THE ECOLOGY OF A BRACKISHWATER *BHERI*, WITH SPECIAL REFERENCE TO THE FISH-CULTURAL PRACTICES AND THE BIOTIC INTERACTION

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CONTENTS

INTRODUCTION

Brackishwater fish-farming is considered to hold out great potentialities in easing the protein food shortage in underdeveloped tropical countries Among the countries in South-East Asia, Java, Formosa and the Philippines have extensive brackishwater farms where the Milk fish, *Chanos chanos* (Forskål), is cultivated on a commercial scale. In India, a specialised type of brackishwater fish culture exists in Lower Bengal, in what are known as *bheris*. In these so-called *bhasabadha* fisheries or *bheris* mullets are cultured along with Cock-up (*Lates calcarifer*) and prawns. As in Hawaii and Formosa, mullets are cultured in brackishwaters of India on a commercial scale.

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Calcutta fish markets receive considerable quantities of fish raised in *bheris* situated in the Salt Lake area and the Sundarbans. These *bheris* not only support several fishermen but also contribute greatly to the fish supplies of the city. Hora and Nair (1944) have given a description of a *bheri* in the Sundarbans. Except for some general remarks contained in Gupta's report (1908) and the references in Chatterjee's article (1933), there are no detailed records of the fishes or the cultural practices in the *bheris* of the Salt Lake area. There are general surveys of the flora (Biswas, 1927), but the ecological features and the economic aspects of the fisheries have not been investigated.* As a part of an investigation of the biology of the Grey Mullet, *Mugil tade* Forskål, the author had opportunities of making some observations on the ecology of a *bheri* in Ghutiari Sharif, situated about 20 miles south of Calcutta on the Port Canning line of Eastern Railway. As the main object of the observations was to assess the conditions of existence of mullets in the *bheri*, particular attention was paid to the fish culture practices and the food relations of the mullets and their associates. An account of these observations is given below.

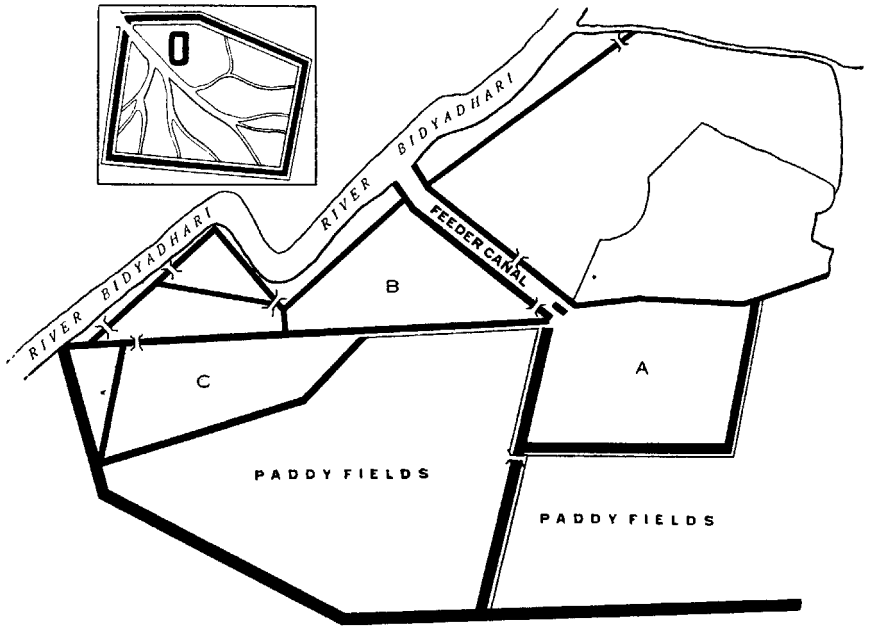
Topographical and hydrological features

The *bheri* selected for observations is located on the bank of the tidal river, Bidyadhari. It has been constructed by embanking the extensive spill area of the river and is divided by subsidiary embankments into eight ponds ranging from about 200 to 800 bighas† (Text-fig. 1). The ownership of the *bheri* is rather complicated, and the proprietary right of a sizeable portion of it is still unsettled. Most of the studies have been made in the two ponds marked *A* and *B* in Text-fig. 1, which are approximately 400 and 300 bighas in extent respectively. These ponds were under the control of one Mr. Mohamed Hanif during the time of investigations, which extended from 1949 to 1951.

The main embankments of the ponds are 6–8 ft. high, 10–12 ft. wide at the base and 6-7 ft. at the crest. Grass (*Graminae*) and *Suaeda maritima* (Family Chenopodiaceae—N. Order: Centrospermae) growing on the embankments serve to bind the soil and thus check erosion. All round the ponds within the embankments, is a deep canal system formed by the excavation of earth for bunding. These canals are about 4-5 ft. below the pond level. Connected to this canal system is another branching canal system spread over the general pond bottom. The remaining portion of the pond bottom is of level ground except for a deeper portion in pond *B*. Besides these, each of the ponds has a subsidiary pond about 4-5 ft. deep with separate embankment all round which is about 2 ft. high. The canals, the subsidiary ponds and the deep areas of the pond always hold a certain height of water, but the other portions generally remain dry during the dry months (Plate I, Fig. 1). The depth of water in the canals varies from 2–4 ft. except during the rainy season when it may be as much as 6–8 ft. As during the spring tides in February, March and April large quantities of tide water are taken into the *bheri*, the water level is usually much higher in this season. The average depths of water in the canals during the dry seasons before and after the tide water is taken in, are 2 to $2\frac{1}{2}$ ft. and 3 ft. respectively. In the shallow portions of the pond, the average depth of water is 6″-9″ in the rainy season and about 1′-2′ when a good supply of tide water is obtained. The rapid silting and the consequent deterioration of the

* An abstract of a paper 'On the biological productivity of a typical brackishwater Tarn (Bheri) of Lower Bengal' by H. K. Mookerjee, D. N. Ganguly and R. S. Mookerjee has been published in *Proc. 38th Indian Sci. Congr.*, Pt. III, 1952. The full paper has not been published, but in the abstract, it is mentioned that the phyto- and zooplankton of the Tarn were studied and the adult fish populations described. The authors have expressed the view that both lentic and mixed environments are exhibited in the tarn.

† 3 bighas = one acre.



TEXT-FIG. 1. A diagrammatic sketch of the *bheri*. *Inset*—Diagrammatic representation of the layout of canals and subsidiary pond in a section of the *bheri*.

Bidyadhari river feeding the *bheri* referred to by O'Malley (1914) and Banerjee (1931), have gone on so much further since then that irrigation engineers consider it almost a defunct river. The maximum tidal range, in the month of August, is about 5 ft. and the minimum, in the month of March or April about 1 ft. These changes have naturally affected the water supply of the *bheris* considerably. Formerly when the tidal range was high, it was possible to take water daily into the farm at high tides, but now owing to the weak tidal impulse, it is possible to do so only for about 4 days during the highest spring tides. The tidal water from the river is led into the ponds through a long canal (Text-fig. 1 and Plate XVII, Fig. 2) and taken in through sluice gates (Plate XVII, Figs. 3 and 4). During spring tides the sluice gates are opened and water is let in. At the turn of the tide the gates are closed so as to prevent the water from flowing out. Due to the absence of any big trees or even growth of bushes, the area is fully exposed to the action of wind, which is very severely felt during squally weather.

The pond bottom consists of ooze-like mud deposited by the silt-laden water as it flows through. The soil is of recent formation and its mineralogical components are listed below in the order of their abundance:

Chlorite
Quartz
Biotite mica
Opaque minerals
Muscovite mica and sericite
Felspar
Calcite.

There is a good deal of variation in the size of individual mineral grains ranging from specks to grains nearly 0·3 mm. (= 0·12 inches) across. Calcite, felspar and

muscovite mica are of smaller size than the rest. Chloritic material and biotite are by far the most abundant. The soil contains about 3% of humus and the moisture content is about 31%. The top layer is composed of fine sticky mud with sizeable quantities of organic matter, consisting mainly of decayed plant and animal matter. Chemical analysis of the soil samples showed the presence of the following radicals:

Chlorides—0·137%.
Silica and other insoluble matter—79·47%.
Iron and aluminium as oxides—8·88%.
Sulphate as SO_3—0·05%.
Calcium as CaO—3·34%.
Magnesium as MgO—1·12%.
Total nitrogen—0·42%.
Nitrate nitrogen—0·004%.
Phosphates as P_2O_5—1·53%.

Meteorological data could not be collected at Ghutiari Sharif, but the monthly normal rainfall figures * in Canning Town which is only about 8 miles from there, and the atmospheric temperature at Alipore † which is nearly 20 miles from this place are available for the period, February, 1949 to January, 1950. These data presented in Table I will serve to give an approximate picture of the climatic conditions of the locality.

TABLE I

Rainfall and temperature data

Month.	Normal rainfall at Canning Town in inches.	Mean atmospheric temperature at Alipore.	
		Maximum (°C.).	Minimum (°C.).
February (1949) ..	0·88	29·7	15·9
March ..	1·45	34·6	22·0
April	1·90	33·2	24·3
May	6·12	33·4	25·3
June	12·07	34·3	26·3
July	14·19	32·2	26·4
August ..	14·61	32·1	26·4
September ..	9·77	32·3	26·1
October ..	4·60	32·8	24·7
November ..	1·14	28·9	16·8
December ..	0·08	26·5	12·2
January (1950) ..	0·45	27·7	14·1

Table II gives the hydrological data for the same period collected during monthly visits. The range of *p*H values was rather limited (7·5–8·3) and the water

* From the data published by the Director of Agriculture, West Bengal.
† Obtained from the Meteorological Office, Alipore.

always remained alkaline in reaction. Table II clearly shows the wide range of salinity obtaining in the ponds. While the salinity may be high during the dry months, the water becomes almost fresh during the rainy season. The rise in salinity is chiefly due to rapid evaporation during the inter-spring-tide periods. If the salinity of the pond water goes high, dilution with the almost fresh tide water at high tides in this season may slightly lower it. While the salinity does not generally go above 35 $^0/_{00}$ in canals and deeper areas of the ponds even during the driest months, the concentration of salt increases rapidly in the shallow regions, and with the complete drying up of these areas (Plate XVIII, Fig. 4) a layer of salt deposit may be seen on the bottom. Except for the extremes in hydrological conditions during the height of the rainy and summer seasons, the interval between two spring tides is the regular period of greatest fluctuations in the quality of the pond water. Table III illustrates the variations in the depth and salinity of the pond water during an inter-spring tide period in the month of May, 1951. The water level and salinity data are represented in graphic form in Text-fig. 2. They bring out the remarkable fact of a rapid lowering of water level during the inter-spring-tide period. Associated with this, is the salinity increase as seen in Text-fig. 2, reaching a high level of $35^0/_{00}$ by the next spring tide period. These wide fluctuations in the hydrological conditions exercise a very strong influence on the faunal elements of the *bheri*, the strongly euryhaline of which are able to sustain themselves under the conditions prevailing.

TABLE II

The water temperature, p*H and salinity of the* bheri *water during the period of observation* (*).

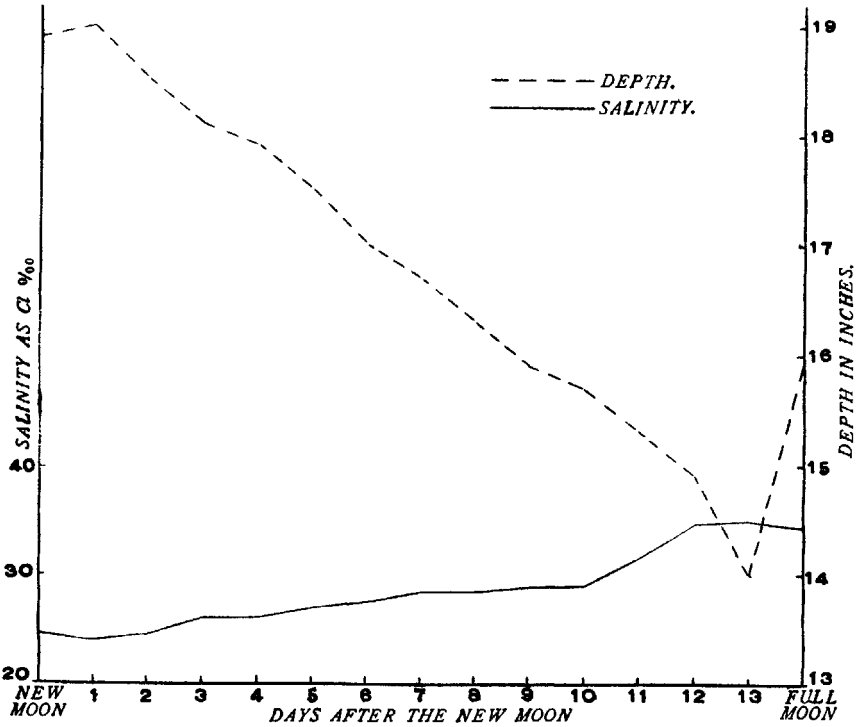
Date.	Water temp. (°C.).	*p*H.	Chlorinity ($^0/_{00}$).
22- 2-49 ..	30·0	7·5	9·90
24- 3-49 ..	28·9	8·0	1·60
23- 4-49 ..	30·0	8·3	9·80
24- 5-49 ..	28·3	8·1	10·89
24- 6-49 ..	29·4	8·0	11·10
24- 7-49 ..	27·5	8·3	1·80
23- 8-49 ..	29·4	7·8	1·57
24- 9-49 ..	35·0	7·9	2·20
24-10-49 ..	26·5	8·0	6·05
23-11-49 ..	25·4	8·2	7·80
23-12-49 ..	24·5	8·3	9·60
24- 1-50 ..	14·4	8·2	9·70

(*) All observations were made at about 8 a.m. in the morning.

TABLE III

The hydrological changes in the bheri *water during an inter-spring-tide period in May, 1951.*

Day.	Depth of water in inches.	Atm. temp. (°C).	Water temp. (Surface, °C.).	*p*H.	Salinity (‰).
New moon	18·9	30·59	30·50	8·3	24·5
1st day after new moon ..	19·0	30·50	30·60	8·3	24·0
2nd ,, ,, ..	18·5	30·60	30·50	8·3	24·5
3rd ,, ,, ..	18·1	30·60	30·60	8·3	26·0
4th ,, ,, ..	17·9	30·60	30·60	8·5	26·0
5th ,, ,, ..	17·5	30·66	30·60	8·5	27·0
6th ,, ,, ..	17·0	30·60	30·60	8·4	27·7
7th ,, ,, ..	16·7	30·50	30·50	8·4	28·4
8th ,, ,, ..	16·3	30·25	30·60	8·3	28·5
9th ,, ,, ..	15·9	30·00	30·60	8·3	28·6
10th ,, ,, ..	15·7	30·60	30·60	8·5	29·0
11th ,, ,, ..	15·3	30·60	30·50	8·4	31·4
12th ,, ,, ..	14·9	30·50	30·55	8·4	34·6
13th ,, ,, ..	14·0	30·25	30·10	8·3	35·0
Fullmoon	15·9	30·00	30·00	8·3	34·2



TEXT-FIG. 2. The depth and salinity of the pond water during an inter-tidal period.

BIOTA

FLORA.—A very striking feature of the *bheri* is the complete absence of submerged phanerogamic vegetation. Even on the embankments and exposed regions, there are few larger plants. Neither the mangrove formation of the type described by Biswas (1927) in the Salt Lake area, nor the dense jungle seen in the *bheris* of lower Sundarbans, is present in this region. The exposed parts of the pond bottom are covered with grass (Family Graminae). The plankton of the ponds is rich in floral elements during a good part of the year. Among the phytoplankters, diatoms form a predominant group. The most common forms are of the genera, *Navicula*, *Pleurosigma* and *Gyrosigma*. Among these, *Gyrosigma scalproides* is very common, especially during the colder months. Other common forms identified from the ponds are *Cymbella*, *Coscinodiscus*, *Cyclotella*, *Fragilaria* and *Amphipleura*. Biswas (*op. cit.*) has given a detailed list of the surface and benthic algae other than diatoms, occurring in brackishwater *bheris* of the Salt Lake area. The Myxophycean genera found in the surface plankton were, *Oscillatoria*, *Lyngbya*, *Spirulina*, *Anabaena*, *Nodularia*, and *Rivularia* and the Chlorophycean genera *Protococcus*, *Pediastrum*, *Hydrodictyon* and *Ankistrodesmus*. The only desmid was *Cosmarium*. There were considerable quantities of algal spores in the plankton almost throughout the year.

A notable feature is the thick growth of benthic flora on the pond bottom. Associated with this algal matrix are many microscopic animalcules, more particularly during the cold months when thick mats of this growth are dislodged from the bottom to float on the surface near the pond margins or to be stranded on the haulms of emergent grass. Schuster (1951) has described this type of phenomenon in great detail. Different species of *Oscillatoria* are the most predominant. *Gloecapsa*, *Symploca*, *Protococcus*, *Enteromorpha*, *Chaetomorpha* and *Polysiphonia* are also common, besides *Lyngbya*, *Anabaena* and *Microcoleus* of the surface plankton. The presence of many of the benthic algae in the surface plankton is due to the constant stirring of the waters by wave and wind action. Diatoms, especially, *Gyrosigma scalproides* are found growing on filamentous algae in the benthic zones. The cold season between December and March appears to be the peak period of floral growth in the ponds, while in the rainy season the quantity of flora decreases considerably. However, *Oscillatoria* and allied forms are comparatively abundant during the rainy season. *Spirogyra* spp. occur in the iliotrophic layer during this season.

FAUNA.—Sewell (1934) has listed the animals that occur in the Gangetic delta and in the Salt Lake area, giving an account of the zooplankton of the area with special reference to copepods. A remarkable feature of the fauna in this *bheri* also, as observed by Chopra (Sewell, *op. cit.*), is the great abundance of individuals of different species of animals. Copepods (*Diaptomus*, *Pseudodiaptomus*, *Acartia*, *Cyclopina*, *Cyclopsis*) and Cladocerans form the most predominant items of the zooplankton in the ponds. Zoea and megalopa larvae, mysids and the young of prawns and shrimps were also generally found in the plankton. Ciliates and Flagellates, Helminths and Rotifers are found only in small quantities, during the rainy months and up to the beginning of winter. The quantity of zooplankton in the ponds, which is fairly high in the rainy season, is gradually reduced as winter approaches.

The dominant elements of macro-fauna, other than the few polychaete worms and the Gastropod molluscs, *Stenothyra* and *Melanoides*, are the Crustaceans and fishes. The common crustaceans are the following:—

Penaeus semisulcatus De Maan, *Penaeus indicus* M. Edw., *Metapenaeus monoceros* Fab., *Leander styliferus* M. Edw., *Palaemon rudis* Heller, *Scylla serrata* (Forsk.), *Varuna litterata* (Fab.), *Metaplax dentipes* (Heller). During the rainy season swarms of megalopa larvae of the common crab *Varuna litterata* abound in the pond waters. The crabs *Scylla serrata* and *Varuna litterata* make holes in the

embankments of the ponds weakening them and ultimately leading to the complete collapse of *bheris* in certain areas.

The following fishes have been identified from the ponds:

Sub-Class Actinopterygii

Family Clupeidae
Pellona elongata (Bennett)

Family Engraulidae
Setipinna phasa (Ham.)
Thrissocles hamiltonii (Gray)

Family Cyprinidae
Barbus (Puntius) stigma (Ham.)

Family Bagridae
Mystus gulio (Ham.)

Family Anguillidae
Anguilla bengalensis (Gray & Hardeo)

Family Ophichthyidae
Pisoodonophis boro (Ham.)

Family Belonidae
Xenentedon cancila (Ham.)

Family Hemirhamphidae
Hemirhamphus limbatus Cuv. & Val.

Family Cyprinodontidae
Aplocheilus panchax (Ham.)
Oryzias melastigma (McClelland)

Family Mugilidae
Mugil corsula Ham.
Mugil parsia Ham.
Mugil tade Forsk.

Family Polynemidae
Eleutheronema tetradactylum (Shaw)

Family Centropomidae
Ambassis baculis (Ham.)
Lates calcarifer (Bl.)

Family Theraponidae
Therapon jarbua Forsk.

Family Lobotidae
Lobotes surinamensis (Bloch)

Family Leiognathidae
Gerres setifer (Ham.)
Gerres abbreviatus Blkr.
Leiognathus insidiator (Cuv. & Val.)

Family Scatophagidae
Scatophagus argus (Bloch)

Family Eleotridae
Eleotris butis (Ham.)

Family Gobiidae
Apocryptes lanceolatus (Bl. Schn.)
Brachygobius nunus (Ham.)
Glossogobius giuris (Ham.)
Gobiopterus chuno (Ham.)
Periophthalmus schlosseri (Pallas)
Scartelaos viridis (Ham.)
Stigmatogobius sadanandio (Ham.)

Family Cynoglossidae
Cynoglossus cynoglossus (Ham.)

It will be seen from the above list that a large majority of the common estuarine fishes of the area is found in the *bheri*. However, the conspicuous absence of two species found in large numbers in the River Matlah is noteworthy. The grey mullet, *Mugil speigleri* Blkr. and the Bombay duck, *Harpodon nehereus* (Ham.), are common in Port Canning and the neighbouring areas during a major part of the year. These fishes have not been found in the Ghutiari Sharif *bheri* at any time of the year, nor in the *bheris* of the lower Sundarbans.

The common frogs *Rana cyanophlyctis* and *Rana tigrina* are occasionally found in the ponds. The little Cormorant (*Phalacrocorax niger* (Vieillot) and the Darter (*Anhinga melanogaster* Pennant), the Common King Fisher (*Alcedo atthis* Linn.), the Common Sandpiper (*Actitis hypoleucos* Linn.), the Brahminy Kite (*Haliastur indus* (Boddaert), the Cattle Egret (*Bubulcus ibis* Linn.), the King Crow (*Dicrurus macrocercus* Vieillot), the Pied King Fisher (*Ceryle rudis* (Linn.)), and the Yellow Wattled Lapwing (*Lobipluvia malabarica* Boddaert) are often seen either on the embankments or in the shallow regions of the ponds. The common crow is closely associated with the homesteads of the fishermen on the embankments.

Fish Cultural Practices

The methods of fish culture in the Ghutiari Sharif *bheri* are very much like those described by Hora and Nair (1944). The cultural operations commence about January-February when the ponds are stocked with fish fry. The ponds, which contain only little water at that time as a result of dewatering for fishing in September-December, are filled with water to the maximum extent possible. Generally, each pond has only one main sluice gate, but during this period emergency inlets are also made so that the intake of water could be enhanced. As stated above it is only during the spring tides that the tidal water reaches the sluice gates. The main sluices are provided with shutters (Plate XVII, Figs. 3 and 4) to regulate the water level. At high tide these doors are opened and the tidal water is allowed to flow in. At the turn of the tide the gates are closed and the water is prevented from flowing out. In front of each main sluice gate is a V- or W-shaped screen of bamboo-gratings (Plate XVII, Fig. 5) with gaps at the apex of the V or apices of the W. In these gaps are placed *atols* (Hora and Nair, *op. cit.*) (Plate XVII, Fig. 6). These *atols* do not serve the purpose of collecting fry for stocking. In fixing them, the open side with the valve-like arrangement of bamboo spindles, is kept facing the pond. Some of the fishes in the ponds such as the mullets have the habit of swimming against currents, and in doing so are caught in these *atols*. The bamboo gratings are kept in front of the sluice gates to prevent the fishes in the ponds from escaping when the gates are open. When emergency gaps are made in the embankments to let in additional quantities of water, the fishermen have an ingenious

device for preventing the escape of fishes from the ponds (Plate XVIII, Fig. 1). The floor of the gap made in the embankment is usually about 4″–8″ above the level of the water. The floor which slants away from the pond is paved with a *patta* of bamboo grating, the end of which projects into the pond. Over this bamboo work is smeared a thick layer of clay. The tidal water that flows over the floor of the gap falls into the pond at a steep angle. Those fishes which approach the inflow of water find it impossible to negotiate the current and are unable to escape from the pond. The fishermen believe that fry of almost all the fishes in the ponds are obtained during this period. But the author's observations in this *bheri* as well as in other areas (Pillay, 1949 and 1954) show that from among the important fishes, only the young of *Mugil parsia* and *Mystus gulio* and the prawns are available during this period. Along with these, fingerlings of other fishes also enter the ponds. From this period onwards, until dewatering takes place, tidal water is let into the ponds at spring tides. But no special effort is made to capture the fry at this time as the water that flows in through the main sluice gates, contains the fry of various fishes. Fry of *Mugil tade* and *M. corsula* have been noticed only during the rainy season, while small fry of the cock-up (*Lates calcarifer*) (1″ to 2″ long) have been found only in July-August.

After the comparatively intensive stocking of ponds from February to April, no attention is paid by the fishermen to improving the growth of the fish crop, apart from letting in water into the ponds, attending to the occasional repairs of the embankments, etc., and keeping watch over the stock. The fishes feed on the autochthonous food material of the ponds as well as those brought in by the tidal water. During the dry months, when the water level falls, several twigs are stuck into the bottom of the canals, to prevent easy fishing by poachers (Plate XVIII, Fig. 3). From about May-June the ponds are fished on a small scale mainly to meet the fishermen's needs. Whenever tidal water is taken in, some fish, prawns, and crabs are caught in the *atols*. 'Tengra' (*Mystus gulio*) are caught by the fishermen by a very ingenious method. These fish also, like the mullets, have a tendency to swim against currents. But they are generally unable to negotiate streams with a strong current. So, on the side of the main sluice gate and the canal leading from it, they dig a shallow canal. The mouth of this shallow channel is guarded by a low fence of bamboo grating and some distance away from it is another similar fencing with a gap in the middle. Tide water from the main feeder channel leading from the river is allowed to flow into the pond through this channel. The fish ascend the channel and gather below the bamboo fencing. At the turn of the tide or when a sufficient number of fish has gathered in the channel it is closed at the mouth either by means of shutters or by putting an earthen bund. The gap in the lower bamboo fencing is also closed. After the water in the channel drains off, the fish that have been trapped in the channel are removed by hand. Cast nets are operated (Plate XVIII, Fig. 6) for the capture of all fishes from the ponds during all seasons.

Large-scale fishing operations are carried out between September and November. As no tidal water is required in the ponds during this period as much water as possible in them is let out. The fishes move into the canals and deeper areas of the ponds where these are fished by means of drag nets (Plate XVIII, Fig. 5), generally during the evening or at night so that the catches could be sold early in the morning. The catches are sometimes kept in live wells (Plate XIX, Fig. 2) or live cages known as *Hapar* (Plate XIX, Fig. 1).

Special deep Crab cages known as *khonga* (Plate XIX, Fig. 3) are also used for keeping fish alive in water but more commonly for emptying the catches from the *atols*. From the *khonga*, the catches are transferred to *hapars*. In the morning the catches are brought in baskets to the Ghutiari Sharif Railway Station, a mile and a half away from the *bheri* (Plate XIX, Fig. 4), and sold wholesale to fish merchants on the station platform, who in turn take them to Calcutta by the first morning train at 4-30 a.m. reaching Calcutta at about 6 a.m.

FIG. 1. A general view of a portion of the *bheri*.
,, 2. The feeder canal through which tide water flows into the ponds.
,, 3. The sluice box through which water is let in.
,, 4. A sluice gate for controlling water supply.
,, 5. Bamboo gratings arranged in the form of a 'W' in front of the sluice gate.
,, 6. An 'Atol' fixed in the gap between two bamboo gratings, erected in the form of a V.

FIG 1. An emergency gap in the embankment, showing the device for preventing the escape of fish.
„ 2. A subsidiary pond for keeping immature fishes.
„ 3. Twigs stuck into the bottom in a canal in the *bheri*, during summer, to prevent poaching.
„ 4. A dried up portion of the pond bed.
„ 5. Fishing in the *bheri* with a drag net.
„ 6. Cast net fishing in the *bheri*.

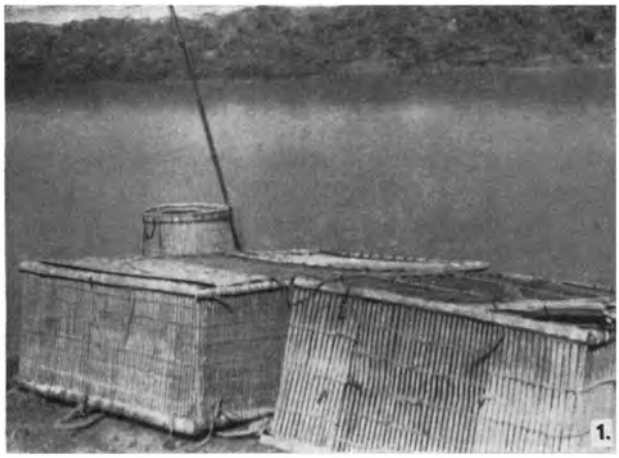


FIG. 1. Live cages known as *Hapar*, used for keeping catches alive till marketed.
,, 2. Live wells dug near the *bheri* for keeping fish alive till marketed.
,, 3. Crab cages known as *Khonga*.

During the usual annual intensive fishing, large numbers of immature fish are also caught and sold. Formerly, it was the general practice to stock them in the subsidiary ponds (Plate XVIII, Fig. 2), where they were allowed to grow till the main pond was again filled with water, and could gain access to the canal system and the pond proper, a practice which is now seldom followed. Another wholesome practice now obsolete, is the annual ploughing of the pond bottom after dewatering, the discontinuance of which is bound to have an adverse effect on the productivity of the *bheri*.

The ponds which were formerly operated by the owners, are now leased out for a period of one or two years on an annual rental of Rs.40 to Rs.50 per acre. As the period of lease is short the lessees are naturally interested in marketing all sizes of fish from the ponds that would fetch a price and not in increasing the productivity of ponds. Due to the complicated nature of the ownership and of the practice of leasing, it has been difficult to collect any reliable statistics of production. It is noteworthy that the canals and the deeper portions of the ponds, which occupy 30% to 40% of their area, are the most productive ones. The present output from such productive areas ranges between 100 and 150 lbs. of fish and prawns per acre. The average prevailing prices of fish in the local market at the time of the investigation were as follows:—

	Rs.	a.	p.	
Small mullets	1	0	0	per lb.
Large mullets, specially *Mugil tade* ..	1	8	0	,,
Cock-up	1	8	0	,,
Tengra (*Mystus gulio*)	0	12	0	,,
Large prawns	1	4	0	,,
Crabs	0	8	0	,,
Small crabs	0	2	0	,,
Miscellaneous fish and small prawns..	0	8	0	,,

Ecological Classification of the Fauna

Based on their ecological significance, the more important elements of the fauna of fish ponds have been classified as dominants, influents and sub-influents (Hiatt, 1944). Dominants are 'animals of outstanding abundance of conspicuous influence in the community', and influents are 'common animals which are usually effective in modifying the well-being or numbers of the dominant group or of other influents without changing the essential structure of the community, their rôles are generally shown in ponds as benefactors, competitors, or predators'. Those animals that 'affect the life of the community, but to a lesser extent than do the influents' are termed sub-influents. Following the classification adopted by Hiatt the faunal elements in the *bheri* have been classified as shown below. With the restricted facilities available to the author, it was not possible to try any of the quantitative methods which provide a more accurate classification. Hence the adoption of the standards employed by Hiatt (*op. cit.*). In addition to the species shown below some rare onés not taken into account in this classification are found, which do not affect the biotal conditions in the ponds in any noticeable manner.

Dominants.

Mugil parsia
Mugil tade
Lates calcarifer
Penaeus semisulcatus

INFLUENTS.

Mystus gulio
Apocryptes lanceolatus
Periopthalmus schlosseri
Leander styliferus
Metapenaeus monoceros
Scylla serrata

SUB-INFLUENTS.

Aplocheilus panchax
Oryzias melastigma
Eleutheronema tetradactylum
Scatophagus argus
Eleotris butis
Gobiopterus chuno
Stigmatogobius sadanandio
Varuna litterata

DOMINANT ANIMALS

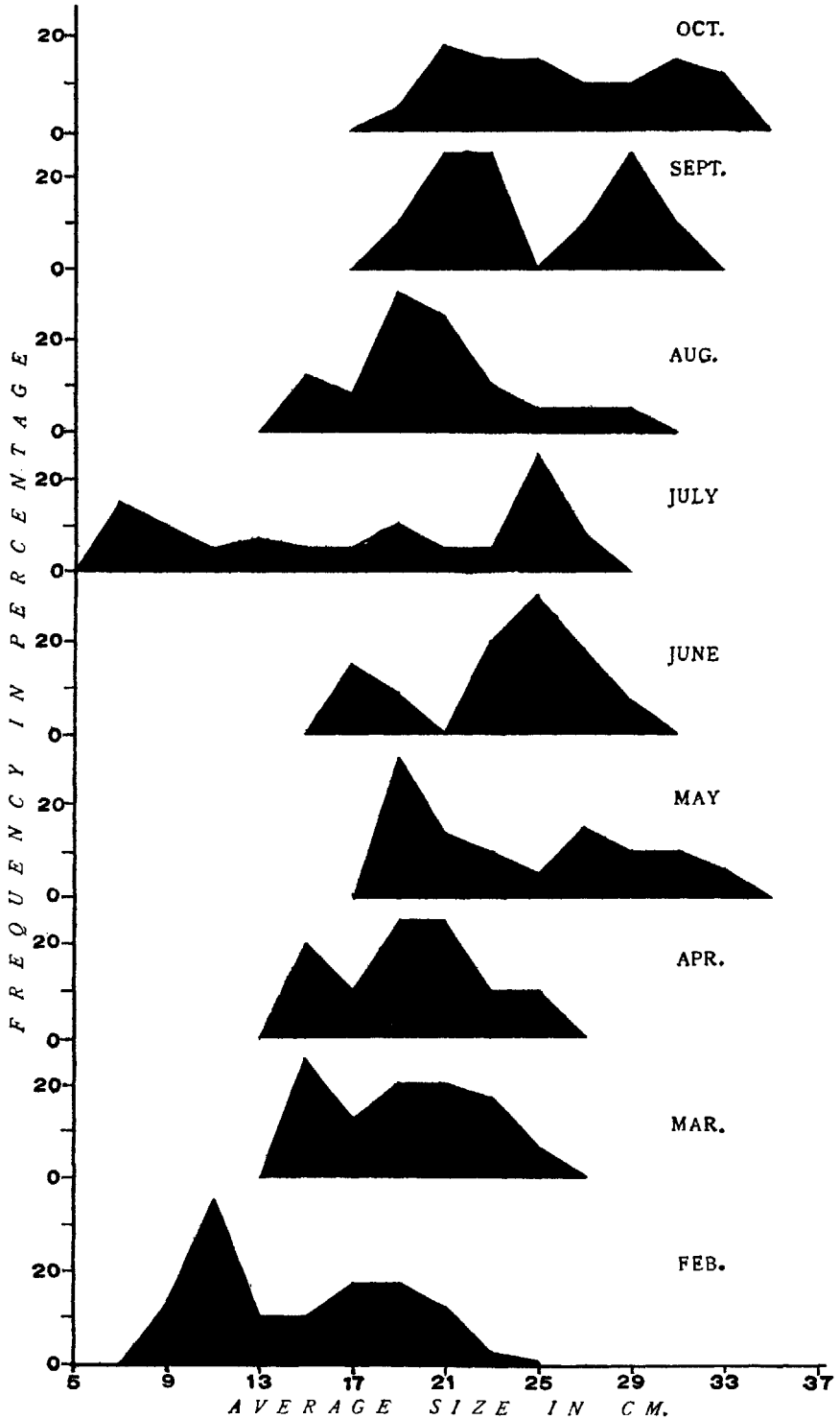
(1) *Mullets*

Grey Mullets.—The Grey Mullets, *Mugil parsia* locally known as 'Parse' and *M. tade* known as 'Bhangon' together form the most dominant group in the ponds. As intensive stocking operations are conducted in late winter when the estuaries teem with their fry, the ponds have always a predominant population of *M. parsia*. From February to April, fry 1″-2″ long are taken into the farm. By the end of the season, that is in about 8 months' time, they attain a size of 4″ to 6″ in the ponds. Though mature females in the fourth and fifth stages of maturity and ripe males with milt oozing out on the application of slight pressure have been seen in the catches, no evidence of their breeding in the ponds has so far been noticed.*

Young of *Mugil tade* ¾″ to 1½″ in length enter the ponds along with the tide water during the rainy season and grow up to 1½″-2″ when the ponds are ready for dewatering. A small percentage of them which survives the fishing activities thus obtains a further lease of life up to the end of the next season when they grow up to 9½″ to 10″ in length. A still smaller percentage surviving up to the end of the third season reaches a length of 13½″ to 14½″. Text-fig. 3 represents the length frequency distribution of the samples obtained from the *bheri* in 1949, and shows that the large majority of the catches consists of O group and I group fishes (*vide* classification given by Pillay, 1954). The available data indicate that the rate of growth of the fish in the ponds is faster than in the natural habitats (Pillay, 1954), though not as fast as that observed in several freshwater fishes cultured in ponds.

Distinction is often made by the fishermen and the fish traders between river mullets, sea mullets and *bheri* mullets. The author (Pillay, 1954) has shown that there are no significant differences between the fish stocks of the estuaries in Port Canning and the sea coast at Junput. A statistical comparison of the morphometry of samples of *M. tade* from the farm and of samples from the sea was made. The values obtained for each of the indices employed for the comparison are given in Table IV. These values indicate statistically significant differences in the six characters examined. In a recent paper the author (Pillay, 1953) has shown that the alimentary canal of *bheri* mullets is significantly longer than that of the river

* A detailed study of the bionomics of this species has been made by Miss K. K. Sarojini, Asst. Research Officer, Central Inland Fisheries Research Station, Barrackpore.



TEXT-FIG. 3. The length frequencies of the samples of the Grey Mullet, *Mugil tade*, examined from the *bheri*.

TABLE IV.

The biometrical data for samples from Junput and from the bheri.

	N_1	N_2	Size range for sample 1 in cm.	Size range for sample 2 in cm.	σ_1	σ_2	SE_1	SE_2	SEd	t
TL/SL ..	200	200	1·1 – 1·3	1·17– 1·31	0·173	0·0519	0·024	0·007	0·025	4·000
TL/L.D.C.P. ..	200	200	8·95–11·25	9·5 –12·10	0·544	0·808	0·077	0·114	0·138	3·115
TL/D.E. ..	200	200	9·89–17·18	10·8 –15·9	1·453	1·201	0·206	0·170	0·289	3·890
TL/HD ..	200	200	3·1 – 4·9	4·3 – 4·9	0·308	0·153	0·043	0·022	0·048	4·375
TL/A.L. ..	200	200	1·6 – 1·8	1·60– 1·80	0·060	0·057	0·008	0·008	0·011	4·000
TL/D.A.F.B. ..	200	200	5·2 – 6·85	5·7 – 7·6	0·366	0·390	0·052	0·071	0·089	4·150

TL = Total length.
SL = Standard length.
L.D.C.P. = Least depth of caudal peduncle.
D.E. = Depth through eye.
HD = Head length.
AL = Length of body from snout to beginning of anal fin.
D.A.F.B. = Depth through anal fin base.

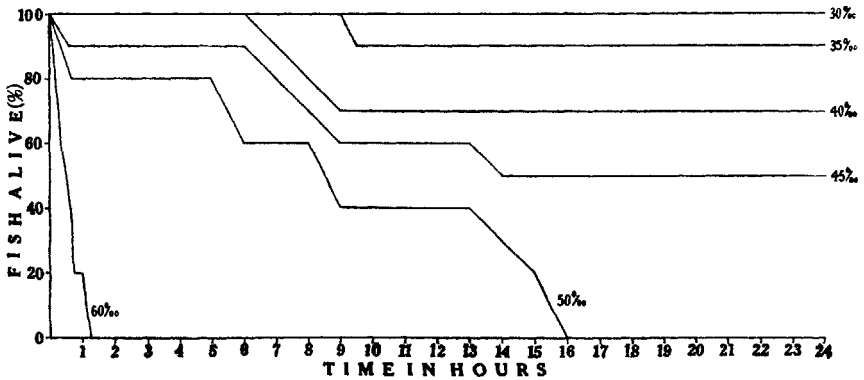
Number 1 denotes samples from the sea (Junput) and Number 2 denotes samples from the *bheri*.

and sea mullets. Sunier (1922) has described similar changes in the external morphology of the Milk fish (*Chanos chanos*) raised in Indonesian *Tambaks* (brackish water ponds). Despite such marked differences, the *bheri* stocks cannot justifiably be considered as belonging to a separate race, as they are raised from those occurring in the estuaries. The changes in the morphometry of the fish are therefore likely to have been brought about by a land-locked environment, as the ecological conditions in the *bheri* are in many ways different from those of the estuaries.

The extreme variations in the salinity of the *bheri* have already been referred to. The mullets belong to a strongly euryhaline group, capable of adapting themselves to lowered salinities as evidenced by the direct acclimatisation practices in some parts of Bengal (Pillay, 1949). But very little is known about their adaptability to the high range of salinities which may prevail in summer in shallow waters as happen in isolated pools of the *bheris*.* To ascertain the lethal limits of higher salinities on *Mugil tade*, a series of experiments were conducted, in the field, with simple equipment consisting of large wide-mouthed jars of about $3\frac{1}{2}$ litre capacity. In the absence of equipment such as used by Sunier (1922) in Indonesia, waters of different concentrations were obtained by dissolving the calculated quantities of unrefined solar salt in fresh pond water.

Fry $\frac{3}{4}''$–$1\frac{1}{2}''$ long were used in the experiment which was repeated thrice with a control in each case, to estimate the mortality due to rise in salinity. The results discussed below constitute the mean of the three separate observations.

Twenty fry $\frac{3}{4}''$ to $1\frac{1}{2}''$ long caught from the creeks were directly transferred to different jars containing water of salinity 30 $^0/_{00}$, 35 $^0/_{00}$, 40 $^0/_{00}$, 45 $^0/_{00}$, 50 $^0/_{00}$, 60 $^0/_{00}$, respectively. The survival data (Table V) under the different salinity levels are delineated in Text-fig. 4. Even though it was not possible to study the effect of different *p*H concentrations and also repeat the experiments with larger fish, the results obtained indicate that a salinity higher than 30–35$^0/_{00}$ is not conducive to the well-being of mullets, at least of the young ones ($\frac{3}{4}''$–$1\frac{1}{2}''$ in length), in the ponds. This observation is of special importance to the *bheri* owners of the Calcutta Salt Lakes, as owing to the diminishing water supply from the Bidyadhari and evaporation and seepage in the ponds, the salinity of the water may increase considerably.



TEXT-FIG. 4. The survival of *Mugil tade* fry under different salinity levels.

* Pillai in a recent paper (Pillai, V. K.—Some factors controlling algal production in Salt-water lagoons. Proc. 5th meeting, I.P.F.C./C. 54/Sym. 3) mentions about his observation that the blue-green alga *Phormidium tenue* can withstand salinities up to 100 parts per thousand. Such observations on Indian fishes do not appear to have been made.

(2) *Cock-up*

Lates calcarifer.—This fish, locally known as *Bhekti*, is an important and highly-priced species. Very little precise information is available on its bionomics. Naidu (1942) observed *bhekti* breeding in the Sunderbans in the winter season, where large numbers of young ones were seen in the pools and ditches on the sides of the estuaries in April. According to Yingthavorn (1951), the spawning season of the fish is in the rainy season (May-September) in Thailand waters. In the present observations also, fry of Bhekti 1″ to 2″ long have been found to enter the ponds in the rainy months only. They attain a size of about 5″ by October-November, when they are fished. Their average growth in the second year is up to 10″ in length. Hora and Nair (1944) reported that in the *bheris* of the lower Sunderbans, the Cock-up was raised in separate canals, so that mullets and other important fishes may not be eaten up by this predaceous species. But in this *bheri* no such segregation is permitted. However there are no intensive stocking operations during the rainy season when their fry are found in considerable numbers, and so the population of *bhekti* in the ponds is not as high as in the larger *bheris* of lower Sunderbans. The species is capable of acclimatisation to very low salinities and can be seen in adjacent freshwater areas into which they ascend from the river through the brackishwater canals. They have never been observed in the highly saline isolated pools during periods of drought.

(3) *Prawns.*

Penaeus semisulcatus is a dominant prawn of very great value in the markets, on the culture of which the fishermen bestow great attention. The *bagda chingri*, as it is locally called, does not breed in the confined waters of the *bheri*. The larvae and young are brought in with the tide during the winter months. They bury themselves in the muddy bottom of the ponds and grow very rapidly, feeding on the food resources of the iliotrophic layer. A length of 3″–5″ is attained by the end of the season when most of them are caught and marketed.

Sources of food supplies

The main sources of food supplies for fish in the *bheri* are the tidal waters and the autochthonous biotal complex. As during the spring tides the river and the *bheri* are connected, the incoming tides bring with them considerable quantities of plankton and suspended detritus. Within a short time after the tidal water is taken in, the suspended matter settles down to the bottom of the *bheri*. This detritus is rich in decaying organic matter which is an efficient fertilizer. During the rainy season, the *bheri* receives some amount of rainwater that flows into it from the embankments. This water also contains some nutrient salts that are washed down from the soil. The scanty decaying macroflora on the embankments also contribute in a small way to the fertility of the ponds. The exposed areas of the *bheri*, as already mentioned, are generally overgrown with grass and *Suaeda maritima*. When inundated for a sufficiently long period with the tide water, these plants decay and add to the fertility of the ponds. Besides these chiefly external sources of fertility, there is the inherent richness of the soil, which mainly contributes to the growth of organisms which serve as food. The thick layers of benthic vegetation on the pond bottom play an important rôle in the sustenance of fish life. In shallow waters, however, the distinction between the benthic flora and the surface flora is not marked. The very considerable zooplankters in the *bheri* water do not, however, seem to be of any great importance as a source of food for the fish.

Biotic Interaction

(1) *Methods*

The biotic interaction in the *bheri* was studied by the examination of stomach contents of samples of ecologically important fauna, *viz.* fishes and crustaceans, collected at different times of the year. The main aim of this study was to obtain a general picture of the food habits and to understand the inter-relationship of the fauna with regard to their food and feeding habits. So the seasonal or other variations in the food elements were not examined in detail. The items of food of dominants, influents and sub-influents alone are presented here, although the gut contents of the rarer species which exercise no significant biotic interaction in the ponds were also studied. For the purpose of this study smaller fishes were fixed and preserved in 5% formaldehyde. The alimentary tracts of larger fish were removed by dissection and fixed and preserved in 5% formaldehyde. Generally, only the contents of the stomach were examined, but when the stomach was empty the foregut was also examined. The contents of the rectum were studied regularly to ascertain the presence of undigested food. The stomach contents were analysed volumetrically by the displacement method in the case of carnivorus species where they were easily separable and were found in measurable quantities. In other cases, the volumes were determined by eye estimation. The prevalence of each item was also estimated and expressed as a percentage of the total number of stomachs examined.

(2) *Food of Dominants*

Mullets.—The author has in a recent paper (1953) described the food and feeding habits of *Mugil tade* in this *bheri*. It was found that it feeds mainly on algae and decayed organic matter in these surroundings. Diatoms and miscellaneous items such as copepods, cladocerans, polychaete remains and foraminiferan shells were also found to have been consumed in small quantities. The food of *M. parsia* in the *bheri* has been independently studied by Miss K. K. Sarojini of the Central Inland Fisheries Research Station. She has found (Private communication) that the food of this species is more or less similar to that of *M. tade*. Both the species feed on the benthic vegetation and organic deposits on the margins and bottom of the ponds.

Cock-up (*Lates calcarifer*).—The Cock-up or the *bhekti* is a well known predaceous species. Day (1878) found that *Boleophthalmus koelreuteri* was the favourite food of this fish, while Wallinger (1907) observed the mullet and the goby (*Boleophthalmus boddaerti*) to be its main food on the Konkan Coast. Mookerjee, Ganguly and Mazumdar (1946) have stated, however, that 60% of its food consists of crustacea and only about 22% of fish, the rest of the food consisting of algae (10%) and miscellaneous matter (Sponge spicules) (5%). Job and Chacko (1947), Devanesan and Chidambaram (1949) and Chacko (1949) have also stated that the main food of *bhekti* consists of fish and prawns. Chacko (1949*a*) found that the young stages were also piscivorous, consuming *Oryzias*, *Aplocheilus* and *Spratelloides* in large numbers. Hora (1947) did not consider its culture a paying proposition. Menon (1948) found that Teleosts formed the major portion (65·34%) of its food, the other items of food being Decapod crustacea, Anomura (23·71%), Brachyura (2·23%), and minor crustacea (2·95%).

During this investigation 75 specimens of *Bhekti* ranging from 3·0 cm. to 24·4 cm. collected from the *bheri* during different seasons of the year have been examined. Table V summarises the food items consumed by the fish.

TABLE V

Gut contents analysis of Lates calcarifer *in the* Bheri

Food items.	% composition by volume.	% of occurrence.
Fish .. .. (*Mugil parsia, Mugil tade, Mystus gulio, Pseudapocryptes*).	74·1	89·0
Crustacea .. .. .. (*Penaeus semisulcatus, Metapenaeus monoceros, Leander styliferus, Varuna litterata,* Crustacean appendages).	25·8	45·0
Plant matter .. .. .. (Dried grass).	0·1	2·5

The above table shows that the economic species of fish and prawns in the *bheri* form part of the regular dietary of *bhekti*.

PRAWN (*Penaeus semisulcatus*).—There appear to be no published records of the food of the common *Bagda chingri* of Bengal (*Penaeus semisulcatus*). Sadasivan (1950) has observed that the young of the allied species *Penaeus indicus* feed on 'fine particulate matter at the bottom, Harpacticid copepods, other small crustaceans and algal matter'. Table VI presents the summary of the gut contents analysis of 104 specimens, 8 cm.–18 cm. in length, examined during this study.

TABLE VI

Gut contents analysis of Penaeus semisulcatus

Food items.	% composition by volume.	% of occurrence.
Crustaceans (copepods)	49·1	88·2
Algal matter .. .. .. (Macro-vegetation and algae: *Chlorella, Microcoleus, Polysiphonia, Symploca, Cladophora*).	42·4	70·6
Insect larvae	4·4	5·9
Detritus	2·6	23·5
Fish remains (*Oryzias*)	1·3	23·5
Miscellaneous matter .. .. (Foraminiferan shells).	0·2	11·8

The above table indicates that crustaceans and algae are the two most important items of food of the species. A good quantity of benthic vegetation forms a regular item of food of the prawn. The adult prawns feed at the bottom of the ponds while the young ones often bury themselves in the mud at the pond bottom.

(3) *Food of Influents*

TENGRA (*Mystus gulio*)

Tengra has been considered as a larvivorous fish. Pearse (1932) found a snail in the stomach of one fish he examined. Chacko (1947) found diatoms,

copepods, prawns, small fish (*Barbus, Oryzias*) fish eggs, fish scales and sand in their guts. The gut contents of 44 specimens, 2″ to 7·9″ in length, are presented in Table VII.

TABLE VII

Gut contents of Mystus gulio

Food items.	% composition by volume.	% of occurrence.
Detritus	36·7	66·7
Copepods	17·5	50·0
Plant matter (Filamentous algae).	14·6	16·7
Decapod crustacea (Adults and larvae).	12·5	33·3
Prawns and their larvae	10·0	50·0
Fish (*Oryzias*)	8·7	16·7

The above results indicate that the fish is omnivorous, detritus being the major item of food. Mature specimens obtained in July-August had empty stomachs.

GOBY (*Pseudapocryptes lanceolatus*)

Pearse (1932) observed filamentous algae, plant remains and mud to constitute the major part of its dietary. Hora (1936) found young ones up to the 20 mm. stage feeding mainly on planktonic copepods, and adults entirely on mud. Mookerjee, Ganguly and Mazumdar (1946) recorded algae as the major food (85%); and Protozoans (5%), insects (3%), and sand and mud (7%) as minor items. The summary of the gut contents analysis of 180 specimens of the fish ranging from 2·6″ to 6·9″ in length is presented in Table VIII.

TABLE VIII

The gut contents of Pseudapocryptes lanceolatus

Food items.	% composition by volume.	% of occurrence.
Algae and algal spores .. .. (*Cosmarium, Desmidium, Spirogyra, Microcoleus, Anabaena, Enteromorpha, Polysiphonia, Oscillatoria, Chaetomorpha*).	78·1	100
Decayed organic matter	10·0	57·1
Diatoms (*Cyclotella, Gyrosigma, Navicula*) ..	7·6	71·4
Sand grains	4·3	57·1

It is seen that this fish is strongly herbivorous in habits and takes benthic vegetation as its main food.

WALKING GOBY (*Periophthalmus schlosseri*)

According to Hora (1936) this fish has a varied menu including almost everything found on the mud flats, and can jump up in the air to a height of few inches

to catch flying insects. The gut contents analysis of 80 specimens, 1·2″ to 2·5″ in length is given in Table IX.

TABLE IX

The gut contents of Periophthalmus schlosseri

Food items.	% composition by volume.	% of occurrence.
Detritus	67·3	100·0
Insects (water beetles) and young spiders ..	18·5	70·0
Microbenthic algae and diatoms .. (*Microcoleus, Oscillatoria, Anabaena, Navicula*).	9·0	25·0
Copepods	5·2	45·0

The table shows that this species of fish has a clear bias to detritus with insects and microbenthic vegetation playing a minor part in its dietary.

SHRIMP (*Leander styliferus*)

The author is not aware of any records of the food of this shrimp in Indian waters. Hiatt (1944) found *Leander debilis* and *Leander pacificus* in Hawaiian fish ponds feeding on microbenthos and detritus. The results of gut contents analysis of 300 specimens, 0·5″–1·75″ long in this investigation are summarised in Table X.

TABLE X

Gut contents of Leander styliferus

Food items.	% composition by volume.	% of occurrence.
Detritus (with decayed and dried up plant matter and sand grains)	53·3	100·0
Filamentous algae .. .. .. (*Polysiphonia, Enteromorpha, Oscillatoria*).	43·3	90·0
Diatoms .. .. .. (*Coscinodiscus, Navicula, Gyrosigma*).	3·1	66·7
Miscellaneous matter (Crustacean appendages, Polychaete remains)	0·3	5·0

This table shows that the food of *L. styliferus* is very much like that of its congeners in the Hawaiian fish ponds, consisting mainly of microbenthic vegetation and organic detritus found on the bottom of the ponds.

PRAWN (*Metapenaeus monoceros*)

The gut contents analysis of sixty-six specimens of *Metapenaeus monoceros* ranging from 2·3″ to 4″ in length is given below in Table XI.

TABLE XI

Gut contents of Metapenaeus monoceros

Food items.	% composition by volume.	% of occurrence.
Detritus (consisting of decayed plant matter, animal remains, sand grains, etc.).	79·1	100·0
Copepods and copepod appendages ..	18·6	63·6
Filamentous algae .. .. .. (*Oscillatoria, Polysiphonia, Cladophora*).	1·8	27·5
Diatoms .. .. .. (*Coscinodiscus, Navicula*).	0·5	2·5

The main food of this prawn in these ponds appears to be detritus. The copepods consumed may have been dead or live ones associated with the benthic vegetation.

CRAB (*Scylla serrata*)

Hiatt (1944) found this crab feeding on shrimps. The gut contents analysis of 88 crabs from the *bheri*, 0·8″ to 4·5″ across the carapace, is presented in Table XII.

TABLE XII

Gut contents of Scylla serrata

Food items.	% composition by volume.	% of occurrence.
Prawns and shrimps .. .. (*Leander styliferus, Metapenaeus* spp.).	65·8	83·3
Fish (gobeids, mullet fry)	13·2	41·6
Detritus and sand	11·1	41·6
Algae and higher plant fragments .. (*Chaetomorpha, Microcoleus, Polysiphonia*)	8·5	41·6
Molluscan shells	1·4	8·3

The main food of the crab consists of prawns and shrimps. Hiatt (*op. cit.*) found no evidence of piscivorous habits in this species in Hawaiian ponds, but the present study indicates that small fishes also form a minor item of its diet.

(4) *Food of Sub-influents*

INDIAN KILLIFISH (*Aplocheilus panchax*)

The Indian Killifish (*Aplocheilus panchax*) has been considered a highly efficient larvivorous fish by numerous workers (for an account of previous work *see* Job, 1941). Hora (1938) observed this fish feeding normally on ants and other insects and on mosquito larvae only when introduced into special areas under favourable conditions. Job (*op. cit.*) corroborated this with his observations in natural environments where the percentage of mosquito larvae consumed by this fish was as low as 4%, the main items of food being ants, water beetles, lower crustaceans, young stages of crabs and shrimps. These organisms together with traces of

minute Gastropods, other molluscs and some miscellaneous animals made up 98½% of the total foods, the rest (1½%) being made up of diatoms, algal filaments, plant remains with sand and inorganic fragments. The gut contents analysis of 20 specimens of the fish from 1·3″ to 2″ in length from the *bheri* given in Table XIII shows that under the ecological conditions prevailing in these ponds, water beetles, insects and insect larvae constitute the main items of food. No mosquito larvae were identified from the guts.

TABLE XIII

Gut contents of Aplocheilus panchax

Food items.	% composition by volume.	% of occurrence.
Water beetles	65·0	75·0
Insects and insect larvae	27·5	50·0
Plant matter (Filamentous algae) ..	6·25	75·0
Daphnids	1·25	25·0

KILLIFISH (*Oryzias melastigma*)

Oryzias melastigma, like *Aplocheilus panchax*, is regarded as an efficient larvivore by several workers, though no detailed work appears to have been done on the food and feeding habits of this species. Guts of forty specimens 0·7″ to 1·2″ in length were examined and the analysis of the contents is shown in Table XIV.

TABLE XIV

Gut contents analysis of Oryzias melastigma

Food items.	% composition by volume.	% of occurrence.
Algae (Filamentous and unicellular) ..	87·1	100·0
Diatoms	8·8	53·8
Sand grains	4·1	46·1

It is noteworthy that no animal matter of any kind was found in the guts of the specimens which were collected mostly from small pools on the margins of ponds where benthic vegetation is obviously the main source of its nutriment.

INDIAN SALMON (*Eleutheronema tetradactylum*)

The Indian Salmon is a well known predaceous fish of the estuaries, feeding on prawns and crabs, small fishes, and bivalves (Gadsen, 1898; Job and Chacko, 1947; Chacko, 1949). Macdonald (1948) observed the young grey mullet to be a 'dainty morsel' of these fish. In twenty specimens ranging from 2·7″ to 11·2″ in length examined by the author prawns and shrimps were found to be the most dominant item of food. The percentage of fish in the gut contents is not high enough to class it as a major enemy of the dominants in the ponds though young mullets are also found in the guts occasionally. The majority of specimens had fed on shrimps (*Leander styliferus*) and Mysids. During the rainy season megalopa larvae of *Varuna litterata* have figured as an important item of food.

LEOPARD POMFRET (*Scatophagus argus*)

Day (1887) found this fish to be a foul feeder, while Mookerjee, Ganguly and Mazumdar (1946) found 72% of its gut contents composed of plant matter (unicellular, multi-cellular and higher plants), and the rest consisting of protozoa, worms, crustaceans, fish scales and sponge spicules. The same authors (1949) found the young stages feeding mainly on diatoms, and fry above 0·8″ long, on animal food. The piscivorous tendency begins to manifest itself from the 1·4″ stage, but the adults are omnivorous. Chacko (1949) reported algae (*Oedogonium*, *Cladophora*, *Spirogyra*, *Oscillatoria* and *Lyngbya*) as the main food of the species. Fourteen specimens of the fish 0·8″ to 3·3″ in length examined by the author had fed on filamentous algae (*Polysiphonia*, *Chaetomorpha* and *Enteromorpha*).

SLEEPER (*Eleotris butis*)

Hora (1936) found in its intestines fragments of shrimps, etc., and classed it as a voracious indiscriminate feeder. In the ten fish examined by the author, only *Leander styliferus* and mysids were found in the guts.

TRANSPARENT GOBY (*Gobiopterus chuno*)

The food habits of this species have been described in a separate paper (Pillay and Sarojini, 1950). The fish from the *bheri* seemed to live mainly on copepods, and occasionally on nauplius and zoea larvae.

GOBY (*Stigmatogobius sadanandio*)

Hora (1936) found remains of amphipods in the guts of this fish. Fifteen examples 1·2″ to 1·7″ in length, from the *bheri* had 67·5% of the gut-contents in the form of detritus, 22·5% of filamentous algae (*Polysiphonia*, *Chaetomorpha*) and 10% animal matter, mainly insect remains. The nature of the gut contents strongly suggests it to be an iliophage, feeding at the bottom of the ponds.

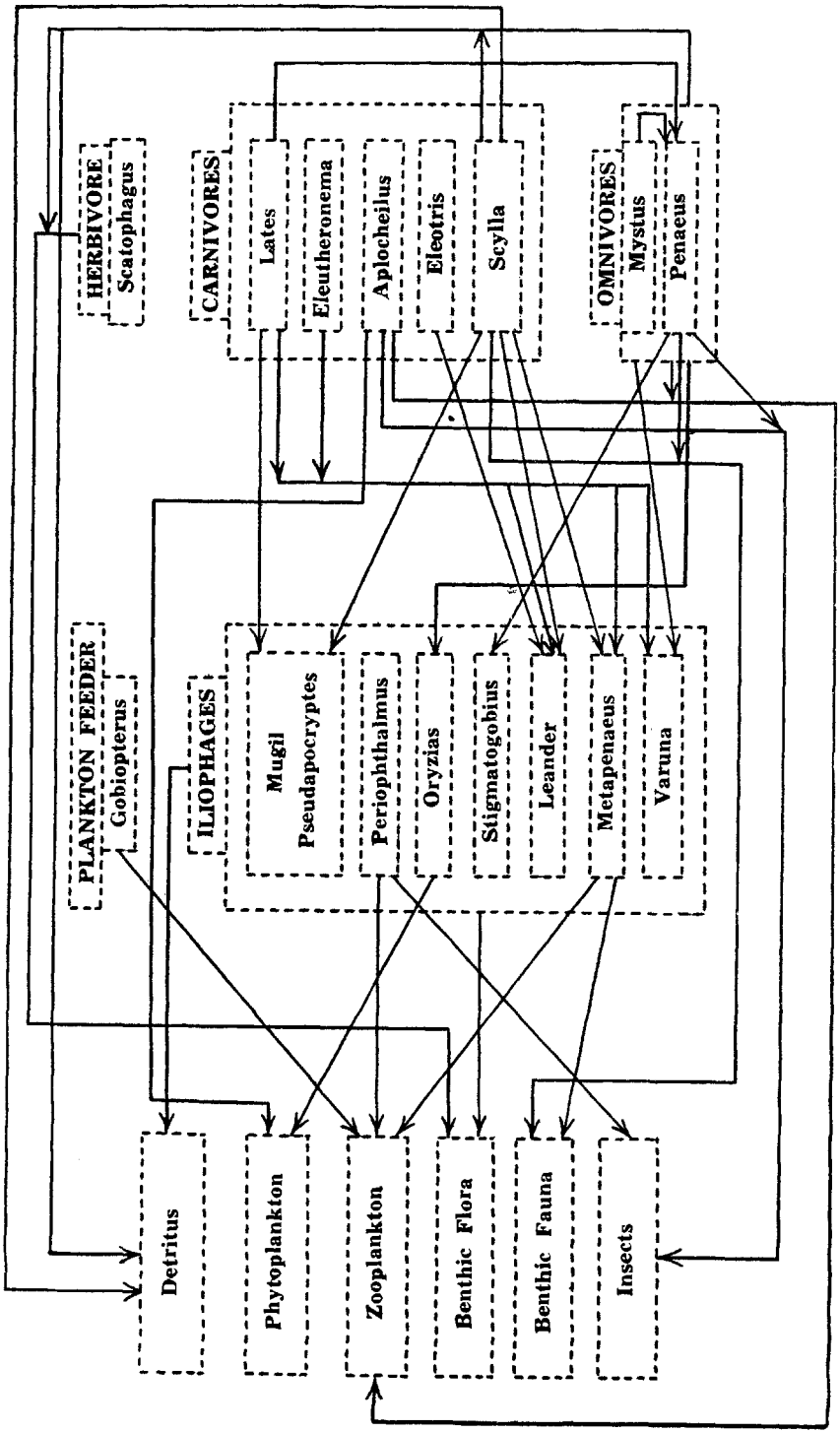
CRAB (*Varuna litterata*)

There does not appear to be any record of the food of this species in Indian waters. Twenty-one specimens of this crab, 0·9″ to 1·2″ across the carapace, had their guts almost full (92·3%) of benthic vegetation (*Polysiphonia*, *Enteromorpha* and *Cladophora*), diatoms (*Cyclotella*, *Surirella* and *Spirulina*). Detritus containing large quantities of decayed and decaying plant matter formed about 7·3% and miscellaneous matter constituted 0·2% of the gut contents. As Megalopa larvae of this crab feed on fish larvae, they might prove detrimental to the fish larvae entering the ponds.

(5) *Inter-relations of the food of the fauna*

The food relations of the ecologically important animals in the *bheri* are represented in Text-fig. 5. One outstanding feature of this relationship is the predominance of iliophagous animals. The benthic flora and detritus form major items of food of the mullets, prawns and shrimps. While the mullets (*Mugil parsia* and *M. tade*), the prawns (*Penaeus semisulcatus*), and the Crabs (*Scylla serrata*) are of economic importance, the gobies (*Apocryptes lanceolatus*, *Periophthalmus schlosseri*, *Stigmatogobius sadanandio*) and the Killifish (*Oryzias melastigma*), are not of any market value. They compete with the dominants in the ponds for food, and should therefore be eradicated as far as possible.

An examination of the tables of analysis of gut contents shows that the surface phyto- and zoo-plankton are not consumed in any appreciable quantities by the



TEXT-FIG. 5. Diagrammatic representation of the biotic interaction of the ecologically important fauna of the *bheri*. The arrows point from the animal to its main food items.

majority of the ecologically important fauna. Tengra (*Mystus gulio*), the *Bagda chingri* (*Penaeus semisulcatus*), the Killifish (*Aplocheilus panchax*), and the Transparent and Walking gobies do feed on them; but it is only the *Bagda chingri* that consumes any appreciable quantities of plankton.

The *bhekti* (*Lates calcarifer*), the Indian Salmon (*Eleutheronema tetradactylum*), the Sleeper (*Eleotris butis*) and the Crab (*Samudra kenkra*) (*Scylla serrata*) are the main carnivorous species in the ponds. Of these, the *bhekti* is definitely a major predator of the dominant animals. As the number of Indian salmon and the sleeper (*Eleotris butis*) in the ponds is not very high, the harm done by them is not very conspicuous. But the crab, *Scylla serrata,* is found in such large numbers that they take a heavy toll of prawns and shrimps, especially their young stages.

The picture of biotic interaction in the ponds indicates a high demand on the benthic vegetation and detritus and a negligible one on surface plankton.

Discussion and Recommendations

The present status of fish culture in the *bheri* is not very satisfactory owing to the conspicuous lack of concerted effort to improve production. As in many other *bheris,* the fishery consists more of capture operations than fish culture. Since such operations ultimately help in reclaiming these areas for paddy cultivation, many of the *bheri* owners attach only a secondary importance to this industry, resulting in this old and beneficial fish cultural practice being given up. Rao (1949) has referred to the great contribution that fish culture in brackishwaters, can make towards fish production in India. An all round intensification of culture operations is essential to increase the productivity of the embanked brackishwaters (*bheris*) in Bengal.

(1) *Water supply.*—An important reason for the deterioration of the *bheri* under observation, like many others in the area, is the unsatisfactory water supply, due to the greatly diminished tidal range in the river in recent years. Although the improvement of water supply by excavation of the river bed is the only obvious solution under the circumstances, it is generally held that the enormous quantities of silt carried down by the river will soon silt up the excavated river bed, reverting to the original conditions in a short period. It has, however, been found that at Taldi only about four miles down the river, a tidal range of 8 to 12 ft. now obtains, giving rise to *bheris* with a perennial water supply in that area. This tidal range is not appreciably different from that obtaining in the river Matlah at Port Canning.* As the distance from Taldi to Ghutiari Sharif is very short, it should not be difficult to improve the river conditions here by the removal of the accumulated silt. Engineers consider this suggestion feasible, and it merits a trial as this will improve the condition of many other *bheris* in the locality.

In the pond system itself, the canals and the main feeder channel can be deepened by proper excavation, resulting in larger quantities of water flowing into the ponds.

The fishes, prawns and crabs in the ponds can withstand wide variations in salinity, and can therefore acclimatise themselves to life in freshwater. It would appear, therefore, that the place of tidal water can be taken by freshwater from the canals outside the *bheri* in which a more or less constant depth of water is maintained throughout the year, even after considerable quantities of freshwater have been drained off during the rainy season. These canals can also be employed for the storage of freshwater, thus converting a portion of the *bheri* into a reservoir for the purpose. The possibility of pumping in river water or providing tube-wells worked with the cheap aid of windmills to feed the ponds, is also worth investigation.

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* Information obtained from Mr. A. N. Banerjee, Outfall Engineer, Calcutta.

(2) *Selective stocking.*—One of the main reasons for low production in the ponds is inadequate stocking. As stated above (page 408) intensive stocking is done during the winter season when the fry of only a few important fishes are available, and the supply of tidal water for stocking purposes has diminished as a result of the silting up of the river. As fry of mullets and young prawns are available in thousands in the shallow pools and swampy areas near the river and the *bheri*, they can be collected with nets made of mosquito-netting during the monsoon season when the fry of *Mugil tade* are also available. A circular type of dip net such as is used by the fishermen for crab fishing (Hora, 1935) in this area and for mullet fry on the Contai coast (Pillay, 1949) can be employed with the aid of a string attached to the circular frame to facilitate dragging in pools. The fry can be transported in earthen handies in the manner adopted by the fishermen of the Contai Coast. The adoption of the stocking method suggested above will not only allow selectivity of fry but also prevent the entry of a large number of undesirable species. A sufficient number of fry of *M. tade* can also be stocked in the ponds.

(3) *Predator control.*—The dominant and palatable *Bhekti*, is a voracious feeder and a confirmed enemy of the economically important fishes including mullets, and the methods of its culture deserve therefore special consideration. Hiatt (*op. cit.*) has expressed the opinion that the rearing of carnivores for market purposes takes the income of the operators into the realm of diminishing returns. According to MacGinitie (1935) the plant weight at the beginning of the food chain is greater than any weight following, due to the dissipation of weight along the food chain. It has been considered (*vide* Pearse, 1939) that bottom feeding fish consume a total of about ten times their own weight each year. He estimated that 10,000 pounds of algae make 1,000 pounds of tiny crustaceans, which make 100 pounds of small fish, and in turn 100 pounds of small fish make 10 pounds of large fish or one pound of man. As in the Hawaiian fish ponds these proportions are very much altered in this brackishwater *bheri* also, since the small and large fish consume algae and detritus directly. The weight ratios estimated by Hiatt (*op. cit.*) *viz.*, 10,000 lbs. of algae and detritus for 1,000 lbs. of herbivorous fish, 1,000 lbs. of herbivorous fish for about 100 pounds of carnivorous fish, might be more indicative of the conversion processes in this *bheri*. About 100 lbs. of small carnivorous fishes may be necessary to make up 10 lbs. of large carnivorous fish. These facts are certainly suggestive of the uneconomic nature of the culture of predaceous fish. However, the fishing industry like any other industry, has to run on the principles of demand and supply. As the Cock-up is a well-relished fish and commands a good market, it would not be advisable to stop their culture. It may be economical, however, to culture them in separate ponds and thus prevent the destruction of the other economic varieties of fish and prawns. The gobies form an uneconomic group of predominant fauna in the ponds. But in the ponds the Cock-ups do not seem to feed on them in large numbers, probably because they are too agile and capable of taking shelter on the exposed mud flats. However, if the fish culturists can capture these numerous small gobies and artificially feed the Cock-up with their flesh, it may serve to fatten them and accelerate their rate of growth. *Eleutheronema tetradactylum* is not a predominant species in the ponds and if selective stocking is resorted to, it should not be difficult to control their population. The crab, *Scylla serrata*, is harmful in more than one way. It is predatory as stated above (page 419) and is responsible, along with *Varuna litterata*, for burrowing and thus weakening the embankments. However, its main food consists of the shrimp (*Leander styliferus*) which is only of secondary importance in the pond-economy. The only means of controlling it appears to be intensive fishing for adults and preventing the entry of young ones through sluice gates by means of suitable wire-net fencing. If selective stocking is adopted, the sluice gates can be covered with such protective devices to prevent the entry of undesirable species.

(4) *Production of food for fish.*—At present the fish culturists do not attempt the augmentation of food resources for the fish in the *bheri*, as is done in the culture of freshwater fishes in ponds. The author (Pillay, 1953) has referred to the best means of increasing fish food resources in the brackishwater farms in India through the culture of algae as practised in Indonesian and Philippine waters, where periodic draining and fertilization contribute to rich growths of algae in ponds. In East Java, ponds are drained as many as four times a year, and sometimes every few days to stimulate growth of Myxophyceae in them (Schuster, 1951). The same phenomenon may be observed in the *bheri*, if it is drained and exposed to the sun for a couple of days. The high organic contents of the soil in these ponds allow of such drainings without much detriment to the basic fertility of the soil, but as pointed out already, the lack of an adequate water supply makes this method impracticable. This circumstance makes it essential that all available water should be conserved for the proper operation of the ponds. So, the most practicable means of increasing the growth of myxophyceae in these ponds seems to be the application of manures to the soil and not to the water which will help to grow only phytoplankton. Schuster (1951) has recommended for Java the use of green manure, about 1,500 lbs. of grass or mangrove leaves per acre, to produce good results. In view of the fact that the fishery owner usually cultivates paddy also in the nearby fields, he may be in a position to use sufficient quantities of green manure to fertilize the ponds, if not superior types of organic manure, as there are considerable swamps overgrown with grass and other vegetation near the *bheri*. These could be collected and deposited in the ponds in suitable localities to decay slowly and supply the necessary nutrient material for the growth of algae.

The provision of 'collectors' for the attachment of algal spores was also suggested by the author in a recent paper (Pillay, 1953). As these will help the young fry only, and not fish larger than about 2" in length, it will not be economical to adopt this suggestion, unless separate nursery ponds are maintained for the purpose.

(5) *Extension of rearing period.*—As stated above (p. 408) the majority of the dominant fishes are caught at the end of about three to nine months. The former practice of transferring these immature fish into the subsidiary ponds at the time of draining and final cropping should be revived so that a better yield could be obtained. At the end of the second year they would have attained a marketable size fetching a better price. As *Mugil tade* and *Lates calcarifer* rapidly increase in weight after the first one or two years of their life, they should be reared for periods longer than two years.

(6) *Development of subsidiary industries.*—*Suaeda maritima*, the characteristic vegetation of the embankments of the *bheri*, is often collected by people for consumption as a vegetable. The fishermen do not evince any interest in the cultivation, utilization and sale of this plant from which they could derive a good subsidiary income. The embankments of the *bheri* are devoid of any large shrubs or trees. Under similar conditions Schuster (1951) has recommended the planting of Tamarind trees (*Tamarindus indicus* L.) on the embankments of *tambaks* in Indonesia. Besides providing good shade, the tamarind fruits command a good market. A full grown tamarind tree produces above 50 lbs. of fruit annually if planted at distances of about 50 ft.

The coconut palm has very strong halophytic tendencies (Ferguson, 1937) and can thrive well on brackish soils. The soil of the embankments of the *bheri*, which is also rich in humus, may prove quite suitable for the cultivation of coconuts.

Summary

A detailed description of the topography of a brackishwater *bheri* at Ghutiari sharif is presented. The salinity of the water was found to fluctuate considerably during different

seasons. The depth of water in the ponds varied with the seasons and the spring and neap tides. The main features of the flora are the scarcity of macrovegetation and the richness of microbenthic growths of algae. Copepods occur in large numbers in the surface plankton. Prawns, shrimps and fishes form the main macrofauna of the ponds. The young of these are allowed into the ponds for purposes of culture. A classified list of the fishes occurring in the ponds is given.

The fish culture practices are described. Young fish and prawns are admitted into the ponds at spring tides, mainly from January-April. A sufficient level of water is maintained in the ponds by letting in water through sluice gates during spring tides. By about October-November, the ponds are dewatered and the fishes and prawns are removed for sale. Mullets, Prawns and Cock-up are the dominant animals cultured. The catfish (*Mystus gulio*) and the shrimp (*Leander styliferus*) also grow in the ponds in large numbers. The estimated production from the ponds is about 100-150 lbs. per acre of inundated area per year.

The ecologically important fauna of the ponds is divisible into three categories, viz., dominants, influents and sub-influents. Their food relations were studied by the examination of the gut contents of specimens caught from the ponds. A predominance of Iliophages has been observed. It was found that the surface plankton is consumed only by very few animals. The Cock-up and the Crab (*Scylla serrata*) are the main predatory species.

Possible means of increasing production from the *bheri* are considered. An intensification of operations is essential for better yields. The water supply has to be improved either by facilitating tidal flow or supply of fresh water at suitable periods.

Selective stocking will enable a better control of the pond fauna. The main predator, the Cock-up, can be cultured in isolated canals or ponds, so that it will not feed on the economically important fishes and prawns.

Regular draining of ponds for increasing algal growths as in Java and the Philippines may not be possible in this *bheri* due to the restricted water supply. However, the production of algae can be increased by the application of suitable organic manures on the pond bottom.

An extension of the rearing period of the fishes like *Mugil tade* and *Lates calcarifer* to two or three years will be desirable from the point of view of economics.

The planting of coconut palms and tamarind trees on the embankments may, besides providing good shade in this open area, help in enhancing the income of the fish culturists.

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