INTRODUCTION

During migration of fishes many physiological and biochemical changes occur in their body, affecting almost all the organs and tissues. Muscular tissue is one which is profoundly affected, since it is called upon to greater activity during migration. Fishes such as the Salmonidae travel several hundred miles to their spawning grounds, and during their sustained migratory movement which might last several months, they are known not to feed. They draw upon their body reserves to provide energy for migration and the metabolites required for gonadal development. Histological studies of various organs and tissues of the Pacific salmon at successive stages of sexual maturation from sea to the spawning grounds by Robertson and Wexler (1960) have shown degenerative and atrophic changes in various organs and tissues. The changes in fat, carbohydrate and protein that occur during this period of activity have been investigated since 1880. In a review of these studies Drummond and Black (1960) have shown that fat and protein constitute the bulk of the fuel reserves for such activities as migration and spawning and the redistribution, interconvertion and utilization are effected at rates adequate to meet the energy demands of the organism.

Muscle tissue in general is a composite tissue composed basically of two types of fibres, the red and white,

showing differences in colour, diameter, blood supply, mitochondrial content, metabolite load, enzyme distribution etc. These two types of fibres have been shown to possess different functional properties, the red adapted for sustained activity utilizing fat as the chief fuel and the white for quick contractions using mainly glycogen as the fuel (George and Berger, 1966; Bone, 1966). Even though much information has accumulated on the biochemical changes in the muscular tissue during migration there is little information with regard to the distinctive changes in the red and white muscle fibres. In salmonids, where extensive studies have been made in relation to migration, the red and white fibres are intermingled throughout the myotome except for a lateral line strip of red muscle (Greene, 1913; Boddeke et al., 1959). It is not practicable therefore to examine the changes in the two types of fibres separately. In the migratory Indian shad, Hilsa ilisha (Ham.), on the other hand though the lateral red muscle strip is well developed as in salmonids, the other musculature consists exclusively of the white type of fibres unlike as in salmonids. The present study is an attempt to shed more light on the histological, histochemical and biochemical changes undergone by the two basic types of fibres constituting the two types of muscles during migration. In order to know whether the changes that take place in H. ilisha were related to migration, or due

to the reproductive stress, similar studies were also carried out on different stages of a closely related non-migratory marine species, Hilsa toli (Cuv. & Val.) collected from the sea, as well as a few individuals of the same species that got drifted on the highest high tide time of the year into the river.

Though a few reports have been made on the occurrence of degeneration in the messeter muscle of the migrating salmon (Greene, 1913; Robertson and Wexler, 1960) and the lateral muscle of the spent sockeye salmon (McBride et al., 1965) there is no comprehensive study on the hitological changes undergone by the muscle during migration. A study on the histological organization of the red and white muscle of H. ilisha during the different phases of migration, was therefore undertaken. Considerable degenerative changes in both muscles were noted and the characteristic changes in both are described (Chapter, 2)

The major role played by lipids as an energy source during the spawning migration of the sockeye salmon, Oncorhynchus nerka, has been shown in a series of studies by Idler and his associates (1959). Since H. ilisha also do not feed during migration, tissue energy reserves have to be mobilized to underwrite the energy demands for the migratory travel as well as for the development of gonads. A histochemical and quantitative study of fat in the red and white muscle was undertaken to evaluate the significance

of this metabolite as a source of energy in the red and white muscles during migration (Chapter, 3).

The importance of the respiratory pigment, myoglobin and the cytochrome system in the oxidative metabolism of muscle is well known. Since no information exists regarding the changes in their level during migration, the concentration of iron, which is an important constituent of the above mentioned substances was assessed in both the types of muscles (Chapter, 4).

Maintenance of ionic equilibrium is essential for the proper functioning of any system. The fishes during migration are exposed to different ionic concentrations as and when they migrate from the sea to the river and vice versa. The changes reported in the sodium and potassium contents of muscular tissue in various species of Salmonidae during their migration from sea to the spawning grounds in river by various workers (MacLeod et al., 1958; Parry, 1961; Thurston and Newman, 1962) have been inconclusive, but have shown that no direct relationship exists between the ionic concentration of the muscle and the different osmotic media which they confront during migration. Hence a study was made to understand how the sodium , potassium and calcium contents in the red and white muscles of H. ilisha are maintained during their migratory ascent (Chapter, 5 & 6).

The energy rich phosphates have been shown to be

directly related to the potassium content (Lardy, 1951; Kachmar and Boyer, 1951) and inversely related to the myoglobin, the cytochrome oxidase activity (Lawrie, 1953) and the fat content (Ono *et al.*, 1959). Studies of Chang *et al.* (1960) on the distribution of phosphorus compounds in the muscles of the sockeye salmon, showed that the total phosphates per unit weight of muscle remained more or less constant in the females during river migration, but decreased markedly in the males upon arrival at the spawning grounds. Since red and white muscles are known to have different levels of phosphates in keeping with the different metabolic adaptations, studies on the changes in the lipid and tissue phosphorus levels were made with reference to their specific concentrations in the two types of muscles (Chapter, 6).

The red and white fibres besides their other differences have been shown to possess different types of innervation. In a comparative study on cholinesterases in the body muscles of fishes, Lundin (1962) claimed that bytyryl-cholinesterase was present only in marine and brackish water fishes, and that freshwater forms lacked the ability to hydrolyze butyrylcholine. On the contrary Bokdawala (1965) in our laboratory demonstrated both the esterases in the lateral muscle of a freshwater fish, *Cirrhina mrigala*. In the light of above mentioned observations, a study on the acetyl- and butyrylcholinesterase activity of *H. ilisha*, which changes its environmental medium from sea to river

during the course of migration, was thought to be of interest. A study of these esterases was also made in two other representative fishes, one from sea and the other from freshwater. These investigations have brought to light certain interesting results with regard to the presence and localization of the two esterases (Chapter, 7).

Further studies on the changes in the cholinesterases levels during the different stages of the life cycle of both the species of Hilsa were carried out with a view to correlate the changes in their activity with factors such as growth, muscular activity, ionic changes and the transition from salt- to freshwater, which occur during migration. The effect of different concentrations of monovalent cations (Na^+ & K^+) added to the incubation media on the activity of both the esterases was also studied (Chapter, 8).

The migratory behaviour and the changes that take place in the body during migration are undoubtedly initiated by hormonal changes. A comparative study of the changes in the endocrine system of H. ilisha and H. toli was made concurrently by other workers in our laboratory. An attempt has therefore been made to correlate the changes in the muscular system with the changes in the hormonal milieu.

It may be mentioned here that some repetitions of facts and statements was unavoidable, since this thesis was prepared with a view to publish it in parts, in the form of separate papers.

CHAPTER 1

HABITS, HABITATS AND FISHERY OF HILSA ILISHA (HAM.) AND HILSA TOLI (CUV. & VAL.)

The Indian shad, Hilsa ilisha (Clupeidae family), is known to migrate from the sea to the river (River Ganges, Indus, Godavari, Kaveri, Narbada etc.) and is an important food fish of India. Previous workers held the view that there are two types of migrations of H.ilisha in the Gangetic system of rivers, one for breeding and the other for feeding (Howard, 1938; Hora, 1941). Studies of Kulkarni (1950, 1951) and Pillay (1958) have conclusively proved that its migration up the river is for the purpose of spawning only. Two distinct spawning seasons have been reported in river Hooghly (Hora and Nair, 1940 a; Pillay, 1957, 1958), one starting with the monsoon season and extending up to November and the other during winter from January to February. In South India only a single wave of migration has been observed, ie. only the monsoon run (Chacko and Ganapathi, 1949). H.ilisha abstains from feeding during migration. According to Chacko and Krishnamurthy (1950) "during this period there is a general absorption of all the tissues of the body; the scales are being affected by the formation of a ring". Based on the number of rings they concluded that H.ilisha spawns about seven to eight times during its life time. Jones and

Menon (1951) have challenged the validity of the above observation. After extensive studies Pillay (1958) came to the conclusion that the so called growth rings cannot be used for the determination of age in the case of H.ilisha. However, unlike in the salmon, no post-spawning death has been reported either by fishermen or by any research worker, in the case of H.ilisha. Hence it may be safely assumed that H.ilisha returns to sea after spawning in the rivers and that they may repeat spawning migrations many times during their life span.

Hilsa fishery in the River Narbada :-

Several workers have shown the occurrence of H.ilisha in and around the Gulf of Cambay and in River Narbada (Campbell, 1877; Moses, 1940, 1942; Pillay, 1948; Kulkarni, 1950, 1951). Kulkarni (1951) made a detailed study of their migration up the River Narbada and the following account is based on his findings.

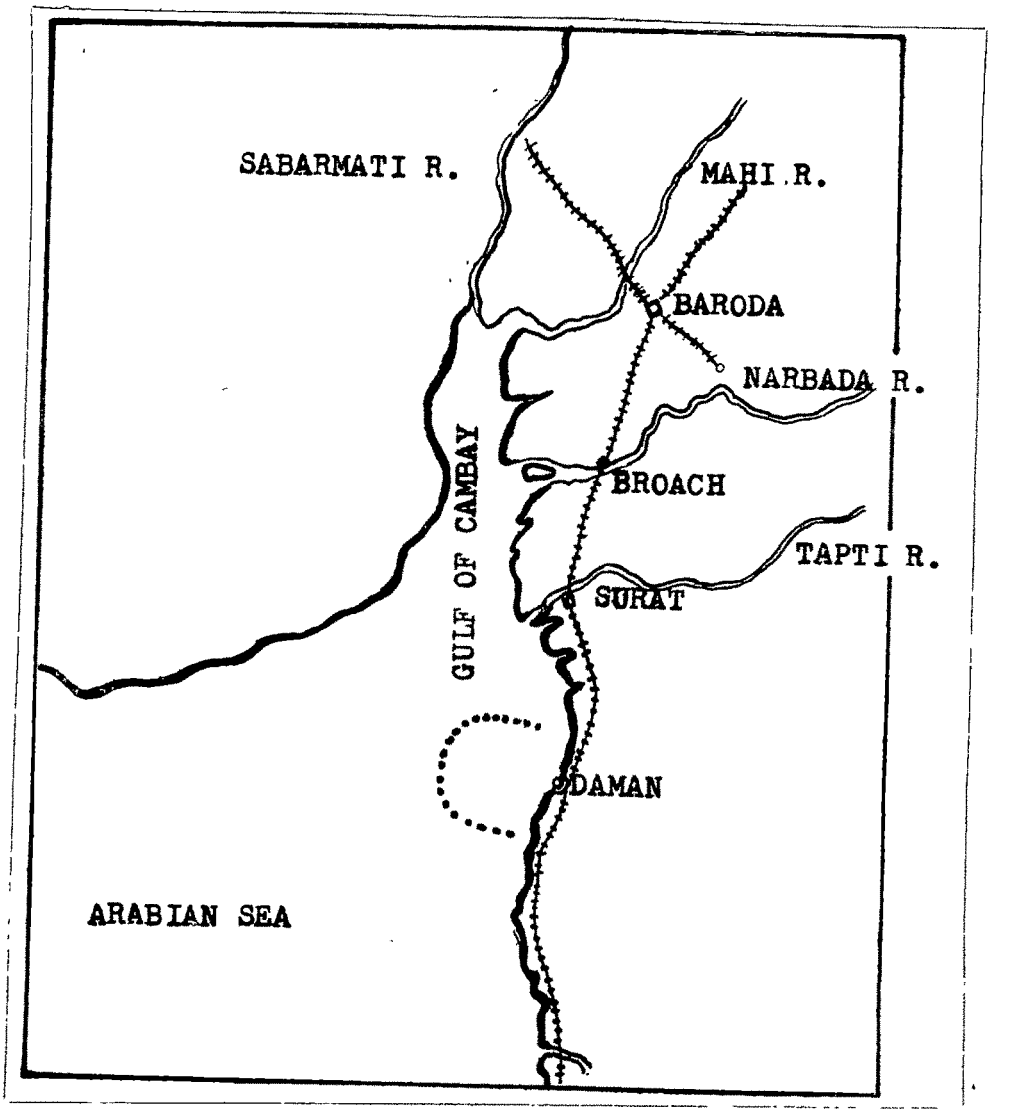
The migration of H.ilisha commences in July and continues till the middle of September. The presence of a small run beginning in March and continuing till the middle of April has also been recorded. Whether this second small run continues unnoticed and develops into the major run in July or it ceases after April is not known clearly. The upstream limit of the ascent of H.ilisha in River Narbada known so far is about 100 miles from sea, which

marks the lower or westward limit of steep hill tracts, over which the river flows with considerable rapidity during monsoon. The range of migration is thus limited to the lower reaches of the river and is short as compared to the extensive tracts travelled by the same fish in River Indus, Ganges etc.

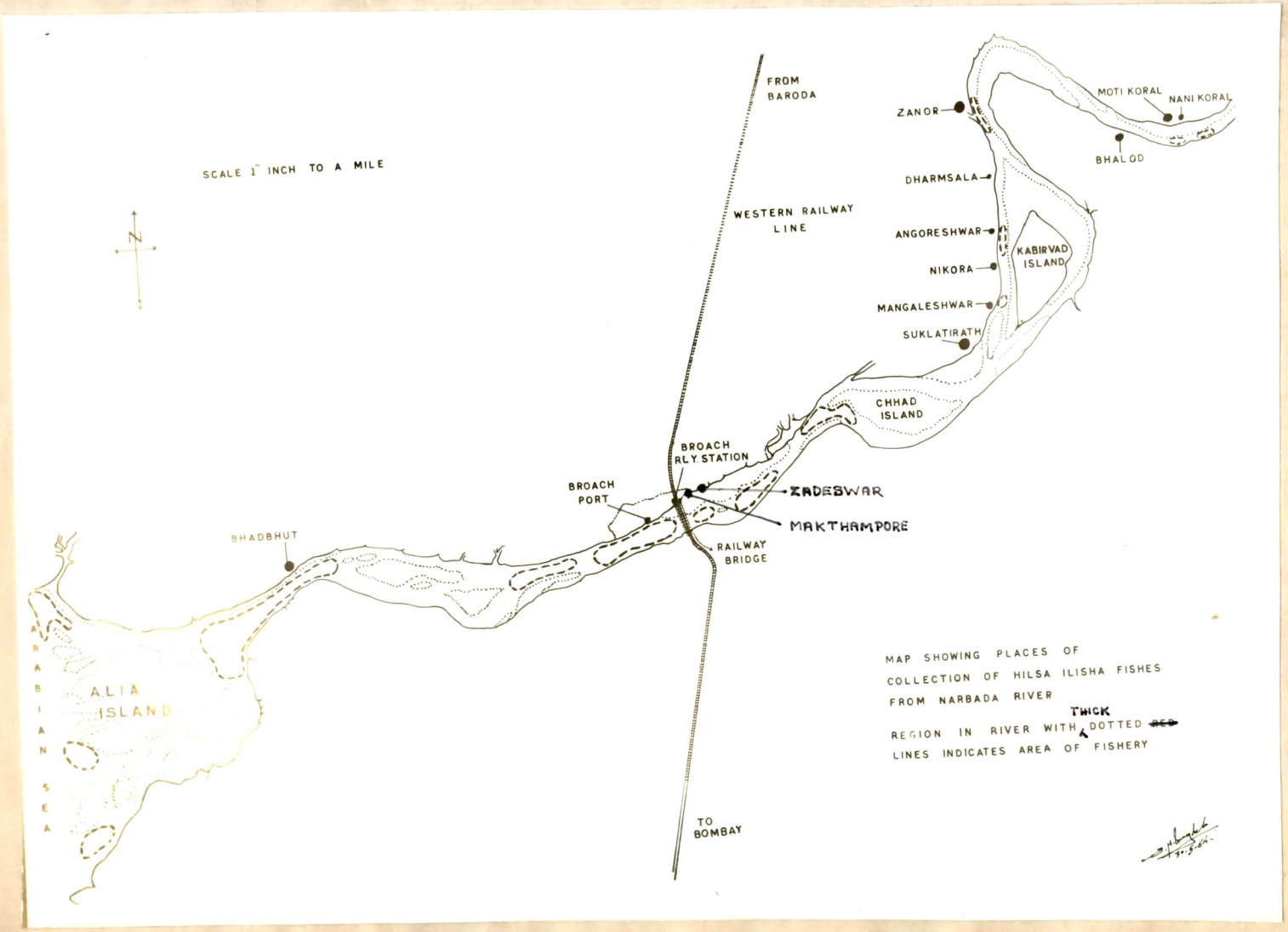
For the present investigation H.ilisha migrating into River Narbada were cought from the river mouth (Bhadbhut) and from the freshwater zone (Makthampore, Zadeswar, Zanor etc.). The places where Hilsa fishing is done are shown in the map 2. Flat bottomed 20 to 30 feet long boats are used by fishermen for Hilsa fishing in Narbada river. Large scale fishing is done with sunken drift nets. They are ordinary drift nets (mesh size 4.5" - 5"), but instead of floating near the surface they are set almost near the bottom and drift at that level. Kulkarni (1951) has given a detailed account of the methods of Hilsa fishing in Narbada. Fingerlings of H.ilisha (3" - 5" in length) - the result of monsoon run - are caught with "bag nets" in the month of January.

The lunar periodicity in the ascent of Hilsa as observed by Kulkarni (1950) was confirmed during the course of the present investigation . It may also be mentioned that lunar periodicity was noted even in the fishing of fingerlings.

The weight of migrating H.ilisha varied from



Map. 1. Gulf of Cambay area. Region in the Arabian sea with dotted lines indicates area of fishery.


SCALE 1" INCH TO A MILE
N
FROM BARODA
WESTERN RAILWAY LINE
ZANOR
MOTI KORAL
NANI KORAL
BHALOD
DHARMSALA
ANGORESHWAR
KABIRVAD ISLAND
NIKORA
MANGALESHWAR
SUKLATIRATH
CHHAD ISLAND
BROACH RLY. STATION
BROACH PORT
ZADESWAR
MAKTHAMPORE
RAILWAY BRIDGE
BHADBHUT
ARABIAN SEA
ALIA ISLAND
TO BOMBAY
MAP SHOWING PLACES OF COLLECTION OF HILSA ILISHA FISHES FROM NARBADA RIVER
REGION IN RIVER WITH THICK DOTTED ~~RED~~ LINES INDICATES AREA OF FISHERY

Map. 2

660 to 1070 g. (average- 836 g.) for females and 360 to 640 g. (average- 567 g.) for males. The length varied from 37 - 46 cm. (average- 40.5 cm.) for females and 33 - 42 cm. (average- 37.5 cm.) for males. All the migrating fishes irrespective of sexes were sexually mature (Vth and VI th stages of gonad). Spent fishes (Stage VII) were also obtained from the places shown in map 2. The above mentioned observations agree with Pillay's finding that only mature or maturing fishes ascend the rivers and the migration is for the purpose of spawning only.

Hilsa toli, a marine fish is available at the west coast of India throughout the year, except during the monsoon season, at which time the fishing is stopped. From the surface drift nets used in the demonstration boats of the Department of Fisheries, Gujarat, for fishing in the sea, H.ilisha and H.toli from the area marked in map 1 were collected during the different months of the years 1964, 1965 and 1966 (except in monsoon season).

Pillay (1953) reported the presence of H.toli in the River Hooghly about 70 - 80 miles from the river mouth . However, this is not considered to be a migratory ascent. According to him (Pillay, 1953) the rise in height and force of the tidal wedge may have caused a considerable diminution of the fresh-water layer and an increase in salinity of the surface waters, and this may have facilitated the inward dispersion of H.toli. So far no author

has reported the presence of H.toli in the Narbada. During the course of the present investigation H.toli were found to be fished in the vicinity of Bhadbhut (2-3 miles inside river mouth) at the highest high tide time of years 1964, 1965 and 1966. A regular H.toli fishery is conducted by fishermen of village Bhadbhut at the mouth of River Narbada during monsoon. Day (1878) reported the concentration of shoals of H.toli at the mouth of the river during monsoon. It may therefore be presumed that the strong currents of the sea might have forced the shoals of H.toli concentrated near the river mouth (as is known from the regular H.toli fishery by fishermen at the river mouth in monsoon season) to drift into the river.