploiting both zooplankton and phytoplankton. In the young stages, diatoms dominate the diet. As the fish grow, however, the composition of the diet shifts towards crustacean items, especially copepods. Spent fish are believed to be benthic feeders as considerable quantity of mud and sand are ingested. The intensity of feeding is very high during the post-spawning period. Some authors have observed a decrease or cessation of feeding activity during the spawning run.

4. SEASONAL VARIATIONS IN HILSA IN THE PADMA AND MEGHNA RIVERS IN BANGLADESH

4.1 Description of fishery

"The Hilsa being by far the most important food-fish in the Ganges, and its fishery one that engages the attention of the vocational fisher-castes far beyond any other, it is natural that extremely ingenious and effective methods have been evolved by a race noted for its inventiveness in this art" (Hornell 1950). The choice of the net depends upon the depth of water to be fished, velocity of the current, time of the year and above all the financial condition of the owner of the net (Ahmed 1960). The following three types are very common and generally used in the Meghna River: (1) Shangla jal, (2) Chandi, and (3) Dora.

(1) Shangla jal (Fig. 4 and 4a)

This is a purse-shaped net with hinged mouth which can be shut instantly when desired. It is also called a clap net.

It can be used from the surface to a depth of several fathoms, as the closing rope may run to a length of 15 fathoms. In outline the mouth is semicircular, the two flexible bamboo lips often over 8 meters in length, bent into a deep graceful curve that gives an easy hinging motion when the mouth has to be shut. The bag is about 3 to 4 meters deep. The netting is of nylon twine and the mesh is from 8 to 11 cm, knot to knot diagonally. The mouth is kept open by a brick or stone weight of 8 to 10 kg tied to the centre of the lower lip. The boat is allowed to drift in the direction of the current with the mouth of the net facing

FIGURE 4. Diagram of Shangla jal in operation (after Jones 1959).

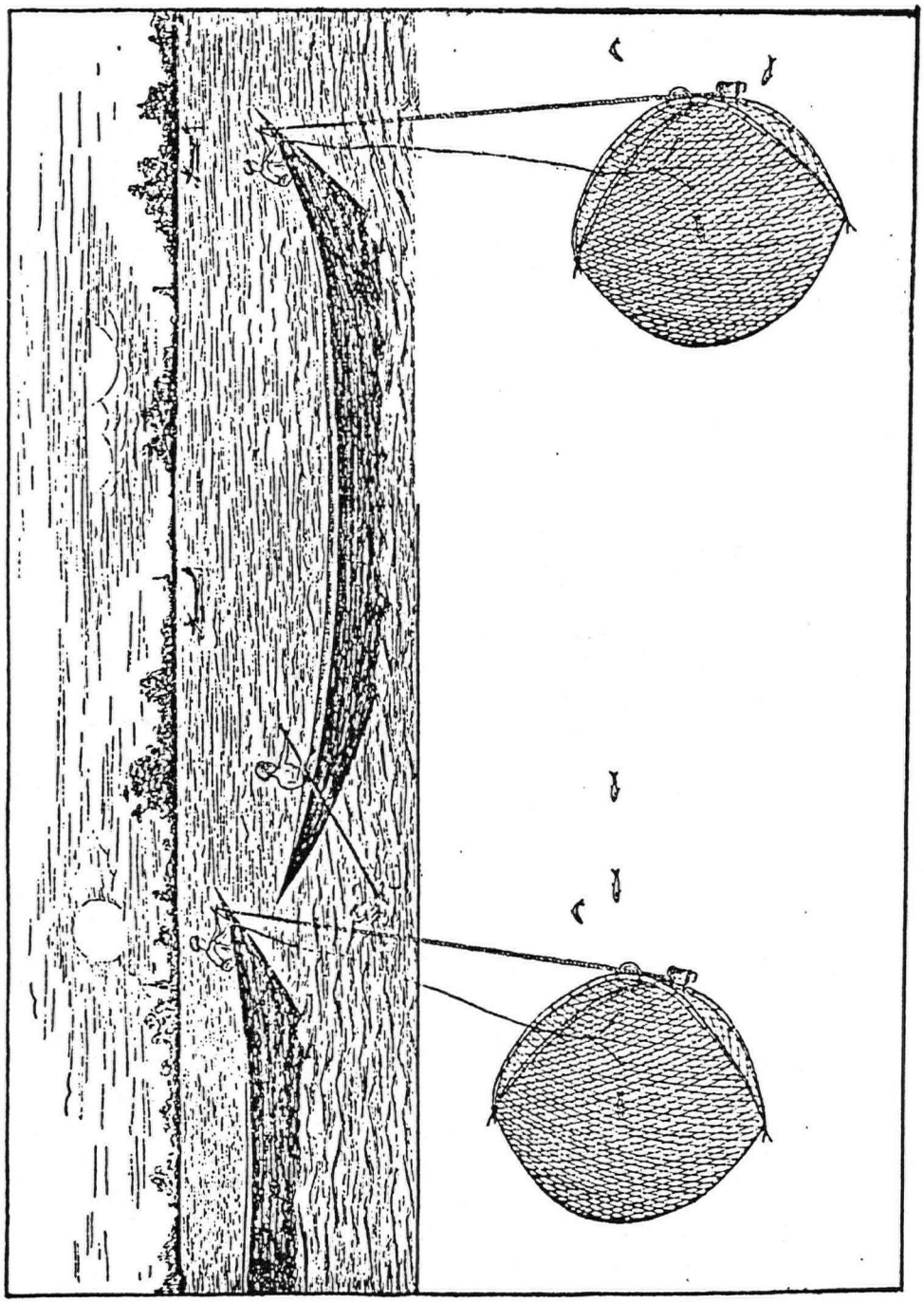


FIGURE 4a. Photograph of open mouth of Shangla jal, at Chandpur.

downstream trapping any fish coming up. There is a fine feeler cord, dividing into three branch lines at its lower end attached at three points on the upper portion of the net to transmit the disturbance caused by the entrance of a fish into the net. The other end of the line is held taut in the fisherman's left hand; the slight jerk or quiver it transmits when a fish enters the net is sufficient signal; the net is instantly closed by a jerk of the haul rope in the right hand. The net is then hauled up and emptied. The net is operated round the year, but peak operational season is during monsoon.

Occasionally when the net is operated at bottom level it gets entangled in submerged obstructions and if efforts to extricate it are of no avail the rope is cut and the net abandoned. When two nets are operated simultaneously from a boat a minimum of three persons are required for the purpose, one at the helm and two others to operate the nets and assist in rowing (Jones 1959).

The boats used for operating Shangla jal are known as dinghis. A dinghi is a plank built round-bottomed shallow boat most common in the Ganges, about 5 to 8 meters in length and about 1-1.5 meters wide, with long pointed bow and stern. The boat is strengthened by ribs and cross-beams with detachable half-split bamboo pieces in the interspaces. Long paddles are used also which serve in steering. When sailing, a bamboo mast is carried in the front with thin split sail supported by a diagonal bamboo yard stepped far in front.

FIGURE 5. Chandi jal.

(2) Chandi jal (Fig. 5)

This is a powerful drift gill net and employed chiefly when rivers are in flood - May to October.

The Chandi jal is made like all large drift nets in a number of short lengths, which are tied together into a long fleet when about to be shot. The size of each piece varies considerably, but generally each piece measures 12 meters in length by 8 meters deep. The nets are of nylon twine, and have a mesh of from 6 to 10 cm, knot to knot. Floats of bamboo are used to buoy the head-line at intervals of about 3-5 meters, while the foot-rope is weighted at similar intervals, usually with thick disc-shaped burnt-clay sinkers each of about 10 to 15 cm in diameter having an eccentrically placed hole, or with fragments of brick. The net can be adjusted to float vertically at any desired depth.

For operational purposes several pieces of net, from 25 to 75, are tied together depending on the length required and the resources of the fishermen. To one end of the head rope a small raft of bamboo is attached and the net is paid out across the river, the other end being tied to a boat. The net as well as the boat drifts down in the current, gilling any ascending Hilsa. When fishing is done at night, a light is kept burning on the raft so that the fishermen in the boat can get an idea of the position of the other extremity of the net. For day-time fishing, the raft is sometimes substituted by a long pole or any conspicuous floating object. Though the net is employed mainly for catching Hilsa, other fishes also sometimes get gilled or entangled in it.

The boat used for the operation of this net is known as the Chandi nauka. This is a shallow plank-built boat with a rounded bottom, longer and wider than the dinghi. It is about 12 to 20 meters in length and about 2.5-3.5 meters in width. The boat is provided with a hood and there is provision for a mast and sail. There are usually 5 to 8 persons in a boat. The net is employed round the year, but chiefly used from May to October.

(3) Dora jal

This net is similar to Chandi jal, but of smaller mesh (5 to 8 cm) and is mainly employed for catching Hilsa. This net goes by the name of Ilish jal in the districts of Khulna and Bogra of Bangladesh (Ahmed 1962).

The net may run from about 60 to over 300 meters and the depth from about 5 to 8 meters according to the width and depth of the river. The net is employed round the year, but mainly operated after the Pooja (October) for a period of about 6 months until March-April. The Hilsa caught in the Dora jal are several cm smaller than those caught in the Chandi jal.

The boat used for the opertaion of this net is known as the Dora nauka. It is the same type of boat as Chandi nauka, but smaller in size.

Generally fishermen catch Hilsa every day. They take little rest, only when preparing and taking their meal. There are a few brave fishermen who prefer night fishing to day fishing, and who

take rest during daytime. During the lean fishing season some of them seek alternate employment.

Few fishermen deliver their catches directly to the fish landing centres. Most of the river fishermen appear to use no ice and have no means of maintaining the quality of the fish. Mostly they sell their catches on the river to a faria (collector). The collector buys the fish from the fishermen, and transports them to the landing centres where they are off-loaded from the collector boats to the wholesale market. From there, following auction, most are trans-shipped elsewhere by truck or by rail, usually packed with ice. At Chandpur, the collector boats bringing fish from freshwater areas operate by sail or oars, and can therefore be distinguished from the larger mechanized boats which deliver Hilsa of marine origin.

4.2 Relations of landings to effort

4.2.1 Method of estimating effort

Assuming the amount of Hilsa transhipped is a fair indication of the actual amount of fish caught (as is discussed later), the changes in freshwater catch could be due either to changes in availability of Hilsa or to changes in fishing intensity. Since there were no data on fishing intensity, I conducted a regular fishing boat count for two consecutive days in every fortnight over an 8-month period, in order to estimate the number of boats during the high and low tide fishing operation on a particular segment of the Meghma River [from Chandpur

to Nilkamal fishing ground (Fig. 1)]. This 10-mile stretch of the Meghna River provides a regular source of Hilsa supply to the Chandpur landing centre. Thus, fishing intensity (boat counts) and landings can be compared from this stretch of river.

Hilsa fishing boat counts started in January 1984 and continued until August 1984 in this selected segment of the Meghna River. On the first week of every month I and a field assistant counted the number of boats engaged in Hilsa fishing from Chandpur to Nilkamal by a scheduled ferry. The fleet consisted of small boats, medium boats and large boats, as described in the foregoing section. While going to Nilkamal by the ferry during high tide, I recorded the number of fishing boats along the near side of the river by naked eye, and boats along the other side was counted through a binocular by an assistant. The next day, while returning from Nilkamal to Chandpur by the scheduled ferry during low tide, the counts were repeated (Table 1).

In order to combine the effort of the three sizes of fishing boats into a single index, each size was assigned a weight according to the estimated average daily catch per boat. Small boats were estimated to take 1 kg/day on the basis of personal observation and discussions with fishermen. Medium boats were estimated to take 6.33 kg/day, and large boats 17.6 kg/day, the latter two figures based on records of monthly catch/boat over a ten-month period (Table 2). Thus, the total intensity of fishing effort for each time was calculated by

TABLE 1. Number of different types of Hilsa fishing gear/day that were in operation during different months of the year, the Meghna River between Chandpur and Nilkamal from January 1984 to August 1984. The values reported are the mean and their standard errors. Each monthly mean is based on four observations.

MONTH	High Tide			Low Tide			Mean of High and Low Tide Counts		
	Clap Net	Dora	Chandi	Clap net	Dora	Chandi	Clap Net	Dora	Chandi
January	22.0	347.0	56.0	15.0	211.0	22.5	18.5±2.2	279.0±43.4	39.3±9.9
February	16.5	344.0	76.5	14.0	167.5	22.5	15.3±2.3	255.8±54.1	49.5± 17.1
March	12.5	300.0	72.0	9.0	279.0	85.0	10.8±1.1	289.5±28.6	78.5± 13.1
April	45.5	223.0	404.0	37.5	167.0	94.0	41.5±10.4	195.0±30.6	249.0± 93.1
May	35.5	178.5	191.0	16.5	174.5	123.0	26.0±6.5	176.5±17.5	157.0± 20.2
June	60.0	124.0	330.5	52.0	102.5	178.5	56.0±8.0	113.3±23.0	254.5± 44.7
July	299.5	62.5	297.5	97.0	50.0	123.0	198.3±58.8	56.3±3.8	210.3± 51.9
August	101.0	31.5	186.0	50.0	29.0	127.0	75.5±15.9	30.2±3.5	156.5± 24.6

TABLE 2. Mean catch/day of Hilsa (kg) by two types of gear in different mouths in the river stretch from Chandpur to Nilkamal of the Meghna River (after Bangladesh Fisheries Resources Survey System, 1984).

Month	Chandi	Dora
May 1982	6.15	4.10
May 1982	10.03	6.12
September 1982	33.82	9.40
October 1982	25.90	6.33
January 1983	10.50	6.00
February 1983	7.75	3.25
April 1983	7.67	3.25
July 1983	13.64	7.35
October 1983	28.67	8.50
December 1983	31.67	9.00
Mean	**17.58 kg/day**	**6.33 kg/day**

adding together the counts of each boat type each multiplied by the weighting factor for that type (Table 3).

4.2.2 Method of estimating landings

The number of baskets of riverine Hilsa landed at Chandpur landing centre during the landing time (from 6 a.m. to 8 p.m.) were counted by two field assistant and by me for each day of fishing boat counts (Fig. 6). The catch is usually offloaded by standard size baskets and the weight of fish per basket is known. The daily total weight of riverine Hilsa off-loaded from collector's/fishermen's boats which had been operating in the river was therefore estimated by basket counts supplemented by weight data when available. Estimates may have been slightly low due to a few fish reaching the landing centre after 8 p.m., but the error is slight. Freshwater Hilsa landing data obtained in this way were also checked against trans-shipment data.

4.2.3 Marine versus freshwater landings

An attempt was made for the first time to find out the ratio between riverine or freshwater versus marine catches delivered to Chandpur landing centre. The method of estimating marine Hilsa was the same as for Hilsa originating from freshwater, except that marine Hilsa were those brought upstream to the landing centre by mechanized boats. It was observed that 2319 metric tonnes, i.e. about 54% of the total Hilsa, was freshwater, while 1999 metric tonnes; i.e., 46% were contri-

TABLE 3. Monthly freshwater landings of Hilsa and fishing intensity (calculated as described in text) for the River Meghna at Chandpur during the period of January to August 1984. Monthly freshwater landings are calculated from eight daily observations. Regression statistics shown below.

Month	**Freshwater Landings (metric tonnes)**	**Fishing Intensity**
January	57.7±.1	2475.4
February	57.2±.3	2503.0
March	220.7±1.8	3223.4
April	203.9±1.4	5653.7
May	231.8±1.5	3904.6
June	506.8±2.2	5248.6
July	434.6±2.2	4251.7
August	606.1±1.9	3018.6

$Y = 59.5 + .06 * \text{Fishing intensity}$

$r^2 = .1286$

$P = .61$

FIGURE 6. *Hilsa* offloaded by standard basket at Chandpur landing centre.

buted by the marine Hilsa (Table 4). Only the riverine catches at Chandpur are considered in the following calculations.

4.2.4 Results and discussion

The regression was calculated of monthly landings on fishing intensity (Table 3). Fishing intensity accounted for only 12% of the variation in freshwater Hilsa landings at Chandpur, and the regression was not significant. The month of highest fishing intensity (5654 in April) produced a moderately low landing (204 tonnes); the highest landings (606 tonnes in August) were produced by only moderate fishing intensity (3018). Evidently, variations in landings are not controlled by variations in effort, among the monthly samples at Chandpur.

The only other available records on landings and effort were from Godavari River on the east coast of India during the monsoon months of the years 1963-1969 (Rajyalakshmi et al. 1972). Regression calculations showed that here again fishing effort accounted for only 14.6% of the variation in yield of the Godaveri River, and the regression was not significant (Table 5).

One further question arises: to what extent are trans-shipment records (which are usually the only historical data available) a reliable indication of actual landings. Since both sets of data were available from Chandpur for the months of January to August 1984 (Table 4), their correlation was calculated. Monthly trans-shipments were very highly corre-

TABLE 4. Rail trans-shipment records, and observed riverine and marine *Hilsa* landings in metric tonnes for the Meghna River at Chandpur from January 1984 to August 1984. The values reported are the mean and their standard errors. Each monthly mean of freshwater and marine water *Hilsa* is based on eight observations and trans-shipment on 30/31 days of observation.

Month	**Rail Trans-shipment**	**Riverine Landing**	**Marine Water Landing**	**Observed Total Landing (Riverine α marine water landings)**
January	108.4	57.7±.1	124.7±2.2	182.4
February	232.2	57.2±.3	167.2±1.1	224.4
March	397.9	220.7±1.8	76.9±1.1	297.6
April	427.1	203.9±1.4	31.6±0.7	235.5
May	360.8	231.8±1.5	25.1±0.5	256.9
June	918.4	506.8±2.2	372.8±4.3	879.6
July	1081.6	434.6±2.2	261.5±1.5	696.1
August	2337.3	606.1±1.9	939.7±7.3	1545.8
TOTAL	**5863.8**	**2318.8**	**1999.5**	**4318.3**

TABLE 5. Estimated yield (y_i) in tonnes and effort in thousands of man-hours (g_i) of Hilsa ilisha in Godavari River by drift gillnets in the monsoon months of the years 1963-69 (after Rajyalakshmi et al. 1972). Regression statistics shown below.

Year	y_i	g_i
1963	7.5	63.7
1964	43.9	306.2
1965	36.3	105.2
1966	15.0	165.3
1967	9.6	221.7
1968	14.3	226.7
1969	18.9	198.0

$Y = 8.73 + .06 * \text{Effort}$

$r^2 = .1465$

$P = .60$

lated with observed freshwater Hilsa landings (p=.003) variability in the former accounted for about 80% of the variation in the latter (Fig. 7). Therefore, changes in either can be taken as a reasonable indicator of changes in Hilsa catch at Chandpur. It has been assumed that the same close relationship was true between trans-shipments and landings at Goalundo.

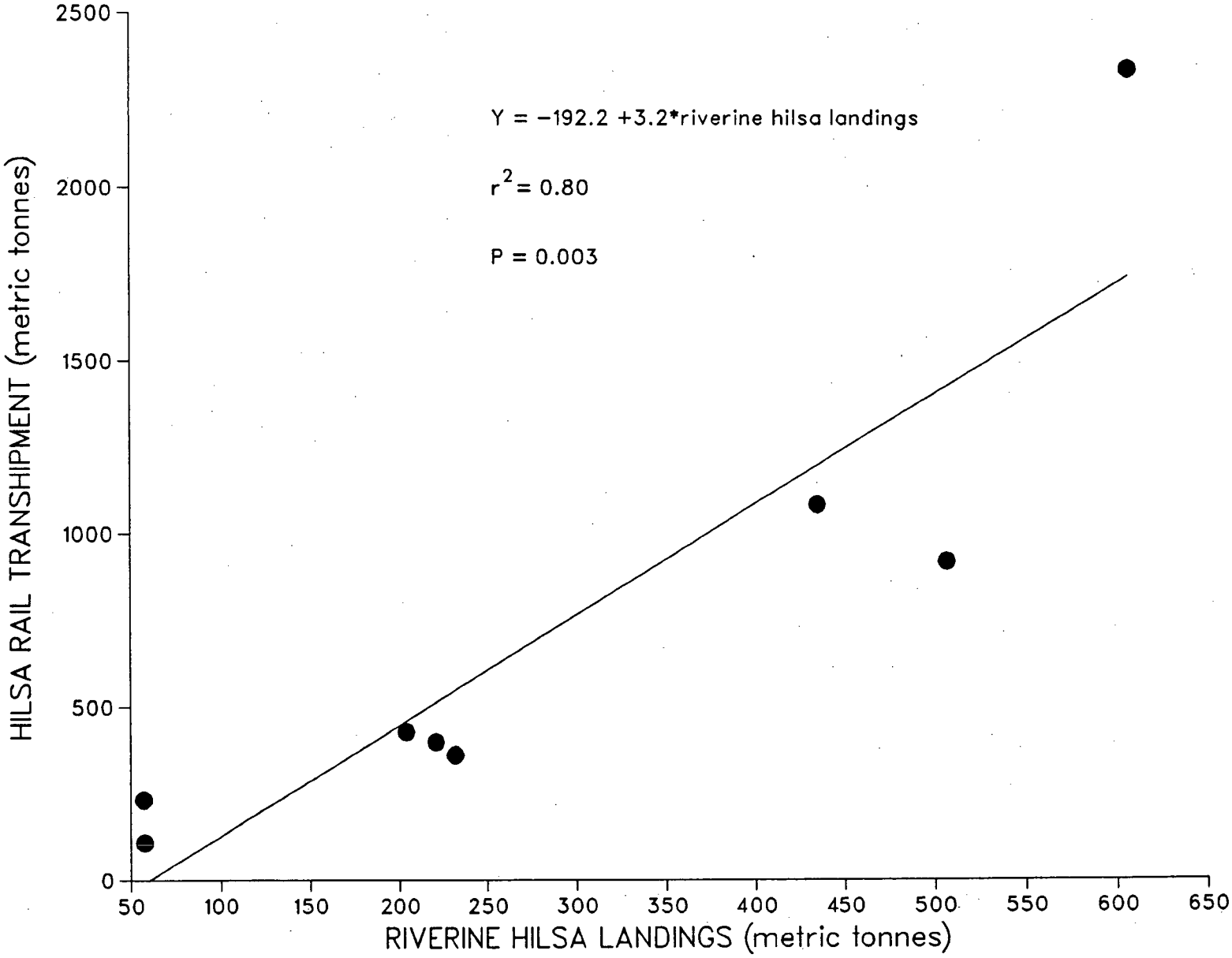
As the foregoing section has established that trans- shipments (or landings) seem to vary primarily according to abundance of fish, not to effort, I am now going to examine monthly changes in shipments and try to relate them to environmental factors.

4.3 Relationship of landings to environmental factors

4.3.1 Sources of data

Records of catch statistics of any fishery are vital for its judicious exploitation and development. There are many difficulties in the way of collection of such statistics relating to the Hilsa fisheries of Bangladesh rivers. These difficulties include the very diffuse and scattered nature of the industry, lack of fixed landing centres, and diverse trade practices. Further, collection of Hilsa landing data is complicated by the traditional nature of the industry in that neither fishermen nor government agencies keep detailed records of landings. For these reasons indirect methods of estimation of landings must be employed such as trans-shipment records (i.e., shipment of Hilsa by railway).

FIGURE 7. Relationship between riverine *Hilsa* landings with rail shipment record of *Hilsa* in the Meghna River at Chandpur.


Y = −192.2 +3.2*riverine hilsa landings
r2 = 0.80
P = 0.003
HILSA RAIL TRANSHIPMENT (metric tonnes)
2500
2000
1500
1000
500
0
50
100
150
200
250
300
350
400
450
500
550
600
650
RIVERINE HILSA LANDINGS (metric tonnes)

Of all the trans-shipment records available, those of the Bangladesh Railway are most reliable and the most useful for analysis of seasonal and annual variation in landings. The advantage of this source of records lies in the detail with which they have been kept (Dunn 1982, Melvin 1984). For instance, daily records of Hilsa trans-shipment at Goalundo have been kept since 1967. This sometimes allows detection of obvious errors by comparing day to day weights. The second and most significant advantage is that records are kept of weight, number of packages, and trans-shipment charges. If an error occurs in the weight, an approximation can be made from either of the other variables and the error can be corrected. Using this strategy has led me to uncover several errors in Dunn's (1982) catch index. Dunn's index documented long-term trends in the Hilsa landings. At Goalundo on the upper reaches of the river Padma the number of packages shipped was erroneously presented as the weight. This error has made landings appear relatively stable between 1976-1981 whereas landings have actually been increasing.

There are however some problems with trans-shipment records as a measure of landings. For instance, the weight includes packing ice which is used in variable quantities according to supply and distance to market. Also, a small portion of Hilsa landed which are consumed by the local people has not been taken into account; however, consumption by fishermen is small because of the high cash value of Hilsa which may be

almost their only source of income. Moreover, the use of certain railway stations for shipment of Hilsa have varied over the years for both economic and natural reasons (closure of landing centres due to siltation). For instance, the rising cost of rail trans-shipment, and improved road construction, have resulted in relatively greater trans-shipment of Hilsa by truck since 1975.

From Bangladesh waters the only seasonal and inter-annual records of riverine Hilsa catch data are available from the trans-shipment of the fish of Goalundo on the Padma river. Subsequent to 1974, however, the trans-shipment data from this site are not representative of riverine Hilsa catch. Firstly, after 1974 trans-shipments of Hilsa at Goalundo have included significant but unknown proportions of both riverine and marine catches. Secondly, the impact of completion of the Farakka Barrage in 1975 on the subsequent Hilsa fishery of the lower Ganges is quite evident (Abbas 1982, Bilgrami and Munshi 1982). Hilsa landings declined above the barrage in India although catches of non-migratory species did not, while the Hilsa fishery in India below the barrage has been steady and actually recorded in 1981 a bumper crop three times the average catch of the earlier years since construction (Anonymous 1984b). Thirdly, subsequent to 1974 these records reflect the steadily decreasing importance of railway freight as the national road transport network improved (Dunn 1982). I have used Goalundo trans-shipment data only from 1967 to 1974 (Table 6) because of

TABLE 6. Monthly trans-shipment of Hilsa through Goalundo Railway station (1967-74) in metric tonnes.

Year/Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1967	243.0	507.0	402.0	188.0	131.0	124.0	199.0	159.0	334.0	229.0	190.0	196.0	2875.0
1968	107.0	102.0	143.0	223.0	282.0	257.0	131.0	132.0	205.0	183.0	166.0	412.0	2323.0
1969	239.0	529.0	734.0	718.0	843.0	1524.0	1006.0	1128.0	1652.0	410.0	207.0	419.0	9409.0
1970	471.0	489.0	1250.0	206.0	893.0	1406.0	380.0	269.0	240.0	124.0	93.0	268.0	6089.0
1971	NR[1]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
1972	30.0	26.0	22.0	22.0	35.0	257.0	255.0	9.0	30.0	90.0	103.0	42.0	921.0
1973	206.0	237.0	240.0	294.0	365.0	975.0	514.0	1269.0	6289.0	613.0	489.0	523.0	12014.0
1974	163.0	235.0	420.0	342.0	495.0	535.0	52.0	31.0	72.0	45.0	42.0	3.0	2435.0

[1]NR = no record

the above reasons. All data on trans-shipments from Chandpur have been excluded from year-to-year comparisons, because they include a variable but unknown proportion of marine fish.

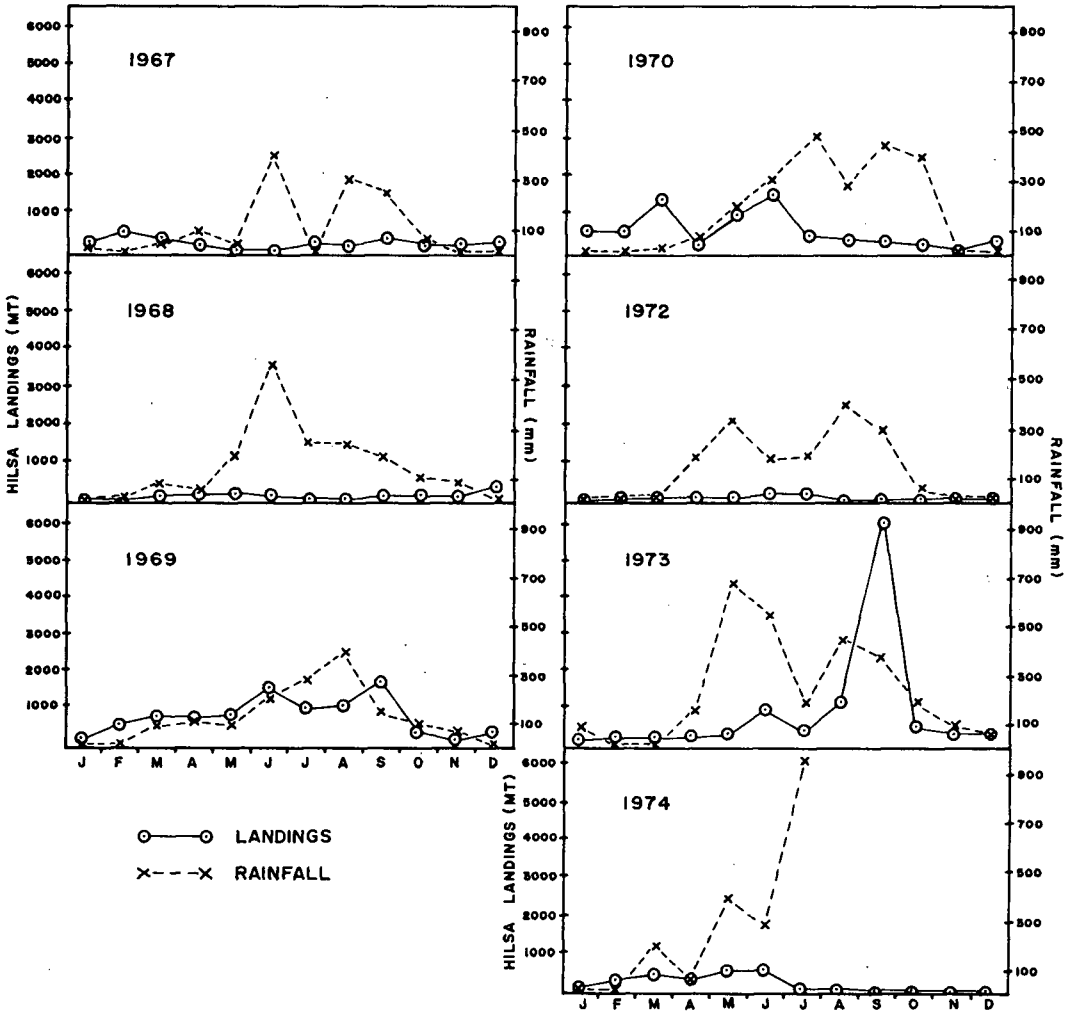
It has also been necessary to exclude from calculations the Hilsa landings in Bangladesh during the liberation (March to December 1971), because of severe disruptions in fishing effort. While fishing was drastically reduced in Bangladesh, fishermen in the Hooghly-Mattah estuarine system of India harvested a bumper crop (Dutta et al. 1973). The seasonal pattern of landings in the estuarine system was more or less similar in all years except March 1971 to February 1972, when unusually high landings were made in August and September [contributing 31% of the annual landings in 1971-72 as against only 2-7% in other years (Mitra and Ghosh 1979)]. Clearly in this instance, geographic shifts in effort produced marked change in distribution of the catch.

Rainfall and maximum air temperature data were collected from the Bangladesh Meteorology Department, while water level and minimum discharge data were collected from the Bangladesh Water Development Board, Dhaka. These data are believed to be reliable.

4.3.2 Relationship of landings to rainfall

Monthly Hilsa landings of the river Padma at Goalundo from 1967 to 1974 are shown in Fig. 8a, along with monthly rainfall data of Faridpur (near Goalundo). (Monthly rainfall data of

FIGURE 8. Relationship of Hilsa landings in metric tonnes (MT) of the Padma River of the Ganges at Goalundo to rainfall of Faridpur (near Goalundo).


1967
1968
1969
1970
1972
1973
1974
HILSA LANDINGS (MT)
RAINFALL (mm)
J F M A M J J A S O N D
LANDINGS
RAINFALL

1974 are not complete.) The month of September 1973 was the most productive (6289 metric tonnes), while the poorest catch was in December 1974 (3 metric tonnes). There were major differences between years in the pattern of landings, and also in the pattern of rainfall, but no obvious relationship between variations in the two. In three years, the landings showed two distinct peaks (June and September in two years, June and March in one, and in other years only a slight peak in May or June). In four years, rainfall showed two distinct peaks, and in the other years a single peak, with peaks occurring in any month from May to August. Peak landings could occur either before or after the month of peak rainfall.

The only other set of data on Hilsa landings and rainfall were those collected during the present study from January to July 1984. Monthly Hilsa landings of the Meghna River at Chandpur from January to July 1984 are shown in Fig. 8b, along with monthly rainfall data of Chandpur. From a simple linear regression, rainfall accounted for about 67% of the variation in freshwater Hilsa landings, and the two were significantly positively correlated ($p < 0.03$), but the time series is short.

4.3.3 Relationship of landings to mean water level

Monthly Hilsa landings at Goalundo are shown in Fig. 9, along with monthly mean water level of the Padma at Goalundo. There was much more regularity between years in seasonal

FIGURE 8a. Relationship of freshwater Hilsa landings of the Meghna River at Chandpur to rainfall of Chandpur.

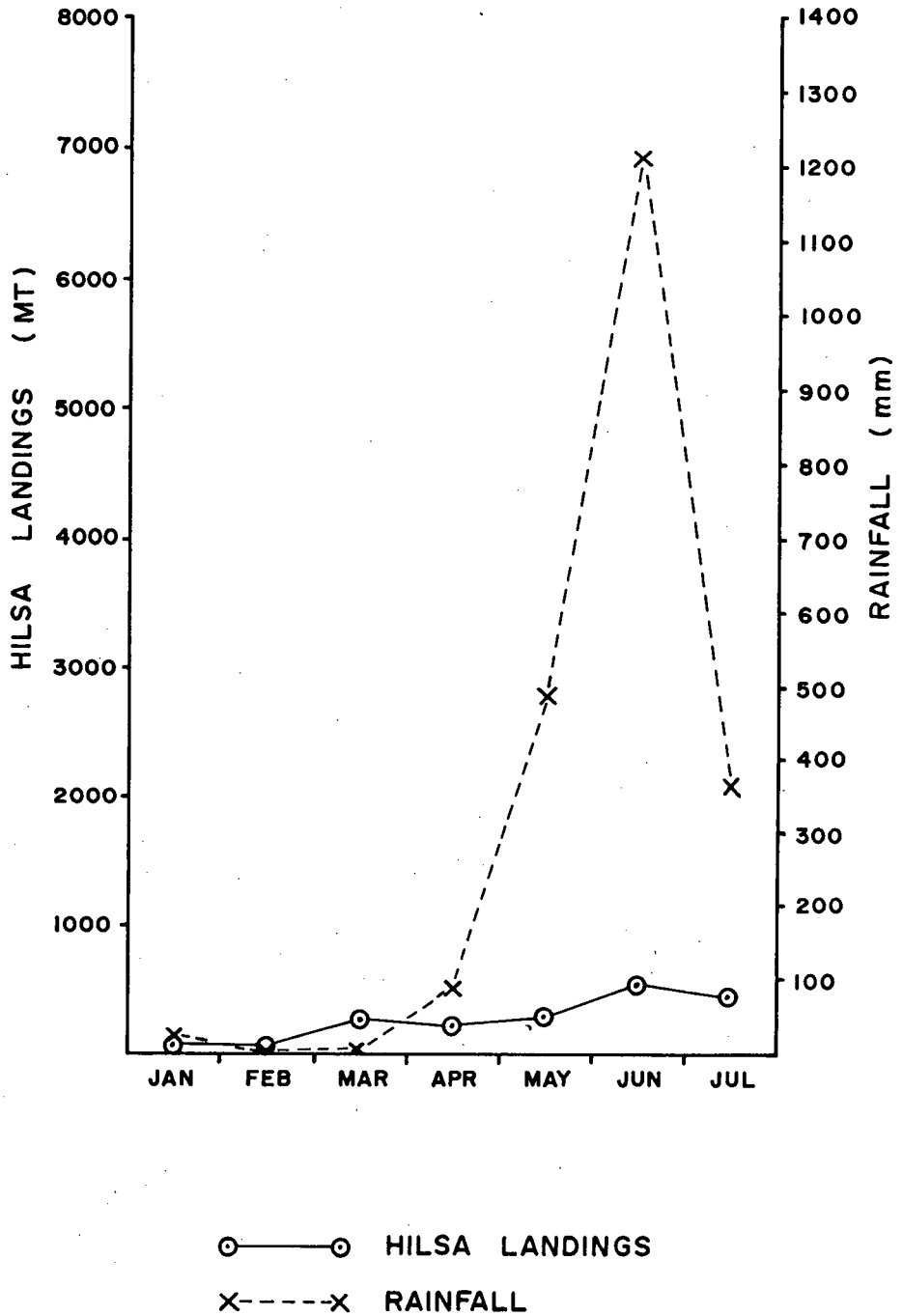
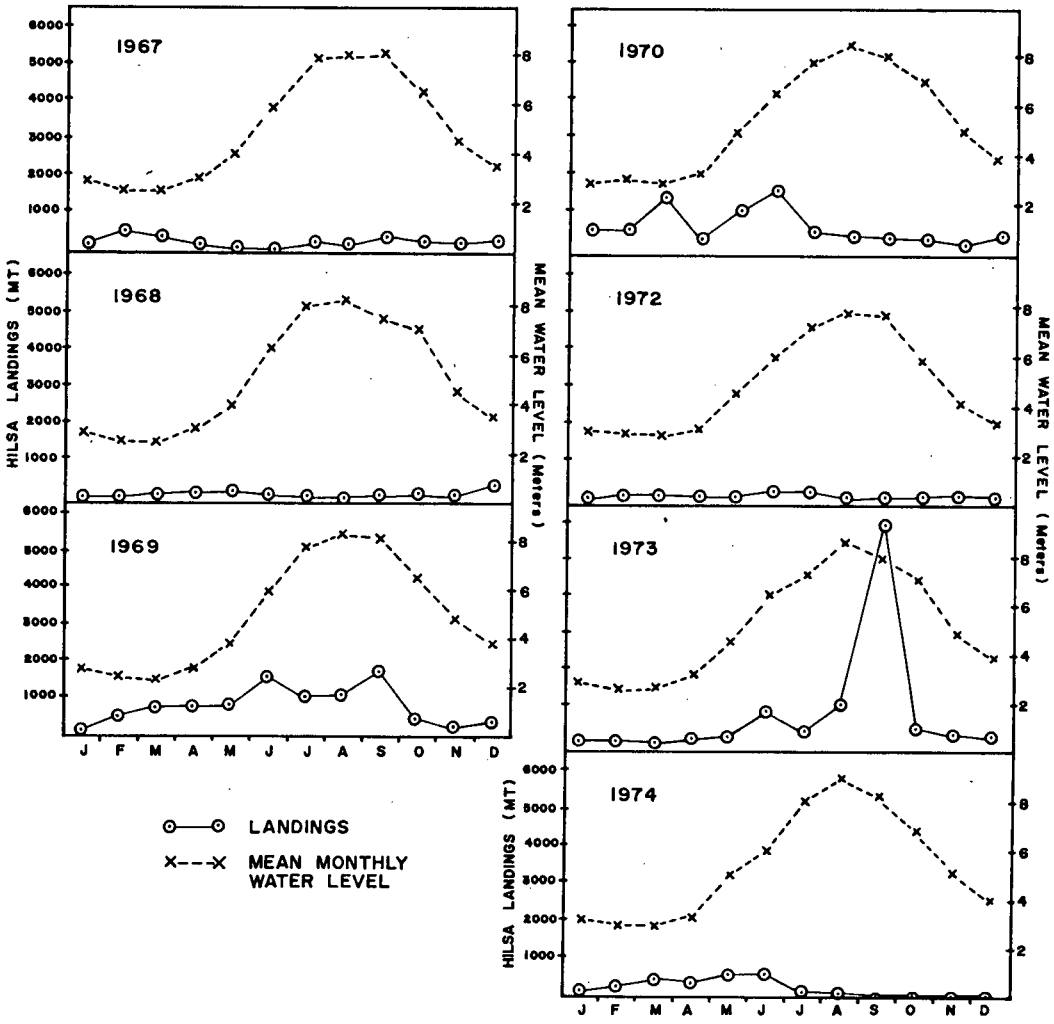

8000
7000
6000
5000
4000
3000
2000
1000
HILSA LANDINGS (MT)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
RAINFALL (mm)
JAN
FEB
MAR
APR
MAY
JUN
JUL
HILSA LANDINGS
RAINFALL

FIGURE 9. Relationship of *Hilsa* landings of the Padma River at Goalundo to mean water level of the Padma River at Goalundo.


1967
1968
1969
1970
1972
1973
1974
HILSA LANDINGS (MT)
MEAN WATER LEVEL (Meters)
J F M A M J J A S O N D
LANDINGS
MEAN MONTHLY WATER LEVEL

patterns of water level than of rainfall. Every year, water level was lowest in February and rose to a high in August. However, as there were major differences between years in Hilsa landings, as described above, there was no obvious relationship between variations in water level and in landings.

4.3.4 Relationship of landings to minimum discharge

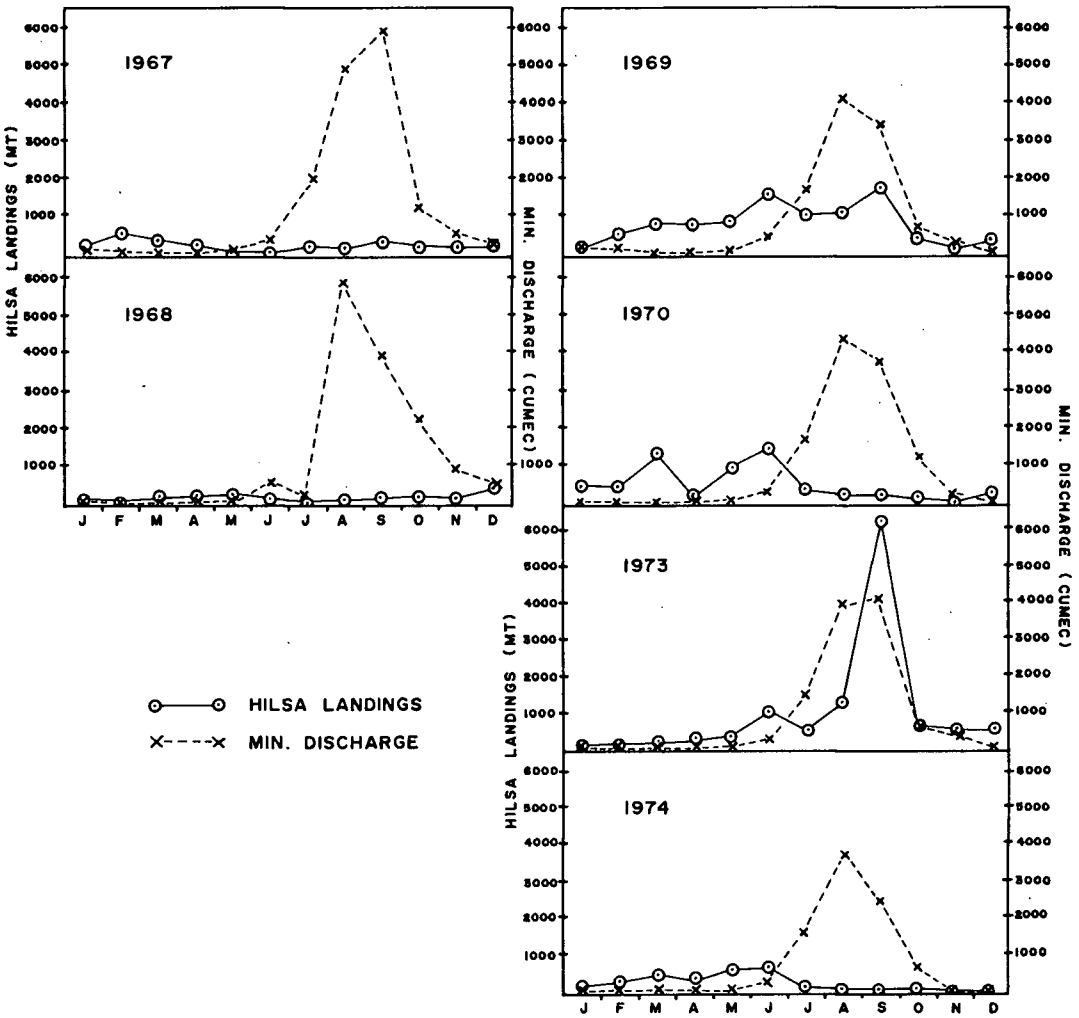
Monthly Hilsa landings at Goalundo are shown in Fig. 10 along with monthly minimum discharge of the Padma river at Goalundo. Seasonal patterns of discharge showed somewhat more variation between years than did water levels, with greater differences in the rates of rise and fall, but the peak always occurred in either August or September. Again, there was no obvious relationship between variations in discharge and in landings.

4.3.5 Relationship of landings to maximum air temperature

Water temperature data of the Padma river at Goalundo are not available, but air temperature data are available. However, water temperatures were available for 13 consecutive months for the Hooghly River of the Ganges, and also air temperatures at Calcutta (near Hooghly). A highly significant positive correlation ($p < 0.01$) was found between air and water temperature (Appendix Table 2).

Assuming that air temperature of Faridpur (near Goalundo) similarly has a close association with water temperature of Padma river at Goalundo, I have plotted monthly Hilsa landings

FIGURE 10. Relationship of *Hilsa* landings of the Padma River at Goalundo to minimum discharge of the Padma River at Goalundo.


1967
1968
1969
1970
1973
1974
HILSA LANDINGS (MT)
MIN. DISCHARGE (CUMEC)
J F M A M J J A S O N D
HILSA LANDINGS
MIN. DISCHARGE

at Goalundo in Fig. 11, along with monthly maximum air temperature of Faridpur. It is observed that highest temperatures were recorded in April or May, and lowest temperatures during December, January and February. Variations from year to year in seasonal changes of temperature are slight, and bear no obvious relationship to those of landings.

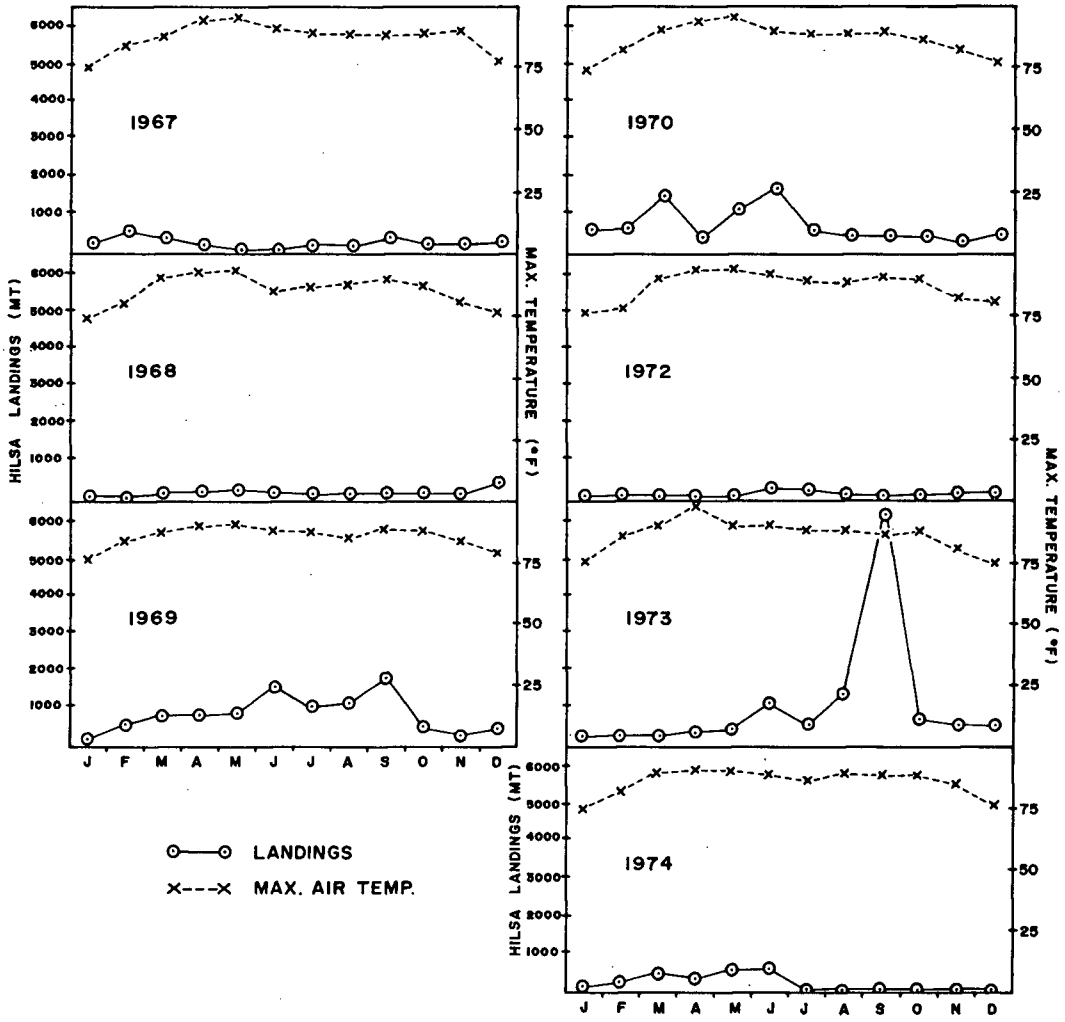
4.3.6 Discussion

"Information from the environment received by the sensory system of a fish can act in two ways to affect its migratory behaviour. Firstly, an environmental stimulus such as rainfall, water current, temperature may alter fish orientation and thereby act as a "director" of movement. Secondly, such stimulus may increase or decrease the intensity of movement, regardless of orientation, and so serve as a 'regulator' of migration." (Northcote 1984).

The environmental control of teleost reproductive cycles has been studied extensively (de Vlaming 1972), including several freshwater species in India (Sundararaj 1981), but little of this work has been directed to Hilsa ilisha. The closest relative whose spawning runs have been studied in detail is the American shad Alosa sapidissima (Leggett 1977), in which temperature has been shown to be an important environmental stimulus controlling run timing.

In tropical and subtropical climates, monsoon rains and subsequent increased stream flow appear to trigger many

FIGURE 11. Relationship of *Hilsa* landings of the Padma River at Goalundo to maximum air temperature of Faridpur (near Goalundo).


1967
1968
1969
1970
1972
1973
1974
HILSA LANDINGS (MT)
MAX. TEMPERATURE (°F)
J F M A M J J A S O N D
LANDINGS
MAX. AIR TEMP.

behavioural responses in fish. Researchers suggest that seasonal and/or annual variation in catch of riverine Hilsa are, to some extent, triggered by seasonal and/or long-term environmental changes. Data supporting this hypothesis are, however, largely circumstantial.

There seems to be no close association between the seasonal timing of Hilsa landings and of rainfall in the river Padma at Goalundo, over the 7-year period examined. Both landings and rainfall may show either two peaks or one in a year, and there is with no suggestion of causal relationship between them. About the only commonality in all years is that rainfall and landings are both low from November to January.

While there was a correlation between rainfall and landings at Chandpur on the Meghna River as measured in the present context, only 7 months' data in one year were available, during most of which time rainfall and landings were rising monthly. Much the same trend appeared at Goalundo (Fig. 8) for the same months in 1969. Since the much more extensive data base for Goalundo demonstrates no such correlation in some years, the correlation during the short series for Chandpur is probably fortuitous.

The reason that rainfall showed more erratic fluctuations than did water level is that flow in the lower Ganges-Brahmaputra is determined by the summation of events (precipitation plus snow-melt) throughout the immense area of the watershed. Water level and discharge records were fairly

regular from year to year in their seasonal pattern. Landings, which displayed sharply different patterns from year to year, are therefore evidently not tied closely to river flow.

The other environmental variable studied, temperature, again showed a fairly consistent seasonal pattern from year to year. Since peak landings did not, it does not seem that temperature is responsible in any simple way for annual differences in run timing.

The conclusion must be that seasonal variations in timing of the landings of Hilsa do not seem to be directly attributable to any of the environmental variables studied (rainfall, water level, discharges, air temperature). Landings are always relatively low in November to January, and this winter season always experiences relatively low rainfall, stream flow and temperature. But in other months, landings in the Meghna River show an erratic behaviour both within and between years apparently independent of the local conditions studied. These variations in landings have been shown not to be due to variations in fishing effort. Perhaps the sources of variation lie in the estuarine or marine conditions affecting the timing of entry into freshwater; fluctuations in numbers of fish arriving at Chandpur may principally reflect environmental influences considerably removed in time and distance from where the fish are landed.

The presence in some years of two peaks of Hilsa runs suggests that there may be two (or more) racially distinct

groups involved. Presence of a monsoon run (June to October) and a winter run (November to March) has been suggested in India (Motwani et al. 1957, Nair 1958, Pillay 1958, Pillay and Rosa 1963). In Bangladesh, Quddus et al. (1984a) believed there are two types of Hilsa: type "A" broad form representative of monsoon spawning, and type "B" slender form representative of winter spawning. On the other hand, in Godavari River only a single wave of migration has been observed (June to October) by Chacko and Ganapati (1949) (as is evident also in certain years at Goalundo). If there are indeed more than one race of Hilsa reaching Meghna River, it may be necessary to first distinguish between them before attributing fluctuations in their timing to particular environmental factors.

Previous observers of factors controlling upstream movement of Hilsa provide conflicting interpretations. Hora and Nair (1940) suggested that the upstream movement of Hilsa was largely dependent on two main factors; viz., monsoon and the state of sexual maturity. The fact that mature Hilsa ascend the river during the winter season, when water levels are low, suggests however that flood conditions are not necessary for inducing the fish to move upstream. In contrast, Day (1873) observed in the winter that a secondary migration of Hilsa occurs in the Indus and Irrawady Rivers and is induced by minor floods caused by the melting of snow in the upper reaches. However, Kulkarni (1951) observed that the summer migration of Hilsa in the Narbada River cannot be explained by any such

secondary flooding. Islam and Talbot (1968) observed that increased stream flow does not appear to be a stimulus that attracts Hilsa, although the peak of the run does occur during peak flows.

On the other hand, Jones and Sujansinghani (1951) indicated a direct correlation between flood water levels and Hilsa landings in Chilka lake and the Mahanadi River in Orissa. They also suggest that other hydrological factors (i.e., low salinity and higher temperature) influence the upstream migration of adult Hilsa. Ramakrishnaiah (1972), however, found no descernible trend between water flow and fishery landings. In contrast, Ganapati (1973) associated the reduced migrations of Hilsa up South Indian rivers with the lack of high discharges to the sea caused by dams or irrigation diversions.

The general rise in temperature in the rivers which occurs during the latter part of the winter when Hilsa migrations are underway has been suggested as a factor contributing to initiation of the run (Jones 1957, Kyaw 1953). In very general terms, this is consistent with the present data, in that each year it is only after the start of rise in temperature in February that landings may start to increase. Temperature rise may be the trigger which induces the first movement into the river mouth from the ocean, but neither it nor the other environmental factors examined can as yet be invoked to explain the subsequent large monthly fluctuations in fish reaching the upstream fishery.

5. ANNUAL VARIATIONS IN Hilsa IN THE PADMA AND MEGHNA RIVERS OF BANGLADESH AND IN THE INDUS RIVER OF PAKISTAN

In addition to seasonal variations in Hilsa, the total annual landings may vary considerably from year to year. The purpose of this part of the study was to document levels of variation of landings betwen years and to try to uncover causes of such variation.

Although precise and comparable spatial and temporal data are not available, it appears that Bangladesh waters contribute about 150,000 metric tonnes (mt) of Hilsa (Melvin 1984). This total may include up to about 50,000 mt realized by the mechanized gill netters operating on the sea front (Raja 1984). In comparison, India contributes about 25,000 mt, Burma about 3,000-4,000 mt (Druzhinin 1970), and Pakistan about 7,000-8000 mt. Data suitable for analysis were available only from Bangladesh waters and from the Indus River.

5.1 Sources of data

For the river Padma at Goalundo the sources, methods and time periods of data collection were outlined in the foregoing chapter. Landings of Hilsa from 1967 to 1974 of the Padma River at Goalundo, with rainfall and mean air temperature of Faridpur from 1962 to 1974, are shown in Table 7. Landings of Hilsa from 1937-1940 of the Meghna River with rainfall from 1933-1940 are shown in Table 8.

For the Indus River I collected Hilsa catch data of 1968 to 1982 from the FAO Yearbook of Fishery Statistics - Catches and Landings. The rainfall and mean air temperature of Hyderabad which represents the rainfall and water temperature of Indus were collected from

TABLE 7. Landings of Hilsa ilisha from 1967 to 1974 of the Padma River at Goalundo, with rainfall and mean air temperature of Faridpur from 1962 to 1974.

Year	Landings (mt)	Rain (mm)	Mean Air Temp. (°C)
1961	-	1892	24.73
1962	-	1615	24.72
1963	-	1676	23.33
1964	-	2045	22.22
1965	-	2007	25.28
1966	-	1519	25.28
1967	2875	1246	25.00
1968	2323	1762	24.72
1969	9409	1526	25.00
1970	6089	2220	25.28
1971	-	1365	24.17
1972	921	1706	24.72
1973	12014	2918	25.28
1974	2435	2920	23.89

TABLE 8. Annual landings of Hilsa and rainfall at Chandpur during the period 1933-1940.

Year	Landings (mt)	Rainfall (mm)
1933	-	2142
1934	-	2073
1935	-	1494
1936	-	2224
1937	(456.78)	1736
1938	298.55	1907
1939	975.97	2204
1940	826.02	1791

Monthly Climatic Data for the World and 25 Years of Pakistan in Statistics. Landings of Hilsa of the Indus, rainfall and mean air temperature are shown in Table 9. These data are believed to be reliable.

5.2 Results

5.2.1 Relationship of landings to rainfall in the Padma River of the Ganges at Goalundo in Bangladesh

I calculated a simple linear regression of the landings of Goalundo with rainfall over different lag periods of from 1 to 6 years (Table 10) for the years 1967-1974 using MISP (Hilborn 1980). A two year lag in rainfall is significant ($p<0.05$) with negative slope, and variability of rainfall accounted for 57.6% of the variation in landings at Goalundo (Fig. 12). The only other regression verging on significance was a positive regression for the 5-year lag ($p=0.0812$).

An interesting record which indirectly supports a negative relationship between Hilsa catch and rainfall two years earlier is the record of packing ice use. Before the Bengal was partitioned into East and West there was unrestricted trade between the two Bengals. Further, in view of the high demand for fish in the cities of Calcutta and Howrah and their suburbs, most of the Hilsa catches were preserved in ice and dispatched to West Bengal. The quantity of ice required to pack a unit weight of fish varies from season to season. In summer more ice is used than in winter. On an average it is observed that a bundle of

TABLE 9. Catch of *Hilsa ilisha* from 1968 to 1982 of the Indus River, rainfall and mean air temperature of Hyderabad from 1962 to 1982.

Year	Catch (in mt)	Rainfall (in mm)	Mean Air Temp. (°C)
1962	-	394	27.46
1963	-	65	28.13
1964	-	387	27.11
1965	-	-	-
1966	-	79	28.38
1967	-	348	27.23
1968	2,500	22	27.43
1969	2,900	17	28.19
1970	12,700	271	27.92
1971	11,100	56	28.05
1972	10,828	27	27.65
1973	11,795	49	27.75
1974	9,098	22	27.75
1975	9,474	145	27.55
1976	9,545	335	27.50
1977	9,129	268	28.40
1978	4,813	416	27.55
1979	9,036	153	27.80
1980	4,427	119	28.20
1981	3,923	117	28.10
1982	6,032	54	27.65

TABLE 10. Regressions of Hilsa landings from 1967 to 1974 of the Padma River at Goalundo, with rainfall for different lag periods.

Lag Period (Year)	F	Total DF	Probability	r^2	Slope	Intercept
0	0.63	6	.5358	.1134	2.11	839.42
1	0.00	6	.9897	.0000	- 0.02	5201.40
2	6.77	6	.0474*	.5755	- 9.15	20612.13
3	0.32	6	.5947	.0616	2.73	498.53
4	0.88	6	.6080	.1507	- 5.94	15977.29
5	4.69	6	.0812	.4845	10.47	-12622.89
6	0.48	6	.5292	.1075	- 5.49	14562.13

FIGURE 12. Relationship of *Hilsa* landings of the Padma River at Goalundo with two-year lag in rainfall.

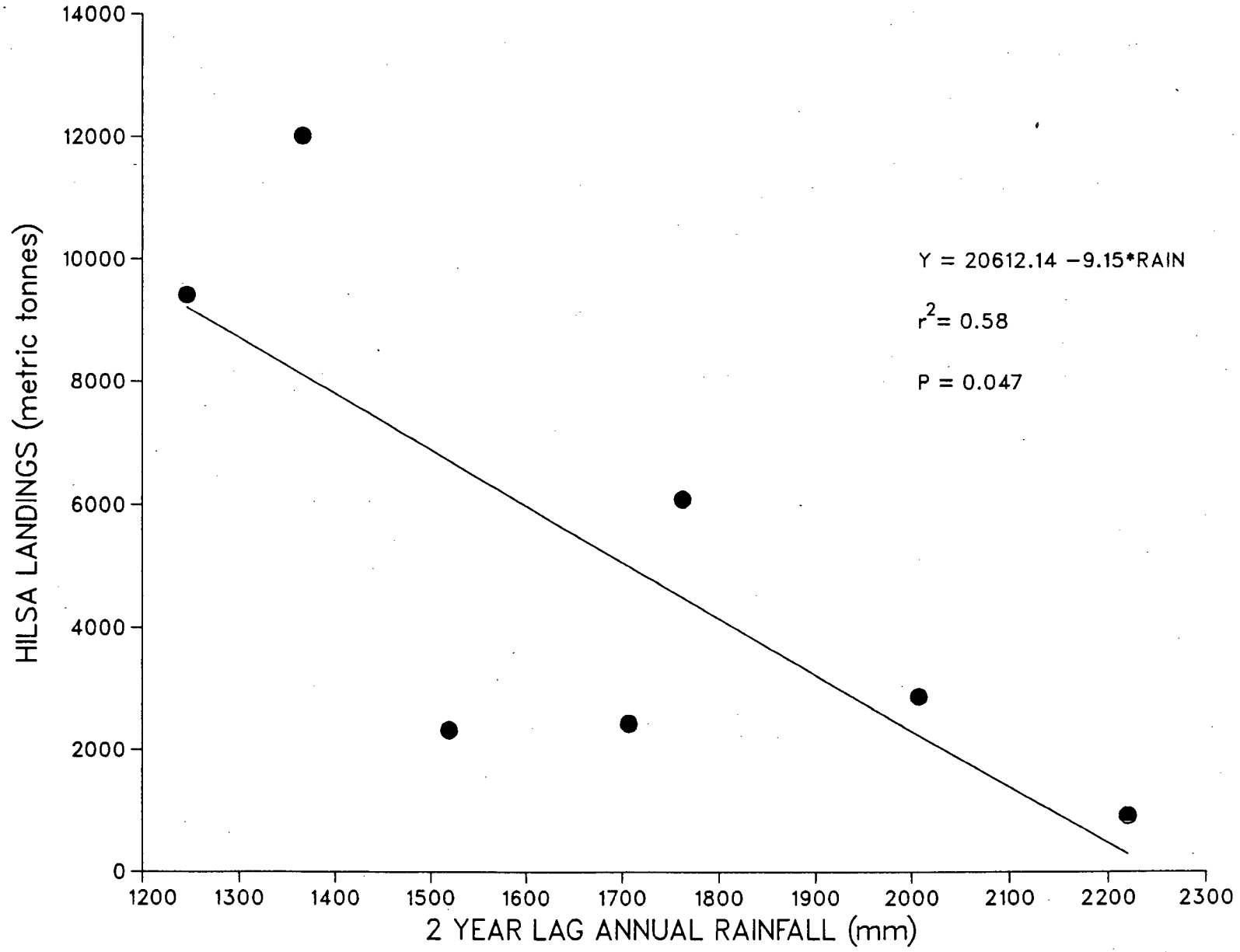

14000
12000
10000
8000
6000
4000
2000
0
HILSA LANDINGS (metric tonnes)
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2 YEAR LAG ANNUAL RAINFALL (mm)
Y = 20612.14 −9.15*RAIN
r2= 0.58
P = 0.047

TABLE 11. Rainfall of Faridpur during the period 1930-40.

Year	Rainfall (mm)
1930	1954
1931	2179
1932	-
1933	1987
1934	1813
1935	1415
1936	1977
1937	1691
1938	2148
1939	2225
1940	1507

TABLE 12. Output of ice (* bundles) in Rajbari (near Goalundo) Ice Factory (after Nayudu, 1939).

Month/Year	1935	1936	1937	1938
January	1,933	748	1,191	-
February	3,130	3,277	3,313	-
March	2,130	4,251	3,714	-
April	2,229	2,028	4,235	3,020
May	2,164	3,297	9,469	8,970
June	5,347	3,208	5,989	9,496
July	4,923	2,739	2,555	5,569
August	3,988	2,710	3,111	2,915
September	3,255	2,928	4,015	2,957
October	1,530	2,934	3,255	1,704
November	1,859	2,250	1,683	-
December	1,879	1,852	4,014	-
Total	**34,367**	**32,222**	**46,544**	

*The above figures are in bundles of ice, each containing 1 1/2 mounds approximately (one mound = 82.28 lbs.)

1.5 mounds of ice is used to pack about 2.5 mounds of Hilsa. Even without converting the output of ice in terms of Hilsa weight, the figures should give a rough index of the trend in the Hilsa fishery in the Goalundo area of the Ganges. In 1935 the rainfall was very low, 1415 mm, (Table 11), while in 1937 (Table 12), the production of ice bundles were the maximum (46,544 bundles, Nayudu 1939), which also suggests that landings of Hilsa in the Padma river at Goalundo has a negative relationship with 2-year lag in rainfall.

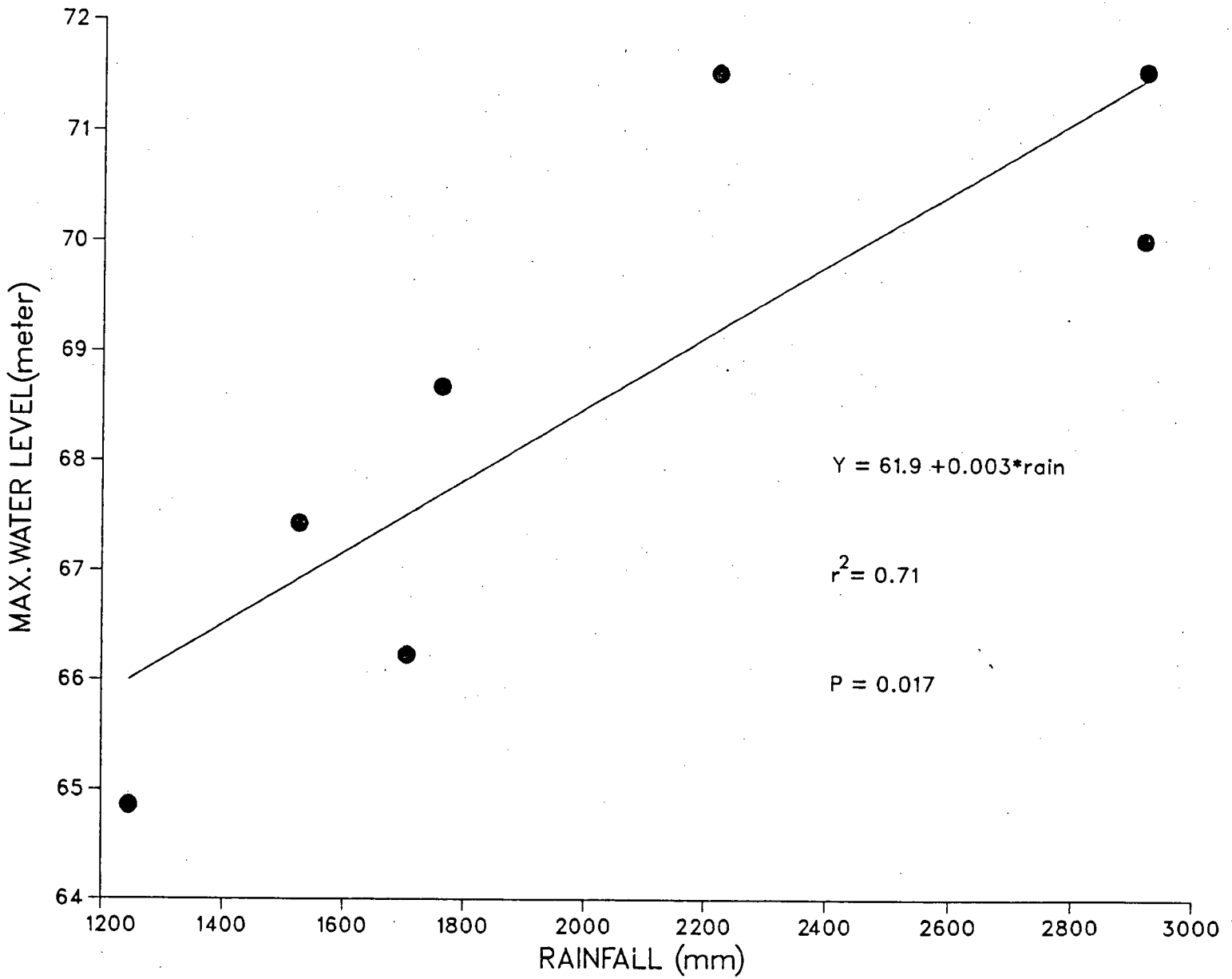
5.2.2 Relationship of rainfall to maximum water level in the Padma River of the Ganges at Goalundo in Bangladesh

In order to find to what extent water level is controlled by local rainfall, I calculated a simple linear regression of the rainfall of Faridpur (near Goalundo) with maximum water level of the Padma River at Goalundo for 1967 to 1974. The regression is significant ($p<.02$) with positive slope; and variability in rainfall accounted for 71% of the variation in maximum water level (Fig. 13).

5.2.3 Relationship of landings to rainfall in the Meghna River at Chandpur in Bangladesh

Trans-shipment data of Hilsa at Chandpur of the Meghna River for the period of 1937-1940 suggests that landings have a negative relationship with 2-year lag in rainfall (Table 8). In 1936 there was a heavy rainfall (2224 mm) which was followed by a very low landings in 1938 (298.55 mt) at Chandpur; in 1937

FIGURE 13. Relationship of rainfall to maximum water level in the Padma River of the Ganges at Goalundo.


MAX.WATER LEVEL(meter)
72
71
70
69
68
67
66
65
64
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
RAINFALL (mm)
Y = 61.9 +0.003*rain
r2= 0.71
P = 0.017

there was a low rainfall (1736 mm) followed in 1939 by a bumper Hilsa landings (975.97 mt).

5.2.4 Relationship of landings to rainfall in the Indus River of Pakistan

From Indus river of Pakistan I also calculated simple linear regression of Hilsa landings with rainfall over different lag periods (Table 13) for the years 1968 to 1982. From these analyses I again found that landings with 2-year lag in rainfall was significant ($p<0.05$) with negative slope and variability of rainfall accounted for 28.7% of the variation in landings at Indus River (Fig. 14). One other regresssion was significant ($p<0.05$) - a 4-year lag, with negative slope.

5.2.5 Correlations between the Ganges and the Indus Hilsa landings with a two-year lag in rainfall

A question comes to the mind whether catch fluctuations are correlated in the Ganges and in the Indus River. Comparable data are available for only the years 1968, 1969, 1970, 1972, 1973 and 1974. Catch and rainfall, given previously for different localities, are summarized in simplified form in Table 14.

In general annual rainfall followed the same trends in the two regions (except in 1969, when rainfall 2-years earlier had been low in the Ganges and very high in the Indus). Landings, on the other hand, did not: trends were opposite in three years (1969, 1972, and 1974) and were the same in the other three years. In 1969 when rainfall 2-years earlier had been

TABLE 13. Regressions of Hilsa landings from 1968 to 1982 of the Indus River, with rainfall for different lag periods.

Lag Period (Year)	F	Total DF	Probability	r^2	Slope	Intercept
0	0.20	14	.6606	.0156	3.32	7360.26
1	0.65	14	.5625	.0480	- 5.47	8683.66
2	5.23	14	.0377*	.2869	-13.27	9878.62
3	0.31	13	.5923	.0253	- 3.56	8761.91
4	5.02	13	.0428*	.2950	-11.34	10151.16
5	1.43	13	.2535	.1066	- 7.53	8597.42
6	0.24	13	.6333	.0220	3.16	7083.90

FIGURE 14. Relationship of *Hilsa* landings with two-year lag in rainfall in the Indus River.

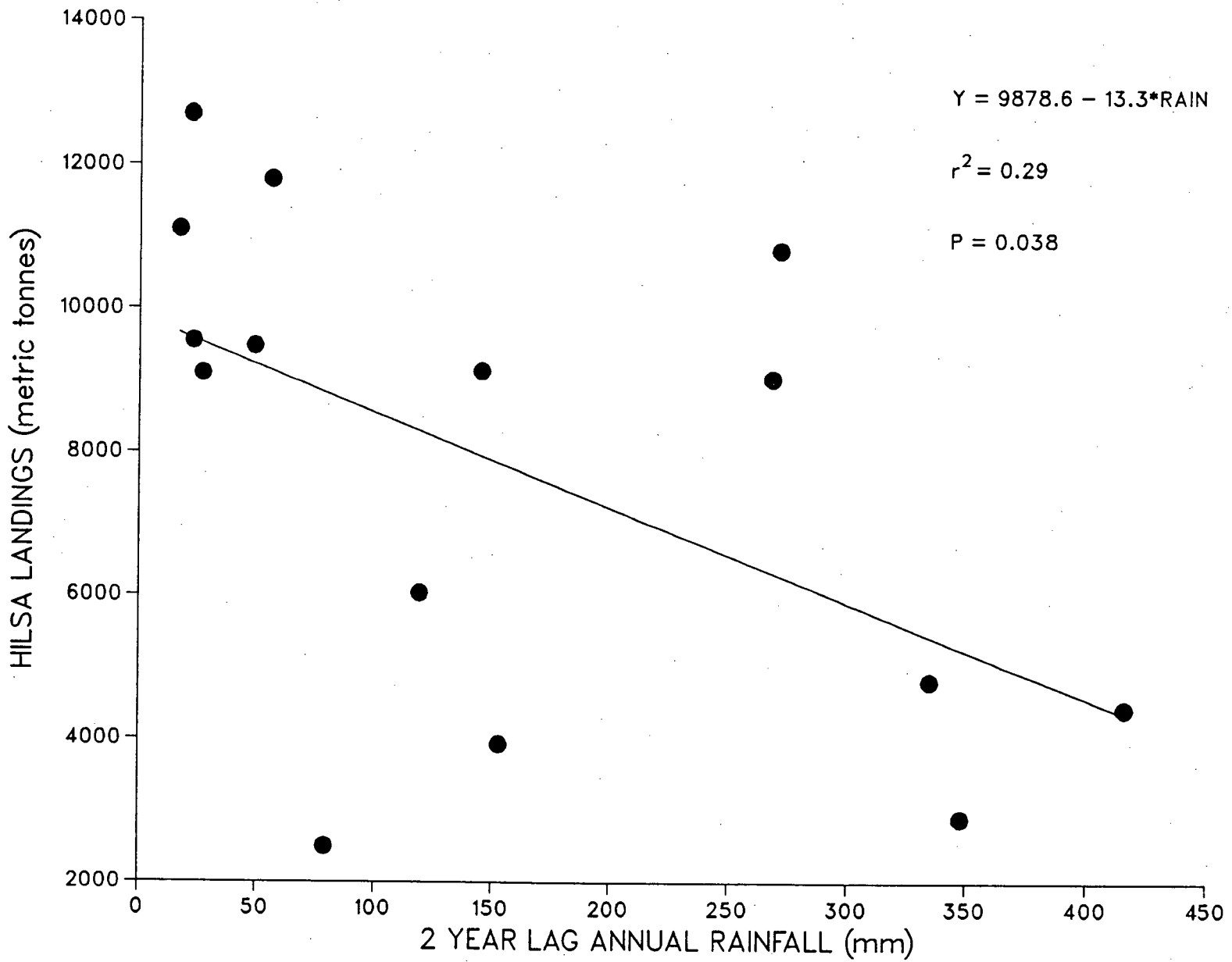

Y = 9878.6 – 13.3*RAIN
r2 = 0.29
P = 0.038
HILSA LANDINGS (metric tonnes)
14000
12000
10000
8000
6000
4000
2000
0
50
100
150
200
250
300
350
400
450
2 YEAR LAG ANNUAL RAINFALL (mm)

TABLE 14. Summary of landings of Hilsa, and of rainfall two years previously in the Ganges and in the Indus River.

River	1968	1969	1970	1972	1973	1974
Landings						
Ganges	very low	very high	high	very low	very high	very low
Indus	very low	very low	very high	very high	very high	very high
Rainfall						
Ganges	low	low	low	very high	very low	low
Indus	low	very high	very low	very high	very low	very low

different in the two regions, landins were also different in the two regions.

Evidently annual variations of landings of Hilsa in the Ganges and in the Indus are not synchronous; they seem to be associated with environmental events which may vary independently in the two regions.

5.2.6 Relationship of landings to mean air temperature in the Padma River of the Ganges at Goalundo in Bangladesh

I calculated a simple linear regression of the landing of Goalundo with mean air temperature (using data in Table 7) over different lag periods from 1 to 6 years (Table 15) for the years 1967 to 1974. Regression on mean air temperature 2-years earlier is significant ($p=0.05$) with negative slope; and variability of mean air temperature accounted for 56.2% of the variation in landings at Goalundo (Fig. 15).

A multiple regression of landings with rainfall and temperature was calculated with a 2-year lag period. The regression was not significant ($p=0.15$), and variability of rainfall combined with temperature accounted for less of the variation (42%) than did rainfall alone.

5.2.7 Relationship of landings to mean air temperature in the Indus River of Pakistan

I calculated a simple linear regression of the landings of Indus River with mean air temperature over different lag periods from 1968 to 1982 (Table 16). There was no lag period

TABLE 15. Regressions of Hilsa landings from 1967 to 1974 of the Padma River of the Ganges at Goalundo with mean air temprature for different lag periods.

Lag Period	F	Probability	r^2	Slope
0	2.80	.1533	.3596	5239.67
1	0.05	.8197	.0105	-1105.73
2	6.42	*.0515	.5623	-7527.59
3	0.88	.6077	.1505	1443.43
4	1.26	.3117	.2024	1562.61
5	0.45	.5334	.0836	-1075.92
6	0.55	.5072	.1004	-1203.42

FIGURE 15. Relationship of Hilsa landings of the Padma River at Goalundo with two-year lag in mean air temperature of Faridpur (near Goalundo).

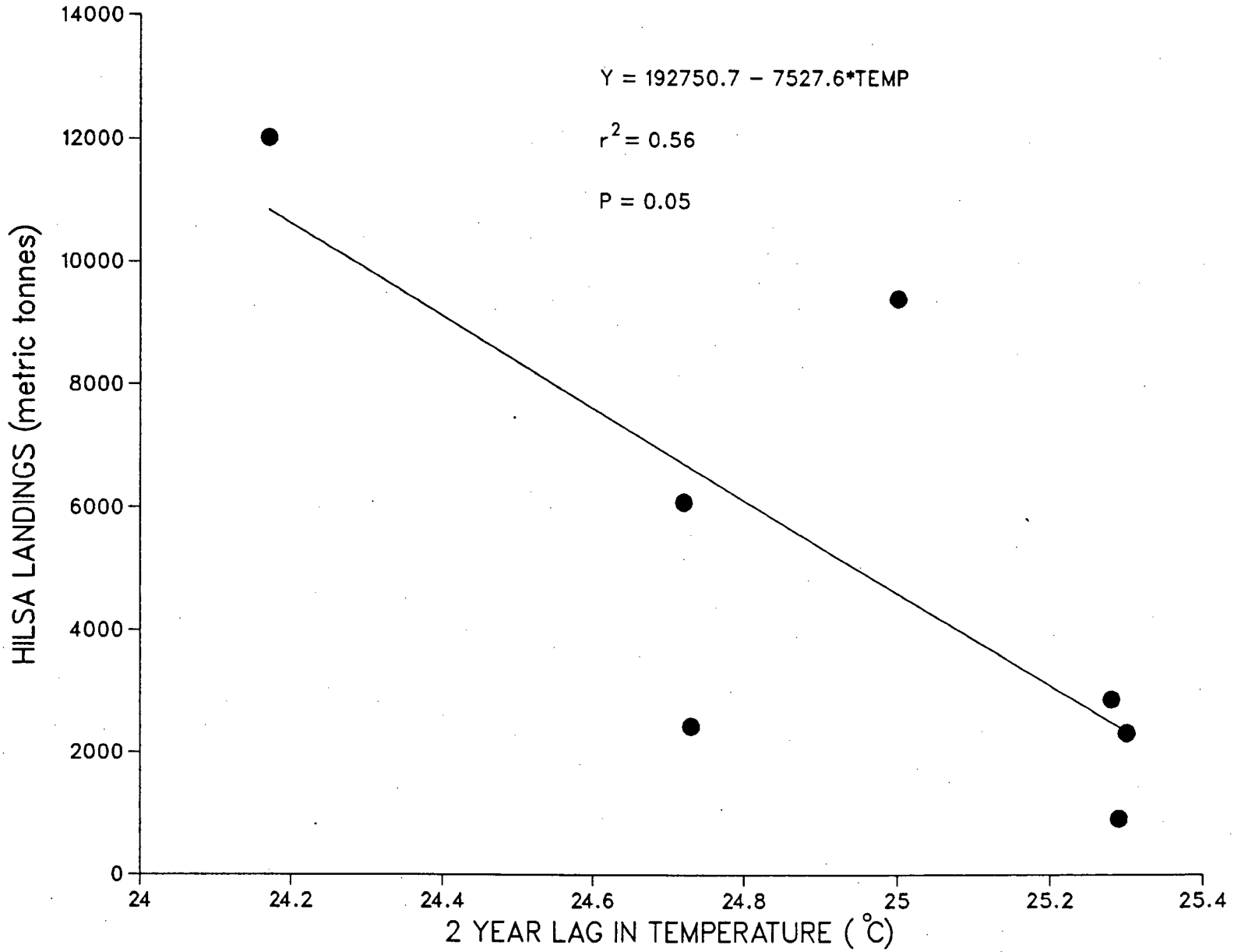

Y = 192750.7 − 7527.6*TEMP
r2 = 0.56
P = 0.05
HILSA LANDINGS (metric tonnes)
14000
12000
10000
8000
6000
4000
2000
0
24
24.2
24.4
24.6
24.8
25
25.2
25.4
2 YEAR LAG IN TEMPERATURE (°C)

TABLE 16. Regressions of Hilsa catch from 1968 to 1982 of the Indus River of Pakistan with mean air temperature for different lag periods.

Lag Period	F	Probability	r^2	Slope
0	0.05	0.81	0.00	-743.41
1	0.24	0.64	0.02	1381.35
2	0.12	0.73	0.00	911.55
3	2.36	0.15	0.16	-3641.89
4	0.95	0.65	0.07	2199.00
5	0.21	0.65	0.02	1053.96
6	0.06	0.80	0.01	-649.96

of air temperature which gave a significant regression. The 2-year lag period of air temperature, which had given a significant negative slope for the Goalundo data in the preceding section, was now significant but with a positive slope for the Indus River data. Multiple regression of landings with rainfall and temperature also was non-significant.

5.3 Discussion

Changes in environmental conditions may influence the spawning success of the Hilsa fishery from year to year. Dunn (1982) suggested that there was a correlation between landings and rainfall with a 5-year lag, and that this supported the contention that Hilsa first recruit to the fishery when they are 5 years old. Some errors are however, present in the data he used. After calculation of the modified data, as shown here no significant correlation was found between landings with 5-year lag in rainfall, and the hypothesis of Dunn (1982) is not supported by my analysis. Hora (1940), and Hora and Nair (1940), also postulated a five- year cycle in Hilsa landings, but his evidence was rather circumstantial.

Day (1873) suggested that Hilsa may attain first maturity at the end of the first year, or at the beginning of second year. Day's (1873) hypothesis was supported by Jones and Menon (1951) based on their observations in the Hooghly River, Mahamadi River, and Chilka Lake. Jones and Menon (1951) reported that males become mature when they are 21.6-25.4 cm in length and 1^+ in age. Females become mature in the second year when they are 26.7-30.5 cm long (Jones and Menon 1951).

Also, Pillay (1958) observed 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 Hilsa are both about 1 1/2 years old. De (1980) suggested that female Hilsa attained first maturity when they are at a size of 34.1 cm in the upper stretches of the Hooghly River. Raja (1984) reported female Hilsa attains first maturity at the size of 32 cm. As can be seen from the above, there is disagreement among researchers as to size at first maturity of Hilsa. This may be due in part to the lack of uniformity in the length measurement used (total, fork or standard length), and or ecological differences between different rivers studied. Although there is even less agreement on age at first maturity, the weight of observations suggest that Hilsa first recruit to the fishery well before 5 years of age, a view supported by the current research of M. Hossain (pers. comm.).

From my analysis I suggest that abundance of adult Hilsa has a moderately strong negative correlation with rainfall two years previously. Mechanisms regulating this negative significant association between rainfall and landings (both in the Padma River and the Indus River) may be that Hilsa are 1^+ year old when they are first recruited to the fishery and the survival of the spawn and fry are optimum when there is a very low rainfall of that year. On the other hand, heavy rainfall may wash out eggs and larvae and consequently after 2 years the catch is comparatively low. In Bangladesh waters, rainfall has been shown here to be positively correlated with water level (in Padma River at Goalundo, $p=.05$). My hypothesis is consistent with that of Wickett (1958) and Vernon (1958) who showed that the survival of spawn

and fry of pink and chum salmon is much less in years of severe floods.

In the Indus River there was a significant negative regression of Hilsa landings with rainfall not only 2-years earlier but also 4-years earlier (Table 13). No such trend regarding the 4-year lag was evident in the Ganges (Table 15), where that regression was non-significant. A possible explanation is that extreme environmental conditions in one year may affect strength of a year-class so sharply as to be reflected 4 years later even in the return of the offspring of that year class. Such a 4 year regularity would be quickly dampened. There is no convincing evidence of a sustained "cycle" in any of the available data series on Hilsa landings.

Although the negative correlations between landings and rainfall 2-years earlier are statistically significant (in each of two widely separated river systems), there is still a large residual variation in landings unaccounted for by rainfall. Considering the nature of the data and the possible complexity of the Hilsa life history, this residual variation is not surprising for several reasons.

Firstly, rainfall has been used as an index of river discharge, and while the two were shown to be significantly correlated at Goalundo, they are not tightly coupled. Only local rainfall was recorded, while river discharge may also be affected by weather conditions or snow melt farther upstream.

Secondly, environmental factors other than river discharge are likely also to affect early survival. Some evidence of a negative correlation has been found between landings and temperature two years

earlier, but as this occurred only in data for the Ganges and not for the Indus, its implications are conjectural.

Thirdly, although most fish may return two years after hatching, the commmercial landings probably include a mixture of more than one age, and possibly of more than one race with somewhat differernt life history patterns. Further, it is not known whether some Hilsa may survive spawning and return in subsequent years.

For these and other reasons the dependency between landings and earlier rainfall cannot be expected to offer more than a rough means to forecast annual harvest. Nevertheless, even this possibility has not been detected until now.

The other principal new observation regarding annual changes in Hilsa catch is that annual variations in landings are not necessarily synchronous in the Ganges and in the Indus Rivers. They seem to be associated with environmental events which may vary independently in the regions. Hilsa from the two river systems if they are anadromous presumably spend their sea-life in two separate marine areas (Bay of Bengal and the Arabian Sea). However, the negative association beween landings and rainfall two years earlier suggest that it is events during the freshwater phases, rather than oceanographic conditions, which are dominant in determining year-class strength. On the other hand, the failure in the first section of this study to detect any clear relationship between short term seasonal changes in riverine landings and local environmental conditions suggest that the details of timing of entry of fish into river mouths may be controlled by events in the estuaries or the oceans.

6. CONCLUSIONS

(1) Monthly variations in fishing effort at Chandpur on River Meghna in Bangladesh, and annual variations in fishing effort in Godavari in India, were not significantly correlated with Hilsa landings in either place. Variation in landings probably depend principally on changes in abundance of Hilsa rather than on changes in effort.

(2) Seasonal changes in recorded rail shipments from Chandpur showed a close positive correlation with observed landings of riverine Hilsa, and can therefore be used as an indicator of landings in years for which no direct observations are available.

(3) Historical events which may affect interpretation of rail shipment records include the influx of marine-caught Hilsa into riverine landing sites with the advent of mechanized vessels, the shift from rail to road transportation of Hilsa between landing sites and consumer centres, construction of Farakka Barrage which diverted water from Bangladesh to Indian waters, and the disruption of fishing in Bangladesh during liberation in 1971.

(4) Seasonal timing and intensity of Hilsa runs in the Ganges varied markedly from year to year, and bore no evident association with seasonal timing of rainfall, mean water level, minimum discharge or temperature. The only seasonal regularity was that in all years few fish were taken in winter months (November to January).

(5) Annual variations in Hilsa landings showed a significant negative correlation with local rainfall 2 years previously. This was true both in the Ganges River in Bangladesh and in the Indus River in Pakistan.

(6) The mechanism regulating the negative association between landings and rainfall 2 years earlier may be that heavy rainfall may wash away eggs and larvae, and that Hilsa are 1^+ years old when they are recruited to the fishery.

(7) Annual landings sometimes vary in opposite directions in the Ganges and the Indus Rivers. In each region annual landings are dependent in part on rainfall 2-years earlier in that region. This dependency offers a means of rough forecast of annual harvest on the basis of previous rainfall data.

LITERATURE CITED

Abbas, B.M. 1982. The Ganges Waters Dispute. Vikas Publishing House Pvt. Ltd. New Delhi. 157pp.

Ahmed, M. 1952. Hilsa fisheries in Sind. Agri. Pak. 3:54-57.

Ahmed, N. 1954. Hilsa fishery of East Bengal. J. Asiat. Soc. Sci. 20:7-14.

Ahmed, N. 1962. Fishing Gears of East Pakistan. Directorate of Fisheries. Govt. of East Pakistan. pp 1-35.

Ahmed, Q.J. 1960. A preliminary note on the Hilsa fisheries of East Pakistan. Agri. Pak. 11:165-172.

Anon. 1967-1976. Bangladesh Railways Transhipment Data of Hilsa ilisha. Railway Offices at Chandpur and Goalundo, Bangladesh.

Anon. 1968-1982. Yearbook of Fishery Statistics Catches and Landings. FAO.

Anon. 1961-1974. Rainfall and Maximum Air Temperature of Bangladesh. Bangladesh Meteorology Department. Dhaka, Bangladesh.

Anon. 1962-1982. Monthly Climatic Data for the World. U.S. Department of Commerce. National Oceanographic and Atmospheric Administration. Sponsored by the World Meteorological Organization.

Anon. 1967-1974. Discharge and water level of Bangladesh. Bangladesh Water Development Board, Hydrology Directorate, Dhaka, Bangladesh.

Anon. 1972. Twenty-five Years of Pakistan in Statistics 1947-1972. Federal Bureau of Statistics, Statistics Division, Govt. of Pakistan.

Anon. 1984a. Gearwise monthly catch/day of Hilsa (kg) in the river stretch from Chandpur to Nilkamal of the Meghna River. Bangladesh Fisheries Resource Survey System, Dhaka, Bangladesh.

Anon. 1984b. Report on first meeting of the working group on Hilsa fishery resources in the Upper Bay of Bengal. Dhaka, Bangladesh. Prepared for FAO/UNDP Bay of Bengal Programme.

Banerji, S.R. 1955. On occurrence of Hilsa ilisha and its fishery in Gorakpur. Sci. and Cult. 21:217-218.

Bhanot, K.K. 1973. Observations on the spawning of Hilsa ilisha (Hamilton) in the Hooghly estuary. J. Inland Fish. Soc. India 5:50-54.

Bilgrami, K.S. and J.S. Datta Munshi. 1982. Limnological survey and impact of human activities on the river Ganges (Barauni to Farakka Range). Technical report. Man and the Biosphere programme project. UNESCO. 5.

Chacko, P.I. and S.V. Ganapati. 1949. On the bionomics of Hilsa ilisha (Hamilton) in the Godavari River. J. Madras Univ. 18:16-22.

Day, F. 1873. Report on the freshwater fish and fisheries of India and Burma, Calcutta. pp 22-23, 35-36.

De, D.K. 1980. Maturity, fecundity and spawning of post-monsoon run of hilsa, Hilsa ilisha (Hamilton) in the upper stretches of the Hooghly estuary system. J. Inland Fish. Soc. India 12:54-63.

de Vlaming, V.L. 1972. Environmental control of teleost reproductive cycles: a brief review. J. Fish. Biol. 4:131-140.

Devanesen, D.W. 1942. Weirs in south India and their effect on the bionomics of the hilsa in the south Indian rivers - The Godavari, the Krishna and the Cauvery. Curr. Sci. 11:398.

Druzhinin, A.D. 1970. Report to the Govt. of Burma on some aspects of Burmese fisheries. 2781/E. FAO, Rome.

Dunn, I.G. 1982. The Hilsa fishery of Bangladesh, 1982: An investigation of its present status with an evaluation of current data. A report prepared for the Fisheries Advisory Service; Planning, Processing and Appraisal Project. FAO, Rome. Fl: DP/BGD/81/034 Field Document 2.

Dutta, P., G.C. Laha, P.M. Mitra, D.K. De, A. Chaudhury, P.K. Pandit, A.R. Chaudhury, R.N. De, B.K. Saha, H.S. Majumder, N.D. Sankar, N.C. Mondal, G.P. Bhattacharya, A.K. Namasudra, S.P. Ghosh and A.R. Paul. 1973. Fishery resources of the Hooghly-Matlah estuarine system. Bull. Cent. Inl. Fish. Res. Inst. No. 19. 24p.

Ganapati, S.V. 1973. Ecological problems of man-made lakes of south India. Archiv. fur Hydrobiologie 71:363-380.

Ghosh, K.K. 1976. Inland fishery resources of India, their estimation and utilisation. CIFRI, Barrackpore, India.

Ghosh, A.N. and T.D. Nangpal. 1970. On the winter breeding of Hilsa ilisha (Ham.). Proc. Indo-Pacif. Fish Coun. 13:132-142.

Hilborn, Ray. 1980. Microcomputer interactive statistics and plotting (MISP), University of British Columbia, Vancouver, B.C., 57 pp.

Hora, S.L. 1938. A preliminary note on the spawning grounds and bionomics of the so-called Indian shad, Hilsa ilisha (Ham.) in the River Ganges. Rec. Indian Mus. 40:147-148.

Hora, S.L. 1940. Life-history and wanderings of Hilsa in Bengal waters. J. Asiatic Soc. Beng. Sci. 6:93-112.

Hora, S.L. 1942. Effects of dams on the migration of Hilsa. Curr. Sci., Bangalore 11:470-471.

Hora, S.L. and K.K. Nair. 1940. Further observations on the bionomics and fishery of the Indian Shad, Hilsa ilisha (Ham.) in Bengal waters. Rec. Indian Mus. 42:35-50.

Hornell, J. 1950. Fishing In Many Waters. Cambridge University Press, London. 207 pp.

Hossain, Z. and S.M.K. Sufi. 1962. Biological and economic effects of barrages on Hilsa ilisha (Ham.) and its fisheries in the Indus. Agri. Pak. 13:346-359.

Islam, B.N. and G.B. Talbot. 1968. Fluvial migration, spawning and fecundity of Indus River Hilsa, Hilsa ilisha. Trans. Amer. Fish. Soc. 97:350-355.

Jones, S. 1957. On the late winter and early spring migration of the Indian shad, Hilsa ilisha (Hamilton), in the Gangetic delta. Indian J. Fish. 4:304-14.

Jones, S. 1959. Fishing methods for the Indian Shad, Hilsa ilisha (Ham.) in the Indian region. Part I. J. Bombay Nat. Hist. Soc. 56:250-275.

Jones, S. and K.H. Sujansingani. 1951. The Hilsa fishery of the Chilka Lake. J. Bombay Nat. Hist. Soc. 50:264-280.

Jones, M S. and P.M.G. Menon. 1951. Observations on the life-history of the Indian Shad, Hilsa ilisha (Hamilton). Proc. Indian Acad. Sci. 31:101-125.

Karamchandani, S.J. 1961. On the location of spawning grounds of Indian shad, Hilsa ilisha (Hamilton) in freshwater regions of the Narbada River. Curr. Sci. 30:373-375.

Kulkarni, C.V. 1950. Breeding habits, eggs and early life history of Indian shad, Hilsa ilisha (Ham.) in the Narbada River. Proc. Nat. Inst. Sci. India 15:169-176.

Kyaw Ba. 1953. Information on Hilsa Fishery of the Mergui District. Union of Burma. I.P.F.C. Communication.

Leggett, W.C. 1977. The ecology of fish migrations. Annu. Rev. Ecol. Syst. 8:285-308.

Mathur, P.K. 1964. Maturity and fecundity of Hilsa ilisha. Indian J. Fish 11:423-449.

Melvin, G.D. 1984. Investigation of the Hilsa fishery of Bangladesh, 1983. A report prepared for the Fisheries Advisory Service, Phase II. Project. FAO, Rome. F1:DB/BGD/81/034 Field Document 5.

Mitra, P.M. and K.K. Ghosh. 1979. Seasonal patterns in the fish landings from the Hooghly-Matlah estuarine system. J. Inland Fish. Soc. India 11:49-55.

Motwani, M.P., V.G. Jhingran, and S.J. Karamchandani. 1957. On the breeding of the Indian shad, Hilsa ilisha (Hamilton) in freshwaters. Sci. and Cult. 23:47-48.

Nair, K.K. 1954. Dams and Hilsa fisheries. J. Asiatic Soc. Beng. Sci. 20:77-79.

Nair, P.V. 1958. Seasonal changes in the gonads of Hilsa ilisha (Hamilton). Phillipp. J. Sci. 87:255-276.

Nayudu, M.R. 1939. Report on a survey of the fisheries of Bengal. Government Press, Calcutta.

Northcote, T.G. 1984. Mechanisms of fish migration in rivers. pp. 317-355. In J.D. McCleave, G.P. Arnold, J.J. Dodson, and

W.H. Neill (ed.). Mechnisms of Migration in Fishes. Plenum Press, New York.

Pillay, S.R. 1963. MS. Maturation and Spawning of the Hilsa, Hilsa ilisha (Hamilton) of the Saurashtra Coast.

Pillay, S.R. and H. Rosa Jr. 1963. Synopsis of biological data on Hilsa, Hilsa ilisha (Hamilton) 1882. FAO Fish Biol Synopsis 25:1:1-6:8.

Pillay, S.R. and K.V. Rao. 1962. Observation on the biology and fishery of Hilsa ilisha (Ham.) of river Godavari. Proc. Indo-Pacif. Fish. Coun. 10:37-61.

Pillay, S.R. K.V. Rao, and P.K. Mathur. 1962. Preliminary report on the tagging of hilsa, Hilsa ilisha (Ham.). Proc. Indo-Pacif. Fish. Coun. 10:28-39.

Pillay, T.V.R. 1952. A preliminary biometric study of certain populations of hilsa, Hilsa ilisha (Ham.). Proc. Indo-Pacif. Fish. Coun. 4:181-194.

Pillay, T.V.R. 1954. Morphological and serological characters of the hilsa, Hilsa ilisha (Ham.) with special reference to racial investigation. J. Asiatic Soc. Sci. 20:69-74.

Pillay, T.V.R. 1955. The biology and fisheries of the hilsa, Hilsa ilisha (Hamilton). A Review. Proc. Indo-Pacif. Fish. Coun. 2:211-219.

Pillay, T.V.R. 1957a. A morphometric study of the population of hilsa, Hilsa ilisha (Hamilton) of the River Hooghly and of the Chilka Lake. Indian J. Fish. 4:344-386.

Pillay, T.V.R. 1957b. On the abundance of the hilsa, Hilsa ilisha (Hamilton) in the Hooghly and Padma Rivers during 1955. Indian J. Fish. 4:150-159.

Pillay, T.V.R. 1958. Biology of the hilsa, Hilsa ilisha (Hamilton) of the River Hooghly. Indian J. Fish. 5:201-257.

Pillay, T.V.R. and A.N. Ghosh. 1958. A note on the hilsa fisheries of Assam. J. Bombay Nat. Hist. Soc. 55:174-177.

Quddus, M.M.A., Makoto Shimizu and Yukio Nose. 1984a. Spawning and fecundity of two types of Hilsa ilisha in Bangladesh waters. Bull. Jap. Soc. Fish. 50:177-182.

Quddus, M.M.A., Makoto Shimizu and Yukio Nose. 1984b. Meristic and morphometric differences between two types of Hilsa ilisha in Bangladesh waters. Bull. Jap. Soc. Fish. 50:43-49.

Quddus, M.M.A., Makoto Shimizu and Yukio Nose. 1984c. Comparison of age and growth of two types of Hilsa ilisha in Bangladesh waters. Bull. Jap. Soc. Fish. 50:51-57.

Qureshi, M.R. 1968. Hilsa fishery of East Pakistan. Pak. J. Sci. Res. 11:95-103.

Raja, Antony. 1984. The Hilsa Fishery of the Upper Bay of Bengal. Consultancy Report (Mimeograph) prepared for Bay of Bengal Programme.

Rajyalakshmi, T. et al. 1972. MS. On the fisheries of River Godavari (Dowlaiswaram to Dummagudem grounds): A final appraisal of characteristics and trends, 1963-69.

Ramakrishnaiah, M. 1972. Biology of Hilsa ilisha (Ham.) from Chilka Lake with an account on its racial status. Indian J. Fish. 19:35-53.

Rashid, H. 1977. Geography of Bangladesh. University Press Limited, Bangladesh. 579 pp.

Southwell, T. 1914. Report on the hilsa hatching operations conducted at Monghyr, Bihar, during August, September, and October, 1912. Bull. Dep. Fish. Beng. Bihar and Orissa 4:1-5.

Southwell, T. and B. Prashad. 1918. On hilsa investigation in Bengal, Bihar and Orissa. Bull. Dep. Fish. Beng. 11:1-12.

Sundararaj, B.I. 1981. Reproductive physiology of teleost fishes. A review of present knowledge and needs for future research. FAO Aquaculture Development and Coordination Programme ADCP/REP/81/16. 82 pp.

Vernon, E.H. 1958. An examination of factors affecting the abundance of pink salmon in the Fraser River. A progress report prepared for the International Pacific Salmon Fisheries Commission. pp. 49. New Westminster, B.C., Canada.

Wickett, W.P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Bd. Canada 15:1103-1126.

APPENDIX

APPENDIX TABLE 1. Development of artifically-fertilized eggs (after Kulkarni 1950).

Time in Hours After Fertilization	Development Features
Within 1/2 hour	Blasto-disc is formed.
Within 4 1/2 hours	Segmentation of blasto-disc, forming a cap of cells covering half of the yolk.
After 8 1/2 hours	Embryonic shield visible.
After 12 hours	Embryo is distinct with head and free tail. A few myotomes visible but the optic vericle is not discernible.
After 15 hours	Contrations of the embryo begin.
After 18 hours	Hatching takes place.

APPENDIX TABLE 2. Relationship between mean air temperature (°C) of Calcutta (near Hooghly area) with mean water temperature of Hooghly River of the Ganges.

Month/Year	Air Temperature	Water Temperature
Sept. 1952	29.1	30.0
Oct. 1952	27.7	31.0
Nov. 1952	24.2	29.5
Dec. 1952	20.4	22.5
Jan. 1953	19.7	22.7
Feb. 1953	24.4	26.0
Mar. 1953	29.7	28.0
Apr. 1953	32.1	31.3
May 1953	31.9	33.0
June 1953	30.2	30.5
July 1953	29.4	31.5
Aug. 1953	29.3	30.5
Sept. 1953	29.1	31.2