AQUACULTURE POTENTIAL OF MANGROVE ECOSYSTEM OF SUNDERBANS, WEST BENGAL, INDIA

S. K. CHAKRABORTY

Department of Zoology, Vidyasagar University Midnapore-721 102, W. B., India

INTRODUCTION

The world production of aquatic biological resources is nearing an almost saturation level due to their nonjudicious exploitation during the last few decades. But in the vast majority of the countries of the world where malnutrition due to protein deficiency is widespread, fish along with other aquatic organisms constitutes the main source of chief protein. Aquaculture (the culture of aquatic organisms for human utilisation) can afford surprising boost to total biological production and offers advantage over other conventional methods of exploitation through controlled supervision on production, harvesting and processing of aquatic organisms.

Mangrove ecosystem - the ecosystem dominated by intertidal salt tolerant halophytic vegetation enjoying the influences of two high and two low tides a day, offers an unique environment for aquaculture development. Aquaculture activities in mangrove swamps date back about 500 years to the development of coastal milk fish culture in Indonesia during the fifteenth century (Macintosh, 1984). Fishery activities by simple nets and traps are a regular practice in mangrove areas. Despite sheltering a number of endemic species of estuarine flora and fauna, the ecosystem also attracts faunal components from adjoining marine, freshwater and terrestrial habitat.

The importance of mangrove ecosystem for its potential for fisheries and aquaculture development has received wide acceptance all over the globe mainly due to two reasons: Firstly, large quantities of energy, in the form of mangrove plants contributed detritus, are exported from the mangrove forest to open water bodies (Odum and Heald, 1975) and positive correlation in between the extent of mangroves and total fisheries yield from adjacent water (Macnae, 1974); Secondly, profitable regional and international markets for high quality aquaculture products are available.

Distribution of mangroves and physiography

India has a subcontinental coastline of 5,423 km along the maritime states of Gujarat (1,215 km), Maharashtra (653 km), Goa (160 km), Karnataka (280 km), Kerala (570 km), Tamil Nadu (907 km), Pondicherry (31 km), Andhra Pradesh (974 km), Orissa (476 km) and West Bengal (157 km). The oceanic islands of Andaman and Nicobar have a total coastline of 1,962 km with extensive bays, inlets and creeks and Lakshadweep has a coastline of 132 km (Alagarswami, 1991). India's brackishwater culture potential is estimated to be about 9 lakh hectares of which only about 26,270 hectares (2.91 %) are being utilised at present, the concentration being mainly in West Bengal (47.7%), Kerala (27.3%) and Karnataka (9.6%) (Srivastava and Singh, 1984). Blasco (1977) has estimated 3,56,500 hectares mangrove forests area for the Indian continent which was reported to be 700,000 hectares in 1963 (Sidhu, 1963). Such loss of mangroves was supposed to be due to over exploitation of highly salt tolerant mangrove wood products by coastal village communities as well as controversy over the inclusion of other plant species within the mangrove area. In India mangrove ecosystem is existing in the coasts of Kutch and Cambay in Gujarat, in Konkan and Malabar coasts as patches and in the estuaries of Cauvery, Krishna, Godavari, Mahanadi and Hooghly-Matlah system.

Deltaic Sunderbans of the Ganga river basin is located in the Hooghly-Matlah estuarine complex on the eastern seaboard of the Indian subcontinent. Indian part of Sunderbans occupies a mangrove area (4264 square kilometre) slightly more than that (4109 square kilometre) of the highly reclaimed counterpart in Bangladesh (Sanyal 1987). The entire area is criss-crossed by a number of estuaries (Viz. Hooghly, Battla, Muriganga, Saptamukhi, Thakhuran, Matlah, Bidyadhari and others) and their tributaries, creeks of varying depth and width forming a good number of deltaic islands. The mangroves in West Bengal comprise 54.7% woodlands, 41.8% water spread areas and salt marshes and 3.5% sand flats and sea beaches (Banerjee 1966). The present Sunderbans lie in between latitudes 21°39' North to 22°30' North and 88°00' East to 89°08' East merideans (Figure 1).

Structural features of mangrove ecosystem

1. *Flora* : 30 species of mangroves are found in Sunderbans (Naskar and Guha Bakshi, 1987). Different mangrove plant species have developed for their intertidal existence various morphological and physiological adaptative features (Macnae, 1968). In Sunderbans, there is a distinct zonation of different mangrove species along the intertidal slope reflecting their adaptation to different prevailing ecological factors viz. duration of tidal inundation and exposure, salinity, sediment characteristics etc. Mudflats are developed in some sheltered areas on the deltaic islands of the Sunderbans due to higher sedimentation load and lower velocity of water. The finer sediment constituting the thick mudflats an rich in organic content and ideal for penetration by plant roots. The surface of these flats are initially covered by thick algal mat and consequently luxuriant growth of mangrove vegetation will occur, showing distinct zonation pattern. Ginsburg and Lowenstam (1958) reveiwed the evidence of stabilising and salt traping powers of filamentous algal and marine phanerograms (mangroves) in shallow sheltered waters. The species replacement of mangroves is a peculiar characteristic of the mudflats by which one species after being developed on a mudflat consolidates, elevates the substratum and creats shades and makes way for another (Paul *et al* 1987). The zonation of mangrove vegetation in Sunderbans showed that the seaward edge of the forest is endowed with saline grass *Porterasia coaretata* which are followed toward landward by *Avicennia officinalis, A. alba, Acanthus ilicifolius, Suaeda maritima, Bruguiera gymnorhiza, Sonneratia apetala and Ceriops roxburghiana* (Chakraborty and Choudhury, 1992). Lugo and Snedaker (1974) inferred that zonation patterns in mangroves represent steady state adjustments rather than successional stages. Sunderbans Mangroves estuarine complex supports the growth of rich algal communities which provide a novel source of nutrients to the whole ecosystem. They remain in the mangrove forest subsystem as an epiphytic assemblage of algae living on the stems, pneumatophores of mangrove trees and on the surface of the sediment as epibenthic form. Besides, a good number of algae remain

in the water subsystem as phytoplankters and play a great role in the total productivity and energy flow of the system (Gopalakrishnan 1972; De *et al,* 1987). This mangrove ecosystem harbours different types of bacteria in abundance in their vegetations, soil, water, litter etc which play the key role in the total nutrient cycle of the ecosystem (Bhowmick *et al,* 1985). Fungi (184 species) and protozoa (44 species) together with bacteria constitute a rich microbial community (Chakraborty and Naskar, 1988).

2. *Fauna*

Mangrove ecosystem of Sunderbans supports a rich estuarine fauna in hundreds of creeks and tributaries, salt marshes, sandflats and mudflats in the form of plankton, benthos and nekton. Zooplankton, an important biotic component of mangrove aquatic subsystem, constitutes the secondary and tertiary trophic levels of mangrove food web. The faunistic composition of zooplankton in this system includes copepods as principal component (67.8% to 97%) of the total zooplankton. A total of 36 copepod species belonging to 19 families and 21 genera were encountered (Sarkar *et al,* 1986). Other zooplanktonic forms are mysidacea, sergestidae, amphipoda, cladocera, ostracoda, cumacea, chaetognatha, hydromedusae etc (holoplankters) and polychaete larvae, nauplius, zoea, megalopa, fish eggs and larvae, echinoderm larvae etc (meroplankters) (Bhunia and Choudhury, 1982). A hoard of benthic fauna both infauna (sessile, semisessile and burrowing) and epifauna (crawlers and creepers) are the happy residents of these habitats which are subjected to various oscillatory exposures of hydrological parameters (Misra *et al,* 1985; Subba Rao *et al,* 1983 Choudhury *et al,* 1984; Chakraborty *et al,* 1992). Most of the benthic organisms have evolved various behavioural and physiological adaptations to cope with the stress due to varying ecological conditions (Vernberg and Vernberg, 1972). Besides, benthic fauna are divisible into three broad groups based on their body sizes — macrobenthos, meiobenthos and microbenthos. There is a distinct zonation of different macrobenthic species along the intertidal slope reflecting their adaptation to different prevailing ecological parameters (Chakraborty and Choudhury, 1985; Chakraborty and Choudhury, 1992). Among the intertidal macrobenthic fauna, brachyuran crabs constitute a dominant faunal component of ecological and economic significance. 26 species of brachyuran crabs belonging to 15 genera and 5 families have been recorded from the deltaic Sunderbans in the estuarine complex of the river Ganga (Chakraborty *et al,* 1986). A total of 30 species of polychaetes spread over 24 genera and 13 families have been documented from this locale (Misra and Choudhury, 1985). Subba Rao *et al,* (1983) recorded 23 species of benthic mollusca from the intertidal zone of Sunderbans, India. These salt marshes also harbour a rich abundance of benthic insects in its different categories of soils. A total of 14 dipteran species belonging to 5 families and 11 genera (Ray and Choudhury, 1989) and about 14 çoleopteran species (Poddar *et al,* 1990) have been encountered. Phytophagus insects living on mangrove plants are noticed in abundance which include 2 species of hemiptera, 1 species of hymenoptera, 8 species of hemiptera, 1 species of homoptera, 16 species of coleoptera and 30 species of diptera (Chakraborty and Naskar, 1988). Actiniasians, Sipunculans, Echicerans, hemichordates, pisces etc are important benthic faunal groups (Choudhury *et al,* 1984; Mondal and Misra, 1985). Rao and Misra (1983) studied meiofaunal abundance in Sagar Island, Sunderbans and found that nematodes constitute the most dominant group followed by copepoda, polychaeta, ostracoda etc. Nektonic groups include the great diversity of fish and prawn species. The nektonic fauna of this mangrove

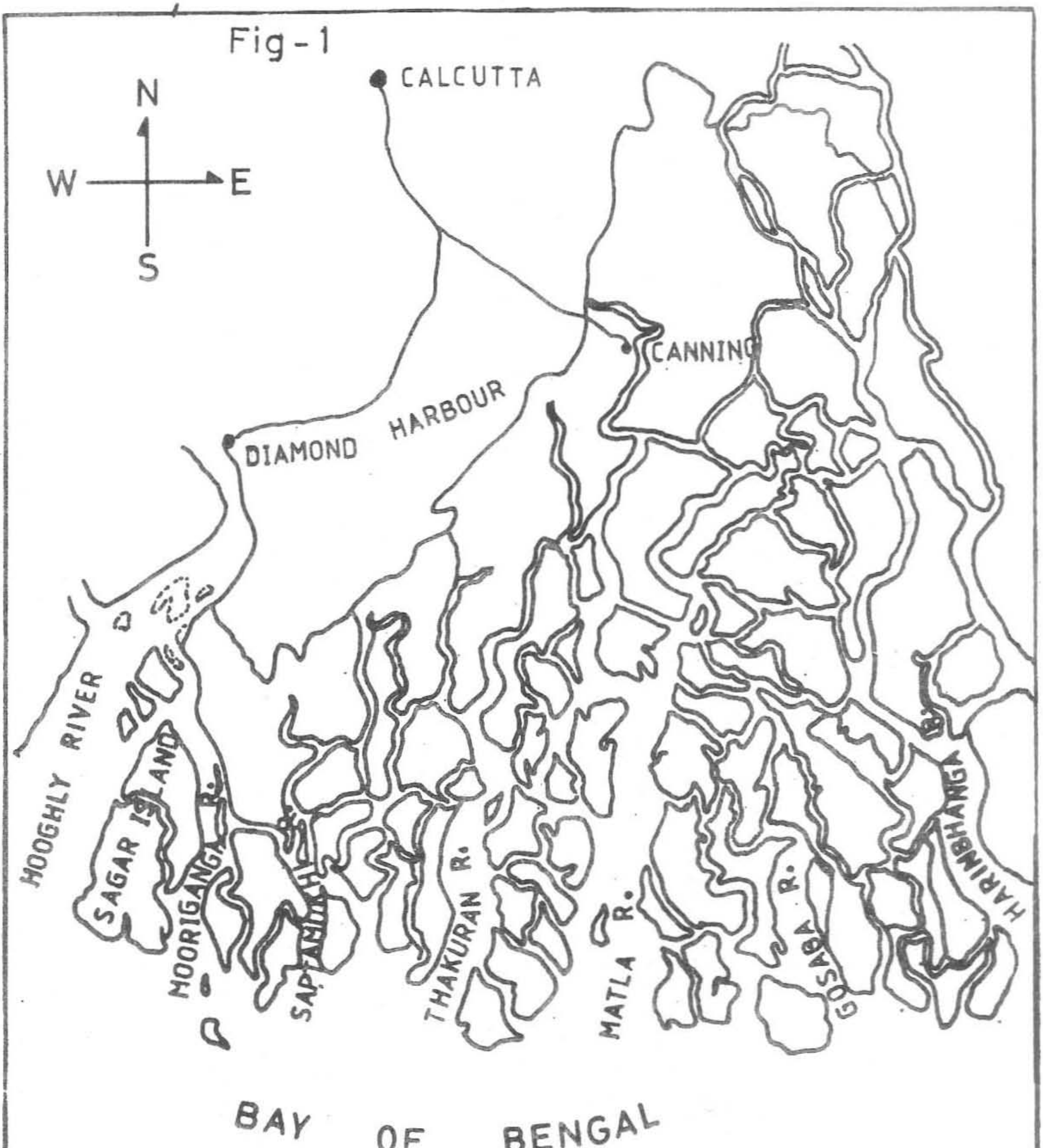
Fig - 1
N
W
E
S
CALCUTTA
CANNING
DIAMOND HARBOUR
HOOGHLY RIVER
SAGAR ISLAND
MOORIGANGA R.
THAKURAN R.
MATLA R.
GOSABA R.
HARINBHANGA
BAY OF BENGAL
(NOT UPTO SCALE)

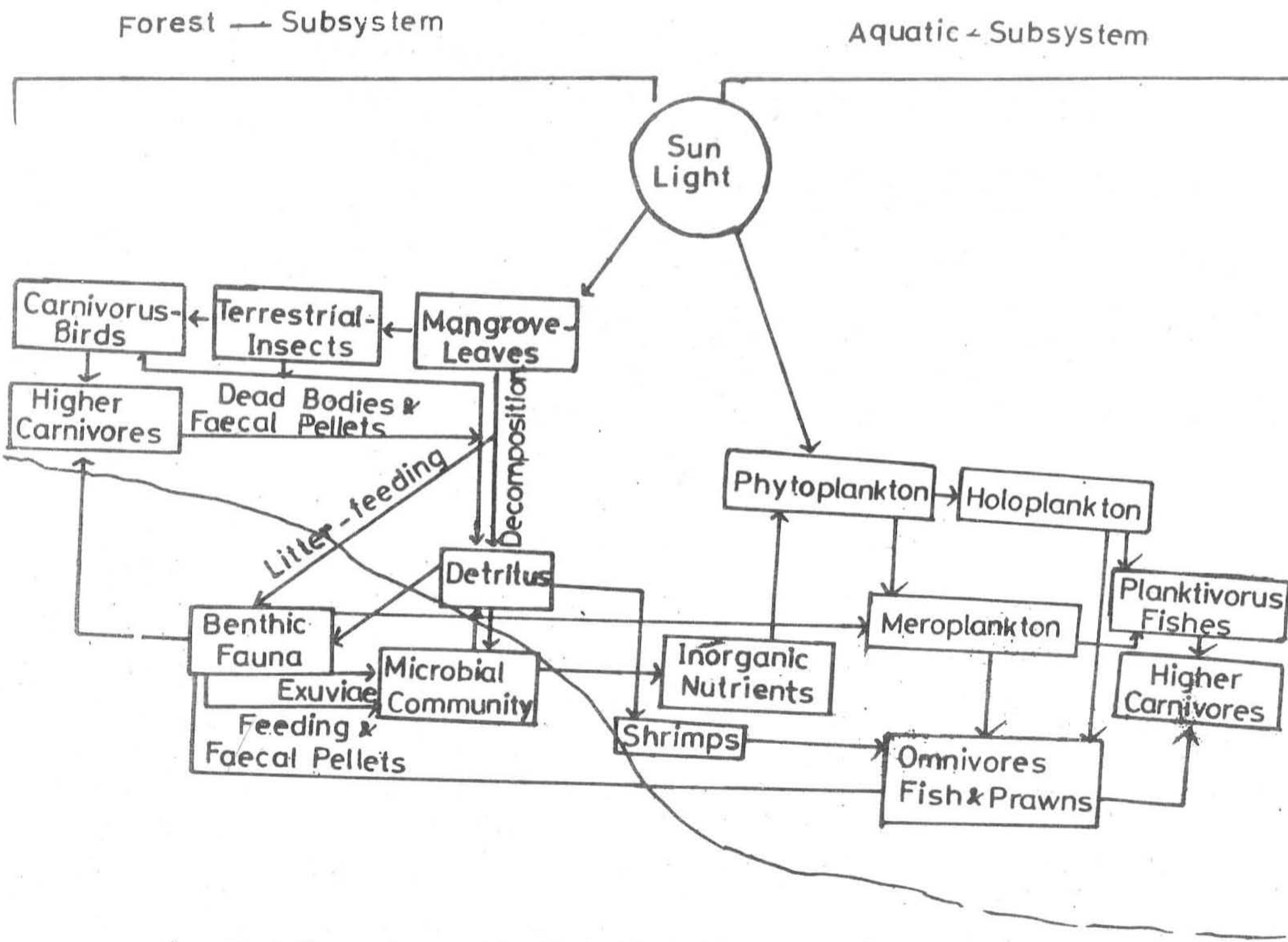

Fig. 2. Diagrammatic representation of food-web in mangrove-ecosystem, Sunderbans

estuarine system can be divided into two broad groups — residents and transients or migrants. The resident species according to their salinity tolerance are grouped into three categories (Pantulu and Bhimachar, 1964). First category (salinity from 6.26% to 32.86%) includes Mullets – *Liza parsia* and *L. tade*; Thread fins – *Polynemus tetradactylus* and *P. indicus; Sciaena miles* and *Sciaenoides biauritus*; Perches-*Lates calcarifer;* Ribbonfish – *Trichiurus savala*; Clupeids – *Hilsa sinensis* and *Coilia bornunsis*; Catfish - *Tachysurus jella* and *Plotosus canius*. Second category (salinity-from 4% to 32.86%) includes *Harpodon nehereus, Setipinna taty* and *Ilisha elongata.* Third category (salinity 32.86%) includes *Pama pama, Coilia ramcarati, Polynemus paradiscus, Setipinna phasa, Sillaginopsis panijus*. The migrant species usually enter the estuarine zone for breeding and feeding. These species can be broadly divided into three categories (Jhingran, 1991). Firstly, marine forms that migrate upstream and spawn in freshwater areas of the estuary are : *Hilsa ilisha, Polynemus paradiscus* etc. Secondly, freshwater species which spawn in saline areas of the estuary are : *Pangasius pangasius* and the prawn *Macrobrachium rosenbergi.* Thirdly, marine fishes that spawn in the saline areas of estuary are : *Tachysurus jella, Polynemus indicus, Penaeus indicus, P. monodon* etc. A total of 172 species of fish has been recorded from the Hooghly Matlah estuarine complex of which 73 occupy the less saline zone and 99 the higher salinity zone (Jhingran, 1991). A total of 26 species of prawns and shrimps spread over in 5 families occur in these estuarine waterbodies of Sunderbans (Gopalakrishnan, 1971).

3. *Water quality*

Rapid and distinct seasonal changes of different environmental parameters are a striking feature of mangrove-estuarine complex of Sunderbans, India. The organisms inhabiting this environment can be expected to react and adapt to physical, chemical and biological changes in the environment. Seasons are well defined in this estuarine system, each of about four months duration. The premonsoon (March to June) is the dry season with occasionally high temperature. The monsoon (South West) season (July to October) receives heavy rainfall and postmonsoon (November to February), comprised partly of the winter season, shows comparatively lower temperature and lesser precipitation. Of all the factors, salinity, perhaps is the most variable component of this ecosystem. Monsoonal flows exert profound influences on every aspect of estuarine environment. Rapid fall in salinity, after heavy precipitation and surface drainage interferes with the distribution of marine forms but during the premonsoon, the high salinity interferes with the distribution of freshwater forms. Salinity of the flowing water fluctuated from 3.12% to 25.84%. (Sarkar *et al,* 1986) while salinity of interstitial water fluctuated from 6.8% to 28.2% (Chakraborty and Choudhury, 1992). Variations in the temperature of surface water was normal for a tropical estuary with a maximum in May (30.7°C) and minimum in January (22.3°C) (Sarkar *et al,* 1986). Dissolved oxygen values did not differ appreciably (2.5 to 3.4 ml/L) but the values were relatively higher during the monsoon period than other seasons (Sarkar *et al,* 1986). pH remained almost constant throughout the year, except during the monsoon (Sarkar *et al,* 1986; Chakraborty and Choudhury, 1992). The gross primary production varied from 17.2 to 42.8 $mgC/m^3/4$. The maximum values were obtained during postmonsoon and minimum during monsoon. The maximum light penetration was observed during postmonsoon periods and minimum during monsoon. The Secchi disc readings varied from 18 cm to 52 cm

(Bhunia & Chaudhury, 1985). Nutrient status of the water depends on the availability of silicate (82 μg/L to 140 μg/L), nitrate (6 μg/L to 18.8 μg/L) and phosphate (0.92 μg/L to 2.3 μg/L) concentration which are instrumental for the total biological productivity of the system (Dey *et al*, 1987). Tidal amplitude varied from 4.6 to 5 metres (Paul *et al*, 1987).

4. *Soil quality*

Mangrove-sediment relationship is of immense importance with regard to the suitability of sites for the construction of aquaculture farms. The alluvial clay soils of estuarine and deltaic environments are most suitable for pond construction (Macintosh, 1984). Textural analysis of Sunderbans mangrove soils (Gupta, 1987) revealed that the soil was mainly silty-clay. The percentage of sand particles varied from 3.81% in Prentice island to 42.62% in Sagar island while that of silt-clay percentage varied from 57.65% in Sagar island to 94.96% in Prentice island. Water holding capacity in silty-clay soil is more (59.03% in Lothian island) than comparatively higher sandy soil (42. 16% in Sagar island). Regarding mangrove soil nutrient status, both the percentage of organic carbon (0.45% to 1.86%) and humus carbon (0.04% to 0.24%) in surface layer were higher than those in subsurface due to the confinement of organic residues in this layer. Available N (85 ppm to 116.4 ppm). P (10 ppm to 42 ppm) and K (331 ppm to 630 ppm), were present in appreciable amounts (Sahoo *et al*, 1985). pH of the mangrove soil varied from 6.5 to 8.1 (Gupta, 1987).

5. *Functional aspects of mangrove ecosystem*

The mangrove ecosystem is an open, integrated selfsustaining system which unlike other ecosystems, is a combination of two subsystems linked together-the shallow water mangrove forest subsystem and aquatic sub-system composed of the swamps and water courses associated with the sea-shore directly or indirectly through the estuary. The shallow water forest subsystem exports energy and nutrients to deeper water of estuary and adjacent coastal shelf. The plankton and nekton, which move freely between the two fixed subsystems producing, converting and transporting nutrients and energy while responding to diurnal, tidal and seasonal periodicities (Odum, 1971). Hitherto productivity of mangrove-ecosystem had been attributed to four reasons: (1) three types of primary production units (marsh vegetation, benthic algae and phytoplankton) which ensure maximum utilization of light at all seasons; (2) ebb and flow of water movements resulting from tidal action; (3) abundant supplies of nutrients; and (4) rapid regeneration and conservation of nutrients due to the activity of microorganisms and filter feeders (Schelake and Odum 1962). A number of operating food chains for this ecosystem may be categorised into two distinct types. Firstly, the grazing food chains that begin with the consumption of live plants (both phytoplankton and mangrove vegetation) by herbivorus consumers and then by carnivorus consumers. Secondly, the detritus food chain that begins from the dead organic matter into microorganisms and then to detritivores and their predators. These different food chains are inter-connected with one another to produce a very complicated mangrove-estuarine food web (Fig-2).

Therefore, physical, chemical and biological processes operating in mangrove ecosystems to sustain high levels of productivity are due to the wide range of interactions among different structural components (viz. soil, water, flora and fauna) of the ecosystem.

The degrading plant litter is consumed by a wide variety of organisms as well as it releases nutrients to mangrove ecosystem for recycling. The litter fall in Sunderban mangrove forest is higher than 550 gm dry wt./m^2/ year found in mangroves at Rookery Bay by Lugo and Snedaker (1974) and 876 gm dry wt/m^2 year as observed by Heald (1971) of mangrove at Everlade Park area in Florida (Jadav and Choudhury, 1985). The mangrove insects and macrobenthic community act as macrodegrader by breaking the large, thick, wax coated mangrove leaves into smaller fragments. Then mangrove microbial communities (viz. bacteria, fungi and protozoa) complete the degradation of litter into detritus. The deposit feeders (viz. crabs, molluses, polychaetes, nematode etc) through their feeding activities turn over the surface sediment layer, thereby exposing new litter surfaces to microbial attack. An understanding of the process of mangrove detritus formation may throw some light on the direct utilisation of decomposed mangrove leaves as manure cum food for aquaculture farms. Experimentally, Vijayaraghavan and Ramdas (1980) have estimated an assimilation efficiency of 92 per cent for juvenile *Metapenaeus monoceros* fed on a diet containing 60 per cent decomposed *Rhizophora* leaves. Analysis of gut content of most of the commercially important mangrove associated fish and prawn species revealed that they are all taking their food which are in plenty in mangrove-estuarine system (viz. phytoplankton, zooplankton, microbenthos, detritus etc). Moreover the soil and water quality are also dependent on the production of detritus as well as on the various types of interactions within the biotic community.

6. *Management of mangrove aquaculture ponds*

In tide-fed mangrove aquaculture ponds, successful culture depends on the frequent exchanges of water between the ponds and river by operating the sluice gates in order to maintain good water quality. Mangrove deltas and estuaries are favoured locations for pond culture operations. Swamplands bordering the bend of an estuary or situated in the angle between two watercourses are ideal because a throughflow water exchange system for the farm can be operated (Macintosh, 1984). Estuarine water is not only enriched with nutrients but it is perfectly buffered against abrupt changes in pH and in proper season it carries with it culturable seeds of many finfish and shellfish. The organic matter brought in by the incoming tides disintegrates and adds to the fertility of the soil (Jhingran, 1991). Tidal range and shore elevation are to be taken into consideration for selecting suitable pond sites. A perimeter dyke with a height of 20-50 cm above the highest-high water level, is built to isolate ponds from the coastal zone (Macintosh, 1984). Dykes are of three types — primary, secondary and tertiary. Primary dykes form the boundaries of the pond system and should be strong enough to withstand waves and floods from the neighbouring waterbodies. Secondary and tertiary dykes divide the pond system into compartments. Mangroves should be maintained or allowed to flourish outside the peripheral embankment in order to supply nutrient rich water to the culture ponds through the main sluice as well as to prevent erosion from the dyke. In Sunderbans, experimental studies have revealed that there should be 65-70% water areas and 30-35% of the land areas can be utilised to grow certain species of mangrove vegetation (*Acanthus ilicifolius, Excoe caria aqallocha; Portaracia coarctate* etc) which have been found to thrive well even with limited brackishwater supply. (Ray *et al*, 1989).

7. *Conclusion*

The scientifically managed aquaculture operations in mangrove ecosystems with minimum capital investment and application of simple technology may yield substantial profit. There is a need for proper management and conservation of mangrove ecosystems. Brackish-water areas suitable for aquaculture should not be allotted for other purposes. The traditional bheries of West Bengal, covering a total area of about 50,000 hectares, are tide-fed ponds dependent on auto-stocking of tide-borne seed resources, could afford a production of about 775 kg/hectare/year of which production of *Penaeus monodon* constituted 18 per cent (CIFRI, 1986). This is also a reflection of aquaculture potentiality of mangrove-estuarine adjoining regions. Judicious selection and application of modern biotechnology will certainly bring forth improved quality and higher production. Over exploitation of biological resources should be avoided. Large scale destruction of juvenile prawns in the nursery grounds is now a burning problem in Sunderbans areas. Along with the prawn seeds, juvelines of other commercially important fishes are also being destroyed. Though complete prohibition in this regard may not be possible due to socio-economic problems, alternative policies like formation of seed protection committee by local fishermen in consultation with panchayat and Government may be formed for judicious utilization of seeds. The numbers of the committee may be trained with respect to the seasonal availability of different finfish and shellfish seeds and usage of nets with proper mesh sizes. Indiscriminate capture of brood females of different prawns as well as other fishes should be avoided. Direct fishing of rare shellfishes like king crabs must be prohibited as they are not only living fossils of great zoological importance but also have medicinal values. During water exchange in between aquaculture farm and surrounding estuary, the outgoing water enriched with chemical nutrients and metabolic wastes should be treated before its discharge. Careful diet, monthly, and seasonal monitoring of water and soil qualities should be done to prevent the occurrence of different diseases. Moreover, the Hooghly estuarine system is being gradually affected by the enormous load of industrial effluents contributed by various industries like pulp and paper, paints and varnishes, rubber and cycle rim, tannery, petrochemicals, thermal power plants etc (Ghosh *et al*, 1989). The impact of such pollution is supposed to be an important factor for the declining trend on the availability of some fish species (9 endangered, 8 vulnerable and 4 rare species) from the area (Pandit *et al*, 1994). Proper steps should be taken to completely eliminate all sorts of anthropogenic stresses from this highly productive estuarine area including pollution.

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