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EFFECTS OF CALCUTTA SEWAGE UPON THE FISHERIES OF THE KULTI ESTUARY AND THE CONNECTED CULTIVABLE FISHERIES[1]

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Contents

Introduction

The present investigations relating to the effects of Calcutta sewage on the fisheries of the Kulti estuary were initiated in 1948, pursuant to the complaints of fish farmers of Kharibaria near Calcutta that the Kulti no longer served as a 'seed' resource for culture fisheries since 1939 when the sewage from the city began to be discharged into it. Several species of Mullets, the Bhetki—a perch—some minor Fishes and a number of Prawns are extensively cultivated in these brackish-water fish farms, locally known as 'bhashabada' fisheries or 'bheris' (*vide* Sewell, 1934, Hora and Nair, 1944 and Pillay, 1954). The affected farms extend to an area of nearly 75 sq. miles to the north and north-east of Calcutta within a radius of about 50 miles and are capable of supplying appreciable quantities of freshly caught Fish and Prawns daily to the city's markets.

Some knowledge is now available in India on the effects of industrial wastes' pollution on freshwater streams and rivers from the observations conducted by Hora and Nair (1944), Bhimachar and David (1946), Ganapati and Alikunhi (1950), Ganapati and Chacko (1951), Banerjea, Motwani and Karamchandani (1956), Motwani, Banerjea and Karamchandani (1956) and David (1957). Nair (1944) and Bose (1944) have discussed at length the problem of sewage pollution in India with reference to the Kulti estuary and Calcutta sewage disposal. Whereas the estuarine and foreshore areas entirely differ in scope and manner of pollution from the freshwater rivers, the standards of assessment also differ widely due to the tidal effects and salinity. In other countries, estuarine and foreshore pollutions affect

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mainly the spawning runs of Salmon or Shad and also damage oyster beds (Alexander *et al.*, 1935 and Galtsoff *et al.*, 1947), but the problem presented by the Kulti concerns a damage caused directly and indirectly to fairly rich capture and culture fisheries.

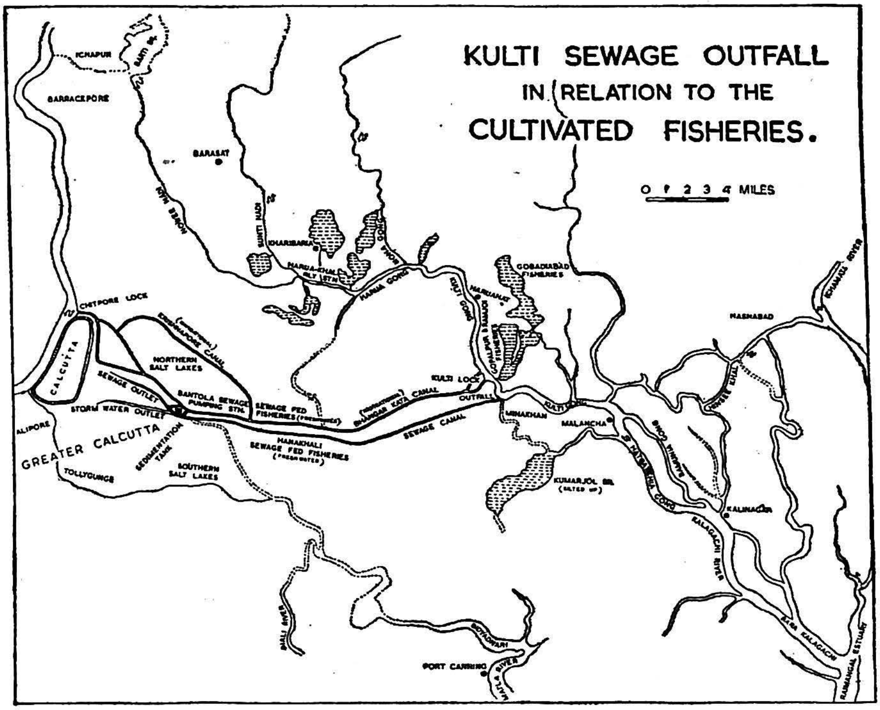
HYDROGRAPHICAL FEATURES OF THE KULTI ESTUARY

A brief description of the Kulti and its surroundings is essential for a proper understanding of the peculiar hydrographical features involved, as pollution is linked closely with the tides and topography. Deltaic Bengal is formed of rich alluvium and clay brought by the combined waters of the Ganga and the Brahmaputra rivers, which enter the Bay of Bengal through the Meghna in East Bengal at the extreme eastern end of the delta now in East Pakistan (Majumdar, 1942 and David, 1953). Between the seasonally alive Hooghly and the perennial Meghna are a number of tidal creeks which are no better than incoming arms of the sea scattered over an area of 6,000 sq. miles. The majority of these tidal rivers are interconnected by channels, the rich overlying soil being covered by the almost impenetrable 'Sunderban' forests. The Kulti estuary is part of an off-shoot from the Royamangal estuary and is variously known as Barakalagachi, Kalagachi, Hatgachiagong, Kultigong and Haruagong to its termination into three narrow arterial channels, the Nonagong, the Sunthee and the Nowee (refer map). The latter are three tidal rivulets spilling into the brackish-water culture fisheries around Kharibaria and swamps in the north-east of Calcutta. The Kulti creek from the junction of Sunthee to Malancha, the stretch now studied, is about 18 miles. The distance between the Kulti outfall to the junction of Barakalagachi with the main Royamangal is 24 miles and to the sea about 80 miles.

In the Bengal estuaries, the tidal pulses travel between 120 and 180 miles from the sea owing to a very low gradient of less than one inch per mile, subjecting the low-lying delta constantly to scours and sedimentations. There are extensive water-logged swamps many of which are converted into rich 'bheris'. Ramjoi and Gobadiabad fisheries, extending together to over 7,500 acres, are the largest near the outfall that open into the sewage mixed waters of the Kulti (map).

There are no perennial sources of flush water to the Kulti *above* the point of sewage outfall, but the Sealdahgong about 5 miles below (map) brings a fair amount of tidal water from the Ichhamathi through the Hinsee Khal and also serves to take away some of the contaminated water. Some fresh water also is brought through it during monsoon months from the Ichhamathi which receives then considerable amount of spill water from the flooded Padma river. Run-off water over a catchment of about 250 sq. miles through the arterial channels of the Nowee, Sunthee and the Nonagong, as well as about 150 sq. miles of catchment over Calcutta and adjacent areas render the Kulti fresh for two months in August and September.

Between 1920 and 1930, sewage disposal became a matter of great concern to the authorities of Calcutta Corporation due to the deterioration of the Bidyadhari, an adjacent tidal creek originally used to carry away Calcutta sewage, and the authorities (Banerjee, 1931 and 1935, and Banerjee and Ganguly, 1947) selected the Kulti as the best medium to carry away the growing load of sewage after a close study of its favourable hydrographical features. The channel depths of the Kulti vary up to 42 feet near the outfall site during high tides. The margin between the lowest low tide and the highest high tide is about 17 feet. During the neap periods a margin of 8–11 feet is usually observed between tides. Average high



water level at the outfall site is 14·50 feet and low water 3·33 feet above the datum. Maximum flood discharge of 27,000 cusecs and ebb discharge of 24,000 cusecs have been recorded at the outfall site, but these figures dwindle to as low as 8,000–9,000 cusecs at low tides, the periods of maximum sewage concentration. Average discharge at 3 feet per second at the outfall site is about 17,000 cusecs, even though maximum velocities of 4·76 and 5·78 feet per second ($3\frac{1}{2}$ to 4 miles an hour) are recorded respectively at flow and ebb tide currents. Considering the cross-sectional areas, the amount of water flowing at any particular point varies considerably within a short distance of about 15 miles. At Haruahot it is less than half as much as at the outfall, but is nearly double at Minakhan and 5-6 times at Malancha.

Mode of Sewage Discharge and Dissipation

The sewage channel from Bantola (where sewage is collected, sedimented and pumped) to the outfall is 17 miles with a slope of 6 feet between points, or less than 5 inches per mile. Methods of sewage treatment are described by Bose (1944) and Nair (1944). The original dry-weather channel proposed to carry only sewage has not been completed and the sewage flow is thereby diverted part of the way directly into the partially completed storm-water channel. Almost all the solids in suspension are dropped in the head reach of the storm-water channel and the incompletely treated liquid sprawls over it taking nearly eight days to reach the outfall. The bed level of the dry-weather channel at the outfall is lower by about $3\frac{1}{2}$ feet from the average low water level of the Kulti. This entails building up of a head in the sewage outlet before it can discharge into the Kulti twice daily during low tides.

The sewage channel is designed to carry a maximum load of 670 cusecs of combined sewage and storm water from Calcutta, though its normal requirement is to discharge about 272 cusecs or 150 million cusecs of sewage per day. At the outfall the channel is provided with 16 vents with a total capacity of 2,200 cusecs discharge, but in actual practice five vents are generally kept open, except during monsoon bursts or near-drought conditions, discharging about 688 cusecs or 4,286 gallons per second. During monsoon months additional gates are opened to prevent spilling of septic sewage on the outlying areas as storm water from the city and around the channel itself has to be drained. Between February and May all the vents except one remain closed for short durations to prevent too much discharge of sewage, when in some years nearly 60 per cent of its water is utilized raw for freshwater pisciculture (mainly Carps) in the Bidyadhari, Bantola, Dhapa and Hanakhali areas.

Sewage discharge occurs 20–22 days in a month as the gates are completely closed for 2-3 days on each side of the full or new moon days during spring tides. Periods of actual discharge have varied from 5½ to 13 hours per day. The levels of water in the sewage channel are comparatively stable in relation to the fluctuating Kulti, where the level first becomes flush with the vents and rises five feet above the normal level of discharge head. Table I gives a fair idea of sewage discharge as gathered from a test record during May and June, 1947, for each of the first and second tidal phases in the course of a day.

There were 22 days in May when sewage drained into the Kulti on an average of 8 hours and 13 minutes per day. Similarly, sewage drained for 9 hours and 20 minutes on an average for 21 days during June.

The ebb flow carries the sewage first downwards for about 2 hours once discharge commences. As the level near the outfall decreases more sewage is drawn into the estuary, when the ratio of sewage increases to 1 : 12 from 1 : 43 within about 3 hours. At the turn of the tide, this surcharged mass, now concentrated near the outfall and diluted for 5 miles below, is lifted upwards for a duration of about 5 hours. Hence nearly a distance of 7-8 miles towards Malancha inclusive of Sealdahgong is affected first by a downward moving mass of sewage and the entire Kultigong above for 18–20 miles by the upward flowing mass of the same sewage. All the time more and more sewage is still being drawn into the Kulti from the sewage channel, surcharging the Kulti as the level decreases. The sewage-mixed upper extremity travels still further for the next 3-4 hours a distance of 6–10 miles entering the arterial channels, finally spilling into the brackish 'bheris' near Kharibaria and other fisheries. As long as the sewage drainage does not cease, this concentrated mass oscillates only within the stretch above the outfall, rendering the estuary a vast septic tank. Channels of the Nowee, Sunthee and the Nonagong and their connecting culture fisheries therefore receive only this concentrated sewage instead of fresh estuarine water in the absence of a by-pass or source of uncontaminated water. It is only 5 miles below the outfall that the sewage-laden water can normally get diluted or dissipated otherwise by an addition of water from the Sealdahgong or lower Kulti as described earlier (map). It is obvious that under the above conditions the upper 24–30 miles of the Kulti and Haruagong above the outfall progressively become loaded with sewage, as the column of drained sewage cannot get past the outfall without receiving still more sewage.

There is no drainage of sewage generally during levels above 10½ feet

TABLE I

Showing Averages of Sewage Drain

	Drainage Starts (Levels in feet)			Drainage Stops (Levels in feet)			Total Drainage Period (In hours and minutes)		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
May, 1947—I Phase	11′ 6″	6′ 2″	7′ 3″	9′ 11″	4′ 10″	5′ 4″	6-10	2-45	4-03
II Phase	13′ 8″	6′ 0″	7′ 9″	10′ 0″	4′ 5″	6′ 1″	7-05	2-50	4-12
June, 1947—I Phase	11′ 6″	6′ 7″	9′ 2″	8′ 8″	4′ 9″	6′ 1″	6-20	2-50	4-25
II Phase	13′ 4″	6′ 6″	9′ 1″	9′ 4″	4′ 9″	7′ 0″	6-30	2-50	4-55

and some uncontaminated water can then reach the outfall region from the lower estuary for about 2 hours during flow tides. When sewage drain is stopped during high spring conditions, the sewage-ridden water above the outfall continues to dissipate below, neutralizing any slight beneficial conditions the flow tide currents might have brought about in the water.

METHODS AND MATERIAL

The above hydrographical features of the Kulti estuary were considered for purposes of sampling since the outfall point can be defined as either polluted or fresh in relation to the height of the tide. The higher the tide, the farthest downstream is the point from which contaminated water would have travelled to the outfall site. Similarly, the lowest the tide, the pollution would be at its maximum and the water examined just above the outfall would have travelled from a remote point above. (Pollution studies in an estuary are conducted considering such tidal factors, unlike in a freshwater river where a continuous stretch has to be examined.) Hence high tide samples of surface water and tow-net plankton hauls at slack periods showed conditions prevailing 10–15 miles below. Likewise, low tide samples just before the slack showed the worst conditions in the sewage-mixed estuary water. A low tide sample taken 1½ miles above the outfall site, close to the Kulti lock (map), revealed the quality of water and plankton that can be expected to move into the arterial channels at high tide. In all 13 sets of water samples and 14 sets of plankton were obtained during 14 visits between 1954 and 1955. Such visits were given within a day or two from a full or a new moon day at spring tides and represented the *best conditions of the Kulti*, as sewage flow was generally stopped for 3–5 days for reasons mentioned earlier. Three such visits when only plankton and fish were examined had also been given during 1948.

Fishes were obtained from fishermen operating various gear and examined fresh. Fishery conditions and distribution of burrowing or mud-flat fauna were studied first-hand, whenever possible, several times.

Hydrographical conditions pertinent to this study were gathered from reports available with the Director, River Research Institute, West Bengal, and the Corporation of Calcutta.

PHYSICO-CHEMICAL NATURE OF AFFECTED WATER

Under normal conditions the decaying processes at work in the Bengal delta are determined by the velocities of tides, rate of sedimentation or scouring and amount of upland flushing water. The tidal Kulti has several times shown signs of deterioration and recovered promptly as available reports show. Bose (1945) has stated that addition of sewage has not altered the physical conditions for the worst as the total solids and salinity of the river under all conditions of tide and season are always greater than those of sewage samples, showing that the effect of sewage on the Kulti is more of dilution at least in the above respects. The huge amounts of colloidal organic matter deposited do not perceptibly act as sensitizers to the silt, nor do they affect the rate of sedimentation even at the slack period of 40–60 minutes between tides. The amount of dissolvable organic matter thrown by Calcutta sewage in 1940 (according to Calcutta Corporation's estimates) into the Kulti was of the order of 7-8 million cubic feet in a year. This would have easily doubled itself during 1954-55 in proportion to the increase in population and expansion of sewers.

Table II indicates the values of chemical tests on samples of water.

Results of analysis of raw sewage at various places along the channel till its outfall are given variously by Bose (1944), Nair (1944) and Basu (1950).

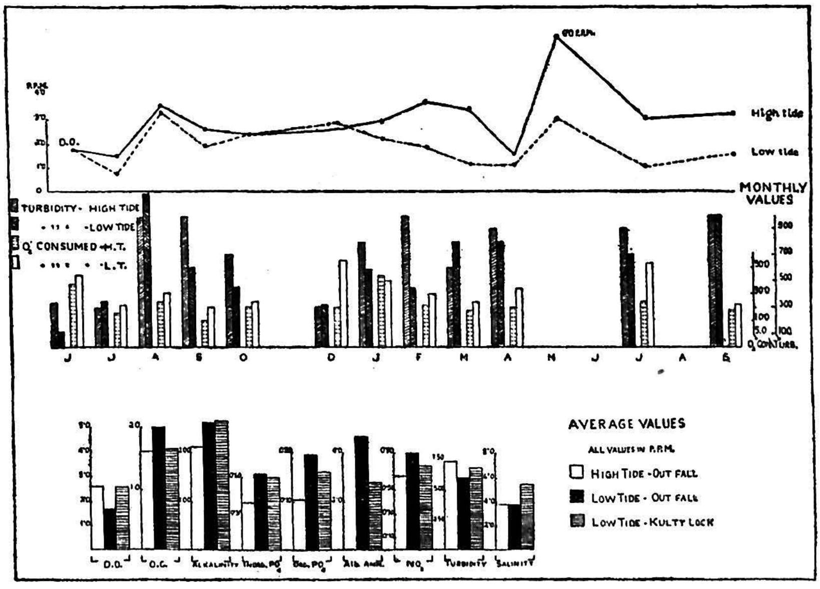
It is observed that mean turbidity figures for the low and high tides are 737 and 611 respectively at the outfall, which are not very high compared to a maximum of 2,500 in the Hooghly in its cleaner section (Bose, 1956). The turbidities encountered in the Kulti do not seem to form a limiting factor for the phyto-plankton production as they are well below levels considered unfavourable.

Little if any silt tends to deposit itself at the bottom except during the short slack periods between tides. Silt deposition, however, has been calculated at 0·54–1·89 m.c. ft. per mile above the outfall, but at the same time a scour of 2 feet during monsoon offsets any marked silting up of the river bed. Particles below 0·02 mm. form almost 100 per cent of the total silt carried by the river, but at times 0·113–8·301 per cent of the silt constitutes larger particles of over 0·075 mm. including minute quantities of sand.

Deterioration of Kulti's upper arterial channels and connected fisheries has actually been in progress due to natural causes of silt deposition or reclamatory practices even before the sewage was introduced. Silt beds, however, are not formed within the Kulti wholly due to sewage action as in many other tidal waters which are not subjected to high velocity currents and receiving heavy amounts of sewage loads from large cities.

At the outfall site a discoloration of water and foul smell can always be detected, disappearing only at high tide slack periods. This does not denote that the water is actually free from pollution at high tides (please refer to D.O. and other values). No solids are thrown into the estuary. Owing to the rapidity of currents, no agglutinized organic particles can settle anywhere in the estuary and the bottom is remarkably free from all signs of organic disintegrated scum and the outfall site cannot be measured from standards of conditions prevailing at similar outfall sites in freshwater rivers.

The pH values observed have a mean value of 7·4 both during high and



low tides at the outfall site, whereas 6·8 to 7·0 are recorded for the raw sewage by Basu (1950). Any minor variations of pH alone in the estuary do not indicate harmful effects on the fish or other organic life, since such values are well within limits prescribed for productive waters.

Dissolved oxygen (D.O.) has only once shown a maximum of 6·0 p.p.m. with a mean reading of 2·68 p.p.m. (13 readings) during high tides. At a time therefore when there should have been an influx of highly oxygenated and fresh tidal water from the lower sections, the D.O. was still poor. Mean values of D.O. at low tides are 1·89 (lowest being 0·8 p.p.m.) and the highest 3·73 p.p.m. in August, at a time when supposedly better conditions should prevail owing to rains. Low tide mean at the Kulti Lock is 2·7 p.p.m. Irrespective of the tidal conditions, the D.O. is consistently far below the normal (5·6 p.p.m. lowest mean noted by Bose, 1954, in the Hooghly) and seems to be quite insufficient for a healthy existence of organic life including fish. These low values tend to enhance any toxical effect already present in the river on fish which could otherwise survive oxygen deficiency to a marked degree.

Similarly, Oxygen Consumed (half-hour in $KMnO_4$ at 100°C.) has varied between 11 and 32 p.p.m. under all tidal conditions. The mean values of 16·16, 20·75 and 16·75 p.p.m. respectively at high and low tides at the outfall and at Kulti Lock at low tide are decidedly high. Oxygen Consumed being proportional to the strength of sewage is generally high, indicating a large load of organic matter at all times.

Alkalinity figures show mean values of 210 p.p.m. during high tides as compared with 259 p.p.m. and 263 p.p.m. during low tides. Even during high tide conditions when there had been no discharge of sewage for 5-6 days, alkalinity was considerably high, showing water's latent capacity for bioactivity.

Albuminoid ammonia combined with traces of free ammonia is indicative of disintegrating organic matter in a sheet of water. Compared with the Tees estuary (Alexander *et al.*, 1935) where albuminoid ammonia was only 0·08–0·82 p.p.m., the average values of 2·32, 4·65 and 2·98 p.p.m. in the Kulti are extremely high. Albuminoid ammonia much above 0·2 p.p.m. is to be regarded with suspicion.

Since presence of nitrate shows treated sewage, values between 0·4 to 1·2 p.p.m. during high tide currents coupled with traces of ammoniacal nitrogen are evidences of a considerable degree of pollution and are of potential hazard to fish life.

Correspondingly increased values are shown by phosphates (both inorganic and organic), which are high even during high tides and indicate the potential capacity for plankton productivity of the Kulti due to fertilization effects provided other undesirable conditions are not present.

Organic matter in the bed silt of the Kulti has varied from 0·4 per cent opposite the outfall to a maximum of 4·0 per cent at the Kulti Lock site and 3·0 per cent at Haruakhal Railway Station (map) and also at Kalinagar at the extremities of the Kulti. This shows the enormous organic matter carried by the Kulti. Organic carbon in silt at the outfall site (200 yards below) has varied between 300 and 780 mg. C/100 of silt, showing the heavy load of humic matter in the river which has contributed towards this absorption.

Biotal Studies

Plankton

In Table III a list of planktonic organisms noted during various hauls is given. No bacteriological studies were undertaken; it is likely that due to an admixture of saline water at the tail end of the dry-weather channel and perhaps some inhibitory causes within the sewage water itself, which seems to carry considerable industrial wastes inclusive of toxicants from a gas generating plant, the usual sewage bacteria and fungi are not profuse. *Sphaerolitus* tufts were not observed but stray strands were recognized. Mycelial threads of *Beggiota* and *Zooglea* were found even in high tide samples. Numerous spores of these complex sewage fungi and mucus-like concentrations of mixed *Mycelia* were found, particularly in the sewage-polluted water at low tides. No sessile *Mycelium* of any group was recorded.

Among Protozoans, *Rhyzopoda* was the most frequently occurring group. Two to three species of *Difflugia* were recorded almost round the year. *Amoeba* noticed in the raw sewage on a few occasions was not found in the estuary, probably having disintegrated in saline water. Except one species each of *Foraminifera* and *Heliozoa*, both of which undoubtedly were of marine origin, all other related Protozoans were conspicuously absent. Amongst Ciliates, only once a few *Vorticella* were recorded, all other genera being unrepresented. Even in the Hooghly, the number of Protozoans are not too high, but those present occur in fairly large numbers unlike in the Kulti (Dutta *et al.*, 1954).

At least two species of sponges have been noted in the Kulti (as identified from spicules), but their origin was uncertain. Several Medusae ranging between 2 and 35 mm. in diameter were collected once in June, 1954, both at high and low tides, but the majority of them were dead when removed during low tides. Stray hydroid colonies have also been recorded at the same time.

Only three species of Rotifers, e.g. *Brachionus*, *Notholca* and colonies of *Conochilus*, were noted at various times. Obviously they were effluent or freshwater in origin and were probably unable to withstand any prolonged change to brackish-water medium.

Polychaete eggs at various stages of development and sometimes within mucilaginous masses were obtained from a few to fairly large numbers during dry months of increased salinity. None showed embryonic movements or other signs of life. Those kept in jars for observation soon disintegrated, indicating that they were probably dead even before collection.

Among the higher forms, the Copepods were represented surprisingly by not more than three species one of which was *Pseudodiaptomus* sp. Generally these and the majority of unidentified Nauplii were already dead on collection during low tides. No Copepods were recorded at all during July and December, 1955—a remarkable feature in any estuary. Considering that the brackish waters of Bengal are very rich in Copepodan fauna (Sewell, 1934), survival of only three representative species in the polluted Kulti and occasional total absence is directly attributable to the ill-effects of pollution. Dutta *et al.* (1954) recorded that the Copepods are the most abundantly represented group of fauna in the Hooghly estuary and listed some 23 genera as against the three now observed in the Kulti. Cladocerans were entirely unrepresented. Zoea and Mysis of unidentifiable Crustaceans were noted in June and July, 1954, and May and September, 1955. These two were mostly dead when collected. *Gammarus*, referable perhaps to more than one species, and *Sagitta* sp. were obtainable alive occasionally even during low tides and appeared more resistant than other Crustaceans. Megalopa larvae of *Varuna litterata* were found dying in large numbers during low tide currents in July and August. Their clustering masses were also found on the margins, the swarms attempting to escape the polluted water. During high tides they were apparently unaffected.

TABLE III

List of Plankton Organisms recognized in the Kulti

Plankton Organisms	June, 1954	July, 1954	Aug., 1954	Sept., 1954	Oct., 1954	Dec., 1954	Jan., 1955	Feb., 1955	Mar., 1955	Apr., 1955	May, 1955	July, 1955	Sept., 1955	Dec., 1955
FAUNA														
Protozoa														
Rhyzopoda														
Arcella spp. (2)		X		X							X	X	X	
Difflugia spp. (3)					X	X	X		X	X				X
Nebela sp.							X							
Foraminifera	X									X		X		
Heliozoa	X								X	X	X			
Mastigophora														
Euglena spp.				X				X						
Infusoria														
Vorticella								X						
Porifera														
Sponge Spicules				X	X	X	X			X	X	X		
Hydrozoa														
Hydroid Colonies	X													
Medusae	X													
Nematoda														
Several spp.			X							X		X		
Rotifera														
Brachionus sp.			X						X	X		X	X	
Conochilus sp.										X	X			
Notholca sp.							X							
Annelida														
Polychaete Eggs	X	X	X			X	X			X	X	X		
Crustacea														
Copepoda	X	X	X	X			X	X	X	X	X	*Ab.*	X	*Ab.*
Nauplii					X	X	X	X	X	X	X	*Ab.*		*Ab.*
Mysids	X	X									X			
Zoea	X	X								X	X	X	X	
Mysis stages	X	X								X	X		X	
Megalopa stages			X									X		
Gammarus spp.		X			X			X		X	X	X		
Sagitta spp.		X												
Mollusca														
Veliger larvae				X									X	
Minute shells					X								X	

Insecta														
Notonecta, *Coryxa*, *Nepa*, Dytiscids													X	X
Insect larvae													X	
Maggots (small)													X	
FLORA														
Cyanophyceae (Blue-green Algae)														
Microcystis sp.	X						X							
Merismopedia sp.					X									
Coelosphaerium sp.												X		X
Spirulina sp.						X	X		X	X				
Oscillatoria sp.		X	X	X		X								
Nostoc sp.	X	X					X							
Anabaena	X	X					X	X	X	X	X		X	
Bacillariaceae (Diatoms)														
Melosira sp.										X				
Coscinodiscus spp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclotella sp.						X	X						X	X
Gyrosigma sp.						X	X							X
Pluerosigma sp.												X		
Navicula spp.							X			X				
Cocconeis sp.										X				
Nitzschia sp.							X			X				X
Fragillaria					X									X
Synedra sp.											X			
Hemidiscus sp.													X	
Chlorophyceae (Desmids)														
Closterium sp.				X	X									
Cosmarium sp.				X										
Pediastrum spp.														
Spirogyra sp.		X	X			X								
Miscellaneous														
Fungi—'Sewage Fungus Complex' (Strands and Hyphae)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Zygotes of Green Algae					X			X						
Zooglea of Micrococci	X	X		X	X	X	X							X
Clupeid Fish Larvae											X			
Gobid Fish Larvae	X													
Peltate Hair of Plants	X	X			X			X	X	X				
Pollen							X							

List of Fishes of the Kulti Estuary

Stray	..	X	Fry	..	F.
Very Rare	..	XX	Juveniles	..	J.
Rare	..	XXX	Adults	..	Ad.
Frequent	..	XXXX			

(No single species can be denoted as occurring 'Very Frequently', 'Commonly' or 'Abundantly' during the studies.)

No.	Scientific Name of Fish	How Occurring	Stage Recorded	Remarks
	Family *Megalopidae*			
1	*Megalops cyprinoides* (Broussonet) ..	XXX	Ad.	Few at a time noted in 'bheen' nets.
	Family *Clupeidae*			
	Subfamily *Clupeini*			
2	*Corica soborna* Hamilton)	XX	J., Ad.	Serial Nos. 2 to 12 are the Clupeids noted variously in the Kulti. (*Hilsa ilisha* was not noted even as fry or juveniles.)
3	*Gadusia chapra* (Hamilton	XXX	J., Ad.	
4	*Hilsa toli* (Cuvier and Valenciennes) ..	X	J.	
5	*Pellona elongata* (Bennet)	X	J.	
	Subfamily *Dorosomatini*			
6	*Anadontosoma chacunda* (Hamilton) ..	X	J.	
	Family *Engraulidae*			
7	*Anchoviella indica* (van Hasselt) ..	XX	J.	
8	*Coilia dussumeiri* Day ..	XX	J.	
9	*Setipinna phasa* (Hamilton)	XXX	F., J., Ad.	
10	*Setipinna taty* (Bleeker) ..	XX	J., Ad.	
11	*Thrissocles hamiltonii* (Gray)	XXX	F., J., Ad.	
12	*Thrissocles purava* (Hamilton)	XX	F., J., Ad.	
	Family *Scopelidae*			
13	*Harpodon nehereus* (Hamilton) ..	XXX	J., Ad.	This species is the well-known 'Bombay Duck', generally occurring in the Kulti between September and December.
	Family *Cyprinidae*			
14	*Amblypharyngodon mola* (Hamilton) ..	X	Ad.	These forms between serial Nos. 14 and 21 are the fresh-water 'Minnow Carps', usually noticed between July and September when Kulti water almost becomes fresh.
15	*Chela laubuca* (Hamilton)	XX	Ad.	
16	*Esomus barbatus* (Hamilton)	XX	Ad.	
17	*Oxygaster bacaila* (Hamilton)	XX XX	Ad. Ad.	
18	*Puntius conchonius* (Hamilton) ..	XX	Ad.	
19	*Puntius sophore* (Hamilton)	XX	Ad.	
20	*Puntius ticto ticto* (Hamilton) ..	XX	Ad.	
21	*Rasbora daniconius* (Hamilton) ..	XX	Ad.	
	Family *Tachysuridae*			
22	*Osteogeniosus militaris* (Linnaeus) ..	XX	J.	Serial Nos. 22 to 28 are the 'Catfish' species in the Kulti. *Mystus gulio* and *Pangasius pangasius* are the only two species of economic value (refer text).
23	*Tachysurus* spp. ..	XX	J., Ad.	
	Family *Plotosidae*			
24	*Plotosus canius* (Hamilton)	XX	J., Ad.	
	Family *Bagridae*			
25	*Mystus cavasius* (Hamilton)	X	J.	
26	*Mystus gulio* (Hamilton)	XXXX	F., J., Ad.	

List of Fishes of the Kulti Estuary—contd.

No.	Scientific Name of Fish	How Occurring	Stage Recorded	Remarks
27	*Mystus vittatus* (Bloch) ..	XX	J.	
	Family *Schilbeidae*			
28	*Pangasius pangasius* (Hamilton) ..	XXXX	J.	
	Family *Heteropneustidea*			
29	*Heteropneustes fossilis* (Bloch)	XX	J., Ad.	These two species (serial Nos. 29 and 30) are the air-breathing forms often washed into the Kulti from adjoining freshwater tracts.
	Family *Clariidae*			
30	*Clarias batrachus* (Linnaeus)	XX	J., Ad.	
	Family *Anguillidae*			
31	*Anguilla bengalensis* (Gray)	XX	J.	
32	*Anguilla* spp. ..	XX	J.	Serial Nos. 31 to 34 are some of the 'true' eels recorded.
	Family *Moringuidae*			
33	*Raitoborua raitoborua* (Hamilton) ..	XX	J., Ad.	Though serial Nos. 33 and 34 are air-breathing, they did not survive in the polluted estuary.
	Family *Ophichthydae*			
34	*Pisodonophys hijala* (Hamilton) ..	XX	J., Ad.	
	Family *Belonidae*			
35	*Tylosurus strongylurus* (van Hasselt) ..	XX	J.	These are the 'Gar' fishes and 'Half-beaks'. They were recorded mainly in outer channels connecting the Kulti.
	Family *Hemirhamphidae*			
36	*Hemirhamphus gaimardi* (Valenciennes) ..	XX	J.	
	Family *Cyprinodontidae*			
37	*Oryzias melastigma* (McClelland) ..	XX	Ad.	
	Family *Mugilidae*			
38	*Mugil cephalus* Linnaeus= *M. oeur* (Forskål) ..	XX	J.	These 'Mullets' have been noted mainly when there was no drainage of sewage.
39	*Mugil parsia* (Hamilton)	XXX	F., J., Ad.	
40	*Mugil speigleri* (Bleeker)..	XX	J., Ad.	
41	*Mugil tade* (Forskål) ..	X	J.	
	Family *Polynemidae*			
42	*Eleutheronema tetradctylum* (Shaw)	X	J.	These 'Thread-fins' have occurred only as stray individuals; *P. paradiseus* in July-September only.
43	*Polydactylus indicus* (Shaw)	X	J.	
44	*Polynemus paradiseus* (Linnaeus) ..	J., Ad.		
	Family *Channidae*			
45	*Channa gachua* (Hamilton)	XX	Ad.	These are 'Murrels', also known as 'Snake heads', and have occurred in monsoon months.
46	*Channa punctatus* (Bloch)	X	J., Ad.	
47	*Channa striatus* (Bloch) ..	X	J.	
	Family *Amphipnoidae*			
48	*Amphipnous cuchia* (Hamilton) ..	XXX	F., J., Ad.	This 'Mud eel' is recorded all the year round.
	Family *Centropomidae*			
49	*Ambassis baculis* (Hamilton) ..	X	J., Ad.	
50	*Lates calcarifer* (Bloch) ..	X	J.	This is the 'Bhetki', a Perch, cultivated in the connected 'bheris'.
	Family *Theraponidae*			
51	*Therapon jerbua* (Forskål)	X	J.	
	Family *Sillaginidae*			
52	*Sillago panijius* (Hamilton) ..	XX	J., Ad.	'Crocodile' fish recorded during monsoon months.
	Family Carangidae			
53	*Caranx carangus* (Bloch)	XXX	J., Ad.	Serial Nos. 53 to 56 are 'Perch-like' fishes occurring all the year round.
	Family *Lobotidae*			
54	*Lobotes* sp. ..	X	J.	
	Family *Lieognathidae*			
55	*Gerres* sp. ..	X	J.	

List of Fishes of the Kulti Estuary—concld.

No.	Scientific Name of Fish	How Occurring	Stage Recorded	Remarks
	Family *Leiognathidae*			
56	*Leiognathus equulus* (Forskål) ..	XX	J., Ad.	
	Family *Sciaenidae*			
57	*Pama pama* (Hamilton) ..	XXX	F., J., Ad.	These are the 'Croakers' recorded from fry to juvenile stages in August-September.
58	*Pseudosciaena coitor* (Hamilton) ..	XX	F., J.	
	Family *Scatophagidae*			
59	*Scatophagus argus* (Bloch)	X	F.	
	Family *Nandidae*			
60	*Nandus nandus* (Hamilton)	X	J.	
	Family *Trichiuridae*			
61	*Trichiurus savala* (Bleeker)	XXX	F., J.	Well-known 'Ribbon' fish, occasionally seen in nets (marine form).
	Family *Stromoteidae*			
62	*Stromoteus sinensis* (Day)	X	J.	Marine Pomfrets occurring in 'bheen' nets.
	Family *Anabontidae*			
63	*Anabas testudiens* (Bloch)	XX	Ad.	'Climbing Perch', mainly a freshwater form, recorded in the Kulti occasionally.
64	*Colisa fasciatus* (Bloch) ..	XX	J., Ad.	
	Family *Eleotridae*			
65	*Butis butis* (Hamilton) ..	XX	Ad.	Serial Nos. 65 to 73 constitute Gobid fishes and next to *Pangasius* and *Mystus gulio* together form sizeable fishery of some meagre value (please see text).
66	*Eleotris fusca* (Bloch) ..	XX	J., Ad.	
	Family *Gobiidae*			
67	*Apocryptes bato* (Hamilton)	XXX	F., J., Ad.	
68	*Brachygobius nunus* (Hamilton) ..	XX	Ad.	
69	*Glossogobius giuris* (Hamilton) ..	XX	F., J., Ad.	
70	*Gobiopterus chuno* (Hamilton) ..	XX	Ad.	
71	*Odontomblyopus rubicundus* (Hamilton) ..	XXX	F., J., Ad.	
72	*Pseudapocryptes lanceolatus* (Bloch) ..	XX	F., J., Ad.	
73	*Stigmatogobius sadanundio* (Bennet) ..	X	J.	
	Family *Periopthalmidae*			
74	*Boleopthalmus boddaerti* (Pallas) ..	X	J., Ad.	
75	*Periopthalmus schlosseri* (Pallas) ..	X	J.	Common 'Mud Skipper'.
	Family *Platycephalidae*			
76	*Platycephalus insidiator* (Linnaeus) ..	XX	J.	
	Family *Cyanoglossidae*			
77	*Cyanoglossus lingua* (Hamilton) ..	X	J.	'Flat Fishes'.
	Family *Mastacembelidae*			
78	*Macrognathus aculeata* (Bloch) ..	XX	J., Ad.	
79	*Mastacembelus armatus* (Lacépède) ..	XX	F., J., Ad.	
	Family *Tetrodontidae*			
80	*Tetrodon* spp. ..	X	J.	

Nematode worms, small dislodged maggots or dismembered limbs of terrestrial insects, all of which were of sewage origin, were frequently collected. Aquatic insects, like *Notonecta*, *Coryxa*, small Dytiscids, *Nepa* and even Crickets, have been observed in plankton hauls several times. All these probably had been washed into the estuary from freshwater channels and suffered no pronounced ill-effects either due to pollution or increased salinity.

Considering Phyto-plankton, various Blue-green Algae were found from time to time. *Anabaena*, *Spirulina*, *Microcystis*, *Oscillatoria* and *Nostoc* were abundant, which indicated a high degree of Polysaprobic condition. These were not only of sewage origin but thrived also in the polluted estuary and were more abundant during low tides. Of the Diatoms, *Coscinodiscus* was the most frequently available genera occurring in each haul but showed a decided decrease in numbers during wet months at lowered salinities. It is probably an indicator Diatom, thriving in polluted estuarine conditions. *Hemidiscus*, a marine form, was recorded on several occasions during high tides. No more than 11 genera of Diatoms were recorded as against 72 species in the Hooghly by Dutta *et al.* (1954). Even under normal conditions the instability of the water and its opacity are inhibiting factors for an abundant production of Diatoms in an estuary compared with clearer fresh or marine waters. In the Kulti, a high degree of pollution further seems to accentuate such unfavourable conditions.

Green Algae were represented by *Closterium*, *Pediastrum* and *Cosmarium* during the rainy season, the Desmids being flushed into the estuary from the adjoining unpolluted streams in monsoon months. A scarcity of Desmids in the estuary otherwise is a clear sign of unrecovered pollutional conditions. A prominent unidentifiable Desmid of marine origin was also recorded several times.

Zygotes of Algae, Zooglea of *Microcystis*, fungal spores, peltate hair of plants and so on were recorded almost consistently in the Kulti.

It is fairly obvious from the above that the plankton forms are severely restricted within the Kulti to only a few forms as a result of pollution.

Littoral and Burrowing Forms

On the littoral zone, swarms of bright green *Euglena gigantia* were obtained from the greenish scum over the exposed mud flats at low tides close to the outfall. It was interesting to observe the phenomenal spread of green patches of this form when the rich organic mud was being exposed to sunlight.

The marginal zone to a depth of 8-9 feet from high tide mark was beset with numerous burrows of the Fiddler Crab (*Gelasimus* sp.), except between August and October when evidently due to decreased salinity they disappeared from the region. This species seems to be the least influenced by pollution, possibly because it is not subjected to adverse conditions of low tides when it leaves the water and comes to the surface of the mud flats from its burrows and seeks the safety of its burrows during high tides. Burrows of other Crabs, e.g. *Sesarma*, *Dotillopsis*, *Metaplax*, *Tympanomerus* and *Pachygrapsus*, show variations in their density, their number very definitely increasing away from the outfall downwards. They were abundant only below Minakhan, two miles below the outfall, and very rare above. On occasions when there had been an unusually heavy discharge of sewage after a short lull during spring tides, these Crabs were found vacating their burrows and reaching high water margins, gradually crowding upwards with rising tide levels. It is not certain if they died, but a periodic egress from their burrows seems effectively to have contributed to their decline in population within the entire affected zone. Similarly, *Varuna litterata* and *Scylla* *serrata*, the two important swimming Crabs, were found dead or dying in low tides. Often they were found on the water's margin, apparently in distress and 'frothing', a very unusual feature, obviously brought on by their vain attempts to breathe atmospheric air. Between May and July once or twice every year, there is usually a high mortality of all the above-mentioned Crabs and other Macrurans as evidenced by the numerous bleached and dismembered limbs and carapaces littered six to seven inches deep in continuous heaps between Haruahot and Malancha along the high tide mark. The receding tides tend to deposit these floating dead animals along the margins. A good number of *Squilla* and even Anomurans could be noticed amongst the shells. This annual extermination of all Crustacean fauna seems to occur on the diversion of the entire sewage into the estuary with the commencement of the rains when the sewage water is no longer required to be fed into the fish farms near Calcutta, Bantola, Dhapa and Hanakhali areas adjoining the sewage channel. Gravid individuals of a few Crabs and Prawns were noticed in the Kulti, but whether they actually can spawn in the estuary is very doubtful.

Another striking feature was an absence of Molluscan fauna along the Kulti margin. During numerous specific searches made in a 15-mile stretch, only dead or floating shells of freshwater Gastropods, e.g. *Pila, Vivipara, Indoplanorbis, Melonoides* and so on, were obtained in the marginal debris. The true saline forms commonly found in the Matlah, such as *Hydrobia, Valvata, Bithynella, Stenothyra* and the common Bivalve, *Cuspidaria*, were totally unrepresented. A few *Teredo* were found embedded in submerged timber. Minute Gastropods were recognized sometimes within the high tide plankton hauls along with some Veliger larvae. Molluscs are very sensitive to pollutional conditions (David, 1957), and their total elimination from the Kulti is not surprising; nevertheless since edible Oysters or Bivalves are rare in Bengal estuaries, an absence of Molluscs is by no means an economical loss.

The burrowing forms of Polychaetes were found along the tidal margin 1½ miles below the outfall. Almost none were seen above the outfall. On one occasion during June, 1948, clustering pink masses of a large species of a free-swimming variety were stranded in the receding ebb tide on the low-lying mud flats below the outfall. These seemed to have become narcotized due to pollutional effects since sewage drain was then in progress. Oligochaetes were unrepresented for nearly a mile downstream as denoted by an absence of casts in the upper region of the intertidal margin.

Associated with the above conditions in the soft mud bathed by the Kulti water were Mole Crickets, Isopods, Beetles and others, all of which were definitely scarcer in the affected zone.

Lack of oxygen alone seems to have little influence on the observed scarcity of the above forms. It is likely that some toxic conditions of water are also partially responsible for the absence of animals which remain bathed in the water for prolonged periods. In considering the associations, it is to be taken into account that stable benthic fauna of the kind noticed in a still-water brackish 'bheri' cannot exist in the estuary proper subjected as it is to violent and turbulent current conditions, tidal and salinity variations.

Effects of Sewage Pollution

Fish-life and Fisheries

All estuarine waters within the Bengal delta yield a rich Fish and Prawn harvest and the Kulti estuary was no exception at least till 1939, the first year of sewage admixture. No comparison is, however, possible since published accounts do not exist regarding the total fishery yield in the Kulti and for that matter from any estuary of the Bengal delta. There is little commercial fishery of any importance at present in the Kulti.

The notable features about the available fishes is that the Mullets, Perches, Thread-fins, Clupeids (Herrings), Croakers and others with Prawns and Crabs, all of which together constitute the bulk of fishery yield of any Bengal estuary such as the Matlah, are almost entirely absent in the Kulti. Between Haruahot and Minakhan not more than six 'bheen' net units (fixed bag-nets—David, 1953) were operated at any one time between June and October, the more profitable fishing season in a year on the Kulti.

Estimated landed fish on any single day did not exceed 250 lb. for the entire 12 miles stretch by these nets, which were being used mainly for about 18 days in a month during spring tides when chances of capture were better since fish are brought up by the faster flow currents. At the end of 1955 even this fishing was given up by the fishermen of the stretch except for two boats near Minakhan, owing to a further decline in catches. 75–80 per cent of the fish consisted (by weight) of *Pangasius pangasius, Mystus gulio* and Gobioid genera, the rest being stray specimens of uneconomical Fish and a few Prawns. In the list of fishes, the species noted at various times by the author are enumerated. The majority of them are recorded from the specimens that would have strayed into the affected zone or washed in by the flow currents.

The only capture fishery that seemingly remains unaffected by pollution and prevalent all the year round is that of the Catfish, *Pangasius pangasius*. Six to eight boats with two to three men in each engage themselves in this capture fishery, netting the river while moving down the ebb and flow currents. The circular cover net, known as 'beshadi', is operated at likely spots. Catches in each boat for 7-8 hours of operation did not at any time exceed 150 lb. (70 kgm.) during June, July and August. In other months only about 20 lb. (9·3 kgm.) were obtainable per boat per day on an average. The specimens were all, however, juveniles ranging in size between 76 and 465 mm., adults having seldom been recorded in the stretch. The cover nets were generally operated near the Kulti outfall where the fish gathered to feed upon the mucilaginous lumps of organic matter brought by sewage. These fish were obviously attracted by the foul smell. Quite often, a good number of *Mystus gulio* were also available in smaller-meshed nets. During very high pollutional conditions even this fishery periodically disappeared.

Stake nets were operated by batches of local fishermen during the spring tide conditions between May and August within the creeks and channels connecting the estuary with the adjoining swamps and other low-lying tracts. At the time *M. gulio* was the predominant fish with a fair percentage of *P. pangasius* in these catches. During the above months, fully mature specimens usually seek entrance to the low-lying freshwater tracts which are flooded by rain water for spawning, which accounts for their large numbers at the time in the river. Between June and July the amount of concentrated sewage let into the Kulti is also less and is appreciably diluted by rain water intermittently.

Cast-net fishermen usually were active in the connecting creeks, catching Eels, *Channa* spp. and small *M. gulio*. Intensity of this method of fishing was never high.

From information gathered it was fairly clear that a rich natural fishery that once existed on the Kulti has disappeared due to pollution. Several species of Sharks and Rays from the sea were also said to be available in pre-pollution days along with other species of Fish and Prawn. The major anadromous fish in the Indian rivers, *Hilsa ilisha*, a Herring, ascends only estuaries which carry considerable amounts of fresh water into the sea, e.g. the Meghna and to some extent the Hooghly, but the blind estuaries like the Royamangal or Matlah do not attract this form as none drain any 'live' river above.

Nair (1944) has briefly described mortality of fish close to the Kulti outfall and noted that dead specimens were found five miles on each side of the outfall, even during the monsoon when sewage was diluted by rain water. During the present investigations, features as described in Table IV with regard to mortality of fish over one single phase of tidal variations and sewage admixture were noted.

From the observations, which approximate to the prevailing general conditions of tide and drainage with only minor fluctuations in levels and durations of sewage flow, it is seen that even though actual drainage of sewage is for about $4\frac{3}{4}$ hours during a tidal cycle of $11\frac{3}{4}$ hours, a total absence of fish is observed for about 8 hours with an additional period of distress indicated for more than $\frac{1}{4}$ hour. Only for a duration of about 4 hours in the course of nearly 12 hours, or about 8 in 24, can fish survive in the Kulti. But these periods of survival shorten further at the time of fresh inflow of sewage into the Kulti owing to higher tidal levels and larger concentrations of stored sewage. Higher up towards Haruahot the survival period diminishes greatly, and finally within the arterial channels that spill into the culture fisheries around Kharibaria, normally no survival period prevails.

On the impact of sewage, any freshly colonized fish population during the short interval of 'no drainage' period at the height of spring tide is exterminated. *M. gulio*, *Thrissocles* spp., small Mullets, *Trichogaster* sp. and some *Puntius* have been collected dead in the Kulti. These fish come to the surface swimming feebly and try to keep to the very edge of the water and even attempt to climb the margin of the bank to escape the polluted water. Many overturn, breathing violently, and even gulp air into their stomachs. Such fish in distress soon recover without any apparent permanent injury on transfer to uncontaminated brackish pond water.

No choking of gills by mechanical causes, by organic debris, silt or fungus was responsible for distress and ultimate death of fish. No bacterial infection, fungal or parasitic attack primarily caused any mortality. Dead fish were found asphyxiated as shown by the greatly swollen nature of the gills and distended opercular cavities. Mucus on the gills or on the body did not coagulate, indicating that no sudden chemical change or acidity was responsible for the observed fish kills. Though deoxygenation of the water is a primary cause of death, some septic conditions caused by toxicity due to sulphide, nitrogen compounds (ammonia and other organic acids) and others, released by incomplete bacterial action in the crude sewage, cannot entirely be excluded as causative agents for hastening the mortality. Some of these dissolved gases can be absorbed through the gills by osmosis and can act upon the circulatory or nervous system of fish (David, 1957).

As already mentioned *P. pangasius* alone amongst all the fishes of the Kulti is the most tolerant form. On days when there was no drainage, these fish were found accumulating below the outfall attracted obviously by the odour of small quantities of sewage leaking through the shutters. Being a foul feeder (stomach contents of this fish at Kulti has revealed sewage debris mixed with mucus-like organic substances and fungi thrown into the estuary), this fish seems to have developed a great resistance to foul conditions. In the absence of accessory breathing organs, the fish has developed certain peculiar adaptive characters. The fin membranes and the lips become unusually pink with a rich supply of capillaries, indicating that probably certain amount of compensation for lack of sufficient oxygen

TABLE IV

Drainage Operation Cycle

Condition of Tide	Levels of Sewage Drain or Stoppage	Approximate Duration (Hours)	Observations
Ebb ..	8′ 2″—Sewage discharge commenced.	..	Water already charged with sewage moved downwards. *No fish life.*
Ebb ..	8′ 2″ to 2′ 6″—Sewage discharge continued with increasing velocity and volume.	2½	Sewage concentration increased. *No fish life.*
Slack ..	2′ 6″—Sewage discharge continued.	½	More concentration of sewage below the outfall. *No fish life.*
Flow ..	2′ 6″ to 7′ 0″—Drainage of sewage stopped at 7′ 0″ with diminishing intensity.	2	Accumulated sewage below the outfall and freshly draining sewage moved upstream with decreasing sewage concentration. *No fish life.*
Flow ..	7′ 0″ to 12′ 3″—No sewage drain.	1½	Sewage-mixed water from below moved upwards with a decreasing concentration as the level rose. *No fish life.*
Flow ..	12′ 3″ to 12′ 9″—No sewage drain.	¼*	Equilibrium stage, there being no freshly draining sewage, but the water moving upstream was still diluted with sewage. *Fish in distress.*
Flow ..	12′ 9″ to 14′ 11″—No sewage drain.	1½	Almost fresh tidal water near the outfall. *Fish survived.*
Slack ..	14′ 11″—No drain ..	¾	Almost fresh tidal water near the outfall. *Fish survived.*
Ebb ..	14′ 11″ to 12′ 0″—No drain.	1½	Almost fresh tidal water near the outfall. *Fish survived.*
Ebb ..	12′ 0″ to 11′ 0″—No drain.	¼*	Appearance of sewage-mixed water moving downstream. *Fish in distress.*
Ebb ..	11′ 6″ to 8′ 0″—No sewage drain.	1½	More concentrated water moving downstream. *No fish life.*
Ebb ..	8′ 0″—Sewage discharge commenced.	..	Cycle repeated as above.

* This short period of distress is characterized by the noise and clamour made by hundreds of piscivorous birds (inclusive of kites and crows) which move up and down with the tides, following and picking up dying fish within this short moving column of water.

is being met by cutaneous respiration. Under rough experimental conditions, 3 to 5 inches long specimens resisted oxygen depletion of up to 2-3 p.p.m. by coming to the surface of the jars and gulping air which was apparently being stored within the buccal cavity, there being no provision for storing air within the operculum. Two to three bubbles of air were being released every 20–40 seconds, the fish coming to the surface to take in fresh air soon after. At times, the fin membranes also became pink in fish so kept for about half an hour and more. In uncontaminated waters showing 5-6 p.p.m. of dissolved oxygen, this feature was less pronounced. Between 1 and 1·5 p.p.m. of D.O. the fish died like any other species in about 8 minutes. This peculiarity in *Pangasius* of storing air within the buccal cavity and its cutaneous respiration seems to have greatly contributed to its survival in the Kulti.

In the sewage channel itself an occasional *Channa* spp., *Heteropneustes fossilis* or *Clarias batrachus*, all air-breathing forms, were found near the outfall. The semi-aquatic burrowing Gobids show certain interesting features. The common Mud Skipper, *Periopthalmus schlosseri*, which is normally found on all mud flats in every tidal creek and estuary of Bengal, was remarkably conspicuous by its absence. Its non-availability in the Kulti stretch all the year round along the tidal margin can be attributed only to sewage pollution. Since it is semi-aquatic and almost terrestrial in its habitat, its disappearance is definitely not due to any oxygen lack but undefined toxic conditions in the water; the species probably is very sensitive to pollution and has assiduously avoided the stretch. The burrowing *Apocryptes bato* and *Odontomblyopus rubicundus* were found mainly between July and October in 'bheen' nets along with stray *Pseudapocryptes lanceolatus*. These forms were recorded with some dead Prawns and *Mystus gulio* in tidal channels at Kharibaria, having been washed in with flow tides. *Boleopthalmus boddaerti* was recorded only twice on the outer muddy banks in October near Minakhan. *Glossogobius giuris*, *Eleotris fusca*, *Ctenogobius nunus* and *Gobiopterus chuno* were variously found under favourable conditions. The semi-aquatic forms of Gobioid fishes seem to be more resistant than all other groups of estuarine fishes to pollutional conditions. These constituted the third item of the meagre fishery yield in the Kulti amongst the economical group.

It has already been pointed out that the numerous Perches, foremost of which is *Lates calcarifer*, the Bhetki; the Mullets, *Mugil tade*, *M. parsia* and *M. cephalus*; several Sciaenids or Croakers such as *Pama pama* and other related large forms; the 'Indian Salmons', or the Thread-fins, e.g. *Eleutheronema tetradactylum*, *Polynemus paradiseus*; Clupeids, mainly *Thrissocles* spp. and *Setipinna phasa*; the 'Bombay Duck', *Harpodon nehereus*; several Catfishes, *Tachysurus* spp., *Plotosus canius* and others, and a rich variety of Prawns and Crabs which form the bulk of fishery yield from every estuary in the Bengal delta, are almost wholly unrepresented in the polluted Kulti. The above groups as a rule seem to avoid the Kulti stretch as adults, but large-sized *Harpodon* have often been collected dead and putrefying within the 'bheen' nets.

Spiny Eels (*Mastacembelidae*) of which *Macrognathus aculeata* and *Mastacembelus armatus* are common in Bengal, the Mud Eels, *Pisodonophys boro* and *Amphipnous cuchia*, the True Eels (*Anguilla* spp.), several Murrels (*Channa* spp.), Silurids, *Heteropneustes fossilis* and *Clarias batrachus* and so on have been observed often in 'bheen' nets and also are dug up from within channels connected with the Kulti below the outfall. The majority of the above species are air-breathing forms or partially so, as described by Ghosh (1934) and Das (1940). But even these inhabited only upper fringes of the channels subjected to high tide floods rather than the low tide margins which drain concentrated sewage.

Several known freshwater fishes, *Puntius sophore, P. conchonius, Chela* spp., *Rasbora daniconius, Esomus barbatus, Oryzias melastigma, Ambassis* spp., and even the Climbing Perch (*Anabas testudiens*) have been at times recorded mainly in monsoon months; their presence in saline waters is no more of some academic interest.

All Fishes and Prawns obtained from the Kulti possess an unpleasant odour. The noxious smell persists even when boiled or otherwise cooked in fishes like Mullets, *Megalops cyprinoides,* Gobioids, *Mystus gulio, Pangasius pangasius* and Prawns like *Penaeus semisulcatus* and *Metapenaeus* spp. Consequently even the few fishes caught in the Kulti fetch very little value in the market as compared with Fish and Prawns from cleaner estuaries. The causative agencies responsible for this unpleasant flavour present in the sewage are unknown. The majority of fish spending some time in effluent-ridden waters seem to absorb these odours (David, 1957) readily.

In the Kulti, though populations of fish, majority of which seem to be feeble swimmers that can drift easily in tidal currents, are brought up twice each day, due to continued low levels of oxygen and other still obscure pollutional causes, they are easily destroyed. Large forms except *Pangasius pangasius* seem to avoid the stretch completely.

Availability of Fish 'Seed' and Cultivable Fisheries

In 51 plankton hauls made in the Kulti, at no time free fish eggs have ever been noticed. Larval and post-larval young of Clupeids, Sciaenids, Gobids and some Zoea and Mysis of Crustaceans are, however, recorded during high tides, when the majority of them were found dead. No gravid fish except the tiny *Oryzias melastigma* and *Gobiopterus chuno* (both bearing fertilized eggs) have been actually observed. During the wet months of July–September when salinity decreases, *Mystus gulio* ascends into the freshwater through the Kulti in a fully mature state to spawn as already mentioned. Young of this species of 16–29 mm. have been collected floating dead in large numbers later in October-November months.

High tide floods bring up some young fish to the outfall site under favourable conditions. This is indirectly evidenced by the occurrence of post-larval young and fry of *Thrissocles* spp., *Setipinna phasa, Mugil parsia, Amphipnous cuchia, Periopthalmus schlosseri* and several Prawns and Crabs within brackish pools and pits along the river's outer margin. These pits, from which mud is removed for reinforcing the embankments, are subjected to tidal flooding at least once in a fortnight during the highest high water conditions. After retaining water for the next few days, these pits are washed again by the next flood currents. Sometimes large-sized Prawns and Crabs are also taken from these pits. All these forms, which usually are not seen in the Kulti water, could have been brought up only within the short durations of high tides from the lower reaches.

A limited number of young Bhetki (*Lates calcarifer*) were being brought up under flood conditions between January and March, when connections between certain low-lying tanks along the Kulti are kept open (by cutting) and high water is drawn into them for trapping young *Lates calcarifer* and Prawns. These practices commonly observed first in 1948 had been given up by 1955 because no Bhetki young were reported found in the intervening years.

The previous observations point towards causes for a deterioration of the cultivable fisheries. Ramjoi and Gobadiabad fisheries indicated that the fishery yield almost wholly consisted of various species of Prawns, mainly *Penaeus semisulcatus* ('bagda chingri'), several *Metapenaeus* spp., *Leander* spp. and a phenomenal number of *Mystus gulio*. Though decline in actual value of the fishery by a lack of Bhetki and Mullets was reported to be about 75 per cent of the original value, at the time of study the entire income was being derived from Prawns and *Mystus gulio*. Mysis stages of Prawns and adult *M. gulio*, while available in the river during various months, are drawn into the fisheries and allowed to multiply or grow in the sewage-fed water. Sewage-diluted water from the Kulti and entrance of fish are regulated by sluices and a complicated system of gratings, the 'atols' (Pillay, *op. cit.*). Organic fertilization caused by sewage intensifies and promotes growth of benthic algae, plankton and other food organisms (Basu, 1950).

The cultivable fisheries near Kharibaria, connected as they are with the arterial channels of the Kulti, however, showed almost a total deterioration. A viscid sewage enters these spill fisheries at every high tide for reasons mentioned earlier. Dead Prawns and Fish inclusive of *Mystus gulio* are brought up and even choke the entrances through which water is drawn into the fisheries. Even the hardier Gobioids that were being collected by stake-nets at channel entrances appeared narcotized near Kharibaria. No healthy Fish or young fry or even Prawns can enter the Nowee, Sunthee and the Nonagong to become available for stocking the upper spill fisheries.

In recent years 4–7 inches long *Pangasius pangasius* collected from the Kulti are being stocked in many ponds within Basirhat subdivision. The species is proving successful as a culture fish, with both freshwater and brackish fish in respective ponds or 'bheris'.

REMARKS

Pollutional conditions prevailing on the Kulti are so unlike any known estuarine pollution that it is not easy to draw comparisons; primarily, biotal and chemical conditions offer no scope for setting up conventional zones of pollution, septicity or recovery as in the case of freshwater rivers flowing steadily in a single direction. There is also a constant shift in the substratum, which is not conducive to a deposition of silt or sludge and encourages a stable benthic population peculiar to polluted waters. No organic detritus can settle and decompose in the Kulti river bed.

In understanding the brackish-water ecology and fauna in the estuaries of India, the contributions made by Annandale (1907, 1915*a* and 1915*b*), Chaudhuri (1922), Hora (1922), Kemp (1917), Pearse (1932), Sewell (1934), Panikkar and Aiyar (1937) and Pillay (*op. cit.*), among others, are most useful. Panikkar and Aiyar (*op. cit.*) have briefly summarised the rigorous conditions of existence facing brackish-water animals which therefore have to make an aggressive attempt to survive. This results in their prolific breeding, curtailment of stages in life history, adaptations to changing salinity conditions by osmotic regulations, possession of integumental structures for aerial respiration, secretion of profuse mucus to prevent desiccation and so on. Majority of the above features are exhibited by the fishes and other organisms of the Kulti in various degrees. In spite of so varied a modification, it is noticed that sewage pollution has thoroughly affected the population mainly by a continued oxygen lack (though not a complete absence) and perhaps by undesirable toxic substances originally present in or released by septic sewage in the process of disintegration. The effects of a heavy load of organic pollution aggravates the situation further. It has been shown that the concentration of sewage is too high to enable most organisms to survive as there is very slow dissipation normally. Observations made by Alexander *et al.* (1935) are on too mild an estuary compared with the Kulti.

As already mentioned, periodic kills of Fish and their fry, or of Crustaceans and their various early stages brought up in swarms by currents, do take place in the Kulti, contributing to a large amount of loss all round. Fortunately the Kulti, with its surrounding fisheries, forms more or less a closed bio-hydrographic system where a heavy load of sewage is confined. Recovery is restricted mainly due to a lack of fresh supply of diluent waters above. Since the sewage can get dissipated quickly only 5 miles below the outfall, the lower estuaries receive such dilutions. But the high tide waters show that the effect is also severe below and the plankton life is much too scarce compared with unpolluted estuarine waters elsewhere.

Sedimentation of organic detritus or sludge being impossible, no polysaprobic organisms are found at the bottom as is normally observed under septic conditions in freshwater rivers. The indicator organisms and sewage-resistant forms are therefore to be found amongst the plankton. Even here, the constant agitation and continuous sewage replenishment has greatly impeded photo-synthetic activity. Phyto-plankton species number about 22, Diatoms being the dominant group besides the Blue-green Algae which is mainly of sewage origin. Considering organic fertilization, phyto-plankton organisms are very poorly represented.

Since the estuary is situated in a sparsely populated area, nuisance value is less. No hindrance to navigation, such as it is, by country boats is caused by accumulation of sludge. Any epidemics due entirely to sewage in the belt also are unknown. Kulti water, or for that matter any estuarine waters, are seldom if ever used for bathing or washing in Bengal. So long as the Kulti remains in its present active form the city of Calcutta need no more worry about its sewage disposal, and being the best medium for carrying away the sewage, fishery importance of the creek and its fisheries assume only a secondary role as compared to the health of the great city.

Certain amount of relief is provided for a loss of the fishery value by *Pangasius pangasius* and *Mystus gulio* whose yield does not seem to have deteriorated. If properly managed, the brackish-water culture can probably be improved as fertilizing action of sewage on the food of available species has been one of enrichment (Prawns and *M. gulio*). Natural stocking of 'bheris' and spill-water fisheries, however, have been affected by excessive pollution. It is also noted that the Kulti or any of the blind estuaries of Bengal which do not have abundant fresh water in the monsoon season do not attract the *Hilsa* from the sea, which migrates hundreds of miles otherwise in the Ganga. Kulti therefore is not a highway for any economical migratory fish between the sea and the freshwater rivers.

The following remedial measures can be suggested, considering that the Kulti offers the easiest means of disposal of Calcutta sewage, and the ill-effects on the fisheries is of less importance than usefulness of easy disposal of wastes from the city:

(i) Completion of the dry-weather and the storm-water channels as originally planned.

(ii) More effective and quicker treatment of sewage and its sedimentation to avoid toxicity developing in the sullage and quicker transport of such sullage to the outfall head.

(iii) At present there does not seem to be a complete bacteriological dissociation of organic matter (contrary to claims made by authorities of Calcutta Corporation). The inhibiting substances should be discovered and eliminated.

(iv) Sewage has to be diluted still more as in its present form it is a very viscid liquor at an incomplete stage of disintegration.

(v) The outfall vents should be opened only at ebb tides so that flow tide drift of sewage to Haruahot can be avoided, if not altogether stopped. This entails a little more vigilance at the outfall site; but the procedure will serve the interest of the fisheries above the outfall as some young Fish and Prawns can then plant themselves in these brackish-water fish farms.

Summary

While determining the effects of sewage from the city of Calcutta upon the fish-life of the Kulti estuarine creek, certain hydrographical, chemical and biological investigations were undertaken. The mode of sewage admixture and the impact of the forceful tidal effects upon dissipation of the sewage load show that the accumulated sewage mainly oscillates in the region without dissipating quickly, and has converted a length of about 30 miles of the creek into a vast septic tank.

The chemical tests of the water have shown a subnormal dissolved oxygen content under all conditions together with other unfavourable factors. At high tides, apparently when the estuary is to be free from contamination, chemical tests still reveal that the condition of the water was quite unsatisfactory to support a normal fish community. The plankton and other biotal organisms are very poorly represented when compared to the adjoining uncontaminated estuaries.

Fish-life is almost totally eliminated by the gross pollutional load and can only exist within the Kulti for about eight hours during the course of two tidal cycles in a day. The obvious ill-effects are mainly due to asphyxiation caused by deoxygenated water. Undetermined toxicants brought from industrial plants as well as those generated by an incomplete bacterial action appear to add to the totality of unfavourable conditions of existence both for Fish and other organisms.

Fishing as an industry is non-existent. Eighty species recorded are mainly brought up by the force of flow currents. The *Pangasius* Catfish, however, seems to be unaffected, having developed certain breathing traits to compensate an oxygen deficiency in its environs.

Fish larvae and Prawn young, which are used as 'seed' for planting brackish-water culture fisheries, have almost entirely disappeared, the numerous 'bheris', particularly within the spills of the Kulti's upper arterial channels, suffering thus a great loss.

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