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WETLANDS OF KERALA: DEGRADATION, RESTORATION AND FUTURE MANAGEMENT-A CASE STUDY OF KAVVAYI WETLAND-A COASTAL WETLAND IN THE NORTHERN KERALA

P S Harikumar
Senior Principal Scientist
Centre for Water Resources Development and Management
Kozhikode(Calicut) Kerala 673571
E Mail: hps@cwrdm.org, Tel: 04952383736 Mobile:09847781444
Web: http//www.cwrdm.org

Wetlands provide fundamental ecological services and are regulators of water regimes and sources of biodiversity at all levels – species, genetic, and ecosystem. It constitutes a resource of great economic, scientific, cultural, and recreational value for the community. Wetlands play a vital role in climate change adaptation and mitigation. Progressive encroachment on and loss of wetlands can cause serious and sometimes irreparable environmental damage to the provision of ecosystem services. Kerala is located on the southernmost tip of India and embraces the coast of Arabian Sea on the west and is bounded by the Western Ghats in the east extending from 8^0 17' and 12^0 48' north latitude and 74^0 51' and 77^0 20' east longitude with total area of 38, 916 sq km.Studies carried out in recent years have pointed out the unfavorable changes taking place in the physicochemical, biological and geological environment of the wetlands of Kerala. They are facing severe environmental problems including loss of areal extent due to anthropogenic pressure, over exploitation of its resources and reduction of its carrying capacity. A classic example is the Vembanad-kol wetlands which once covered an area of 2033.02 km2 and its river basins spread over 6126.48 km2 area. The area of Vembanad Lake during 1917, 1970 and 1990 had declined to an extend of 290.85 km^2, 227.23 km^2 and 213.28 km^2 respectively (Gopakumarand Takara, 2009). A total of 63.62 km^2area had reclaimed from the lake during the period 1917-1970, was primarily for formation of polders and to enlarge the extent of the Wellington island and Cochin PortThe wetlands of the State are classified into two broad categories namely Inland and Coastal wetlands. The total area under wetlandswas calculated as 127930.07 ha, out of which the inland wetlands cover about 34199.57 ha and the coastal wetlands about 93730.50 ha(MoEF, 1990). Recent areal estimates by various agencies on wetland categories including water-spread area, aquatic vegetation and turbidity show that there are 1762 wetlands in the state. In addition, 2592 wetlands smaller than 2.25 ha had also been identified Thus the total wetland area estimated was 160590 ha. The major wetland types included were River/Stream (65162 ha), Lagoons (38442 ha), Reservoirs (26167 ha) and Waterlogged (20305 ha) areas.The beauty and purity of the wetland is needed to protect it in a wise use concept under Ramsar Convention (Ramsar, 2007).The wise use of wetlands is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". Vembanad-kol, Ashtamudi and Samsthamkotta, are already designated as Ramsar sites in Kerala. In addition to this, two more wetlands - Kottuli in Kozhikode District and Kadalundi in Kozhikode and Malappuram Districts - have been identified by the Ministry of Environment and Forests, Government of India, under National Wetland Conservation Programme. In this paper, we discuss the degradation, conservation steps and management action plans of Kavvayi Lake, a wetland in the Western Ghats of Kerala.

Kavvayi Wetland, a large coastal backwater body spread out in northern Malabar in Kerala,is located in the humid tropical climatic region of the State where rainfall is the predominant climatic factor. The average annual rainfall of the Kavvayi Wetland System is about 3112.3 mm. The south-west monsoon contributes about 86%, north-east monsoon about 8.7% and non-monsoon period during December to May contributes about 5.3% of the annual rainfall. Thus the rainfall is highly seasonal, with heavy dependence on the six month period from June to November. Kavvayi Wetland System consists of the Kavvayi backwater body and five west flowing rivers originate from the Western Ghats and draining to the wetland viz. Nileswar, Kariangode, Kavvayi, Peruvamba and Ramapuram.

The Kavvayi Wetland System (including basin area of five rivers draining to the wetland) has a geographical area of 1264.62sq.km. Out of the five rivers, Kariangode basin is the largest and Ramapuram is the lowest. The annual discharge to the wetland from five rivers is about 4351MCM, of which more than 94% of their annual discharge is during monsoon and remaining 6% only as non-monsoon flows. The flow duration analysis of the rivers indicated that about 50% of the time, these rivers have very negligible flows. The water balance study of all the five river basin draining into the Kavvayi Wetland shows a water surplus on annual basis. Whereas, the basins shows water deficit during the non-monsoon periods in meeting all the water demands. Hence, a system approach is necessary for arriving at an appropriate decision with regard to the optimal utilization of fresh water within the river basins.

The bathymetric survey reveals that the water spread area of Kavvayi Wetland at mean sea level is 9.1 sq.km. The maximum and minimum depth of the Wetland body is 8.9 m and 0.5 m respectively. The maximum depth of the wetland body is observed near to the estuarine. The maximum and minimum width of the Wetland body is 1754.12 m and 155.81 m respectively. The width of the wetland body at estuarine is about 421.31 m. The volume of the Wetland at MSL is estimated at 31.58 MCM. The bathymetric survey reveals that the present lake water spread area is 9.1 sq.km at MSL and corresponding lake volume of 31.58 Mm^3.The water balance study of Kavvayi wetland reveals that the average annual inflow from the total drainage area of the wetland is 4351MCM, which is equivalent to an average annual surface inflow rate (Si) of 138m3/sec. The mean annual precipitation in the wetland and the mean annual evaporation from the wetland is estimated a 3112 mm/year and 1430 mm/year. The average annual outflow from the wetland to the Arabian Sea is about 138.62 m^3/sec or equivalent to an annual volume of 4371.5 MCM. The long term mean water residence time in the Kavvayi lake and turnover rate are estimated as 2.6 days and 139 days/year, respectively. It is seen that, there is a considerable seasonal variability in water residence time within the Kavvayi lake system.

Kavvayi wetland is rich in biodiversity. A sacred grove viz. Edayilakkad island preserves many rare and endemic species. One of the endangered species of bird, White bellied sea eagle and Nervilia species are endemic to Malabar region are also found in this region. The wetland area is rich in mangroves and mangrove associates. Kavvayi wetland acts as fertile ground for many migratory birds.

The physico chemical and biological characteristic of the wetland is directly influenced by the rivers draining into the wetland system. The quality of surface water is interpreted through the Canadian Council of Ministers of the Environment (CCME) Water quality Index. Most of the sampling stations of the Kavvayi Lake show poor water quality according to the Canadian Council of Ministers of the Environment Water quality Index. The various ionic concentration of the river reported comparatively high value in the downstream stations.Similar trend as that of Kavvayi Lake was also observed for the physico chemical parameters of rivers draining into it. The concentrations of physico-chemical parameters of all the five rivers were very low in monsoon season; it may due to the dilution effect.The maximum value of BOD was observed for the surface water sample collected from Kokkinisseri of Peruvamba River. Bacteriological contamination is prevailing in most of the surface and groundwater samples of Kavvayi wetland system.

Heavy metals such as Fe, Mn and Cu were present in almost all the soil samples. According to Canadian Environmental Quality Guidelines for soil quality, some of the samples collected from Kokkal, Thekkekkad and Edayilakkad were found to be contaminated with cadmium and lead. Cation Exchange Capacity of sample collected from Kokkal Island was also high which indicates that heavy metal concentration increases with Cation Exchange Capacity. Soil Texture analysis reveals that most of the soil samples are sandy and maximum clay content was found in samples collected from Kokkal Island. Organochlorine pesticides like Aldrin and Endo- alpha were also detected in the soil samples of Kavvayi Wetland System.

Physico-chemical analysis of surface sediment samples collected from Kavvayi wetland systems indicated that all the samples except one was alkaline. The sample collected from Edayilakkad reported a pH of 3.01. Concentrations of chloride, sulphate, exchangeable sodium, exchangeable potassium, exchangeable calcium and exchangeable magnesium were found to be higher in the sediment samples. Texture analysis indicated that all the samples were sandy type.
Heavy metal analysis of the sediment samples indicated the presence of iron, manganese, copper, lead, cadmium, nickel and zinc in the surface sediments. As per USEPAsediment quality guideline, (KV-6) Ayittikadavu is heavily polluted with lead,

nickel and copper. Mixing Point of Kavvayi River in to lake (KV-2) was heavily polluted with nickel and lead. All the sediment samples except two at stations (KV-9 and KVE-1) were found to be heavily contaminated with lead.

The degree of contamination (Cd) of three stations, KV-2 (mixing point of Kavvayi river into Lake), KV-6 (Ayittikadavu), and KV-11 (mixing point of Nileswar River into Kavvayi Lake) indicated considerable degree of contamination. Sampling stations KV-1, KV-13, KVVP-1 and KVPB-2 were found to be moderately contaminated and all the other stations showed low degree of contamination.

Sediment samples were found to be contaminated with organo chlorine pesticides. Aldrin, Endo-alpha and Endo-beta were detected in sediment samples. Major fraction of sedimentary inorganic phosphorous in surface sediment consisted of NaOH-P (Fe-bound and Al-bound phosphorous) whereas HCl-P (Ca-bound phosphorous) constituted only a minor fraction. Higher concentration of organic phosphorous was also detected. Phosphorous release was from Fe-bound, Al-bound and from organic fractions. Hence in Kavvayi Lake, there can be a choice of considerable release of phosphorous from sediments into surface water.

A study was done to assess the core sediment quality and surface water quality of selected stations of Kavvayi wetland system. Physicochemical characteristics of sediment samples showed that chloride concentration was found to be high which may be due to the salinity intrusion and detected comparatively at a high concentration in Puthiyapuzhakara. A regular trend was observed for cations and anions. Most of the cations were present in the surface sediments and its concentration decreases towards the bottom. Most of the samples from the three stations of Kavvayi wetland system have comparatively high organic matter content. Organic carbon decreases from surface to bottom in all stations. The highest concentration of organic carbon was found in Puthiyapuzhakara. The concentration of inorganic and total phosphorus was found to be high in the bottom portion of the lake. Majority of the sample in the Kavvayi wetland was found to be in sandy (95%) nature. Samples collected from mixing point of Kariyamkode River into Kavvayi Lake had maximum clay content. Heavy metals such as Fe, Mn, Cu, Pb were present in all the samples. Cd was only present only in 24-28cm layer in station (Mixing Point of Kavvayi River into Kavvayi Lake). When compared with USEPA sediment quality guidelines, it was found that mixing point of Kavvayi River into Kavvayi Lake was highly contaminated with Cd and mixing point of Kariyamkode River into Kavvayi Lake and Puthiyapuzhakara was highly contaminated with Ni, and Lead. Statistical analysis was also done to ascertain sources that affect heavy metals distribution in the wetland, inter- elemental Association was evaluated using the Pearson correlation coefficient.

Physicochemical status of the surface water samples indicated that all the surface water samples collected were found to be within the BIS limit. . The high electrical conductivity values may be attributed to the presence of dissolved solids in the water. The maximum EC value of 49800 µs/cm was recorded at site KVL-04. The low value of chloride was recorded at KVL-01 could be due to the fact that the particular site is away from the intrusion of the sea water. Among the seven water samples, chemical parameters such as chloride, calcium, magnesium showed higher values in sample KVL-04 (Puthiyapuzhakara). The highest value of sodium was measured at site KVL-03 it may be due to salinity intrusion. The high potassium level recorded at KVL-03 was an indication of the influence from domestic discharge and agricultural effluents especially from fertilizers containing potassium which can be leached through soil run off into the lake. By measuring dissolved oxygen levels it was found that the wetland supports aquatic life. Bacteriological analysis revealed that all samples were contaminated with Total Coliform and Faecal coliform. Among all these station only KVL-06 (Neeleswaram) showed E.coli contamination. As the spatial and vertical distributions of elements in sediments in creek environment are influenced by so many factors including geochemical and biogeochemical process like sedimentation, precipitation and flocculation particulate substances and hence it is difficult to find the principle one. Present study shows that the vertical concentration of elements is not varying remarkable which indicates that there is a continuous and same source. Pollution load index indicated that the sampling station taken for our present study was not polluted, but it was contaminated with Lead and Cadmium. It is however suggested that heavy metal contamination (pollution) of the wetland should be checked and monitored regularly for environmental pollutions. Due emphasis need to be given to the study of metal distribution, so that contribution of manmade and natural effects may be assessed.

Fed by five rivers and spotted with small islands, Kavvayi wetland is considered as the biggest wetland ecosystem of North Kerala, spreading across an area

of 1264.62 sq km. The wetland body stretches from Kavvayi near Payyannur to Neeleswaram in Kasaragod and is under threat of pollution, land filling, wetland encroachment, destruction of mangrove forests, sand mining, etc. By bringing in strict protective regulations, a long term demand of nature lovers, the illegal mining and reclamation activities could be kept at bay. Kavvayi is an important wetland system and the government should take immediate steps to bring it under nationally important wetland and Ramsar Convention sites. A well functioning wetland provides fish and wildlife habitat, water quality protection, natural floodwater storage and reduction in the erosive potential of surface water. A degraded wetland is not able to effectively perform these functions. Human activities cause wetland degradation and loss by altering water quality, quantity and flow rates. The most important threat to the coastal backwaters is the upstream anthropogenic activities, which exert stress on the downstream area. Increasing pollutant inputs and changing species composition can be the result of the introduction of non-native species. These disturbances can be minimized with strong co-operation between the downstream and upstream population along with the related authorities in restoring the valuable wetlands.

The Kavvayi Wetland system has been facing threat from land reclamation. The environmental problems identified in the catchment area of the wetland include: sand mining, laterite mining, unscientific development of tourism, over exploitation of minerals and resources, aquatic weeds which multiply very quickly and cover the water bodies, destruction of mangroves and unscientific construction of bunds that have been posing a threat to the biodiversity of the wetland which is home to some rare species of hydrophytic plants, birds and fishes, urbanization or anthropogenic pressure and community pressure for fuel, food and fodder. The other major threats include; dumping of wastes, coconut husk retting, sand and shell removal, weed choking, waste disposal by intensive aquaculture, agricultural practices along the catchment area.The impact ofclimate change in the wetland ecosystem has to be undertaken as long measure. This in turn is leading to shallow wetland areas to being swamped and some dwarf species of mangrove trees being submerged and drowned. The primary pollutants causing wet-land degradation are fertilizers, human sewage, animal waste, pesticides, heavy metals etc.

The wetland is located in one of the most populous coastal segments of the Malabar Coastline of India. Most of the people in the Kavvayi islands have adapted to the beneficiaries of this wetland as their livelihood. Fishing and artificial mussel culturing is one of the important income sources of the inhabitants in the Kavvayi wetland islands. Boat services and coir retting also provide earning for common man. Tourism is one of the fast growing sources of revenue. Various activities of tourism development are going on in the various areas of the wetland and are also giving way to gradual sustainable development of economic infrastructure of the wetland.

The goal of management planning for Kavvayi wetland system is to conserve its rich biological diversity and maintain full range of ecosystem services derived from the wetland system in order to sustain livelihoods of dependent communities. The purpose is to put in place effective management practices which enable integration of biological diversity, ecosystem service values in river-basin, ecological and economic security of the people dependent on the wetland resources and coastal zone level conservation and developmental planning. In order to achieve this, management planning has been organized along with the subcomponents, via land and water resources management, biodiversity conservation, ecotourism development, livelihood improvement and institutional development.

Desired stages in the Management Action plan of Kavvayi Wetland System include:

- Create awareness for the inhabitants and the concerned administrative bodies about the need of a MAP for Kavvayi Wetland
- Institutional arrangement for execution of the MAP
- The designated authorities support the institution to help in achieving the goals and objectives proposed in the MAP
- Monitoring and evaluation of the progress in the implementation of MAP objectives
- Achievement of the MAP goals resulting in an improved Kavvayi Wetland System

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OXYGEN DEPLETION IN STRATIFIED LAKES – WHY SHALLOW AND DEEP LAKES REACT DIFFERENTLY?

Alfred Wüest
Aquatic Physics, Eawag and EPFL, Switzerland
E-mail: alfred.wueest@eawag.ch

Abstract– Oxygen is the most important ingredient in natural waters, both for aquatic organisms as well as for human consumption. Critical for hypoxic levels are the deep-waters during stagnation periods, typically during summer or warm/wet periods, when the water column is density stratified. The oxygen supply to the deep-water is then reduced and the decomposition of organic matter leads to oxygen depletion in the stratified part of the water column. Especially in shallow lakes the oxygen removal can be drastic.

In this talk, I will show how the oxygen depletion mechanismsin lakes take place and how the depletion is related to the driving factors such as the high primary productivity (via high nutrient loads), the molecular diffusion of oxygen into the sediment, the molecular diffusionof reduced substances out of the sediment and finally the deep seasonal mixing during winter, which refills the deep oxygen reservoirs. In this talk, I will clarify how these different processes affect the oxygen budget and which of the processes can be influenced directly via the primary production (i.e nutrients) and which processes are depending on the morphology as well as how climate change is affecting the future of lake (deep-water) oxygen budgets. The examples shown in the presentation will be set into the context of the water quality in Switzerland, which went through a drastic improvement in the last 40 years.

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Mangroves – Threats and conservation strategies

K. R. Candrashekar,
Department of Applied Botany, Mangalore University,
Mangalagangotri, Mangalore - 574199, E mail: profkrchandrashekar@gmail.com

Mangrove ecosystem in the world covering an area of approximately 190,000 to 240,000 distributed in about 117 countries, harbour 193 plant species, 397 fishes, 259 crabs, 256 molluscs, 450 insects and more than 250 other associated species. Mangrove ecosystem has the highest level of productivity among natural ecosystems, and performs several ecosystem services. However, the continued exploitation of mangroves worldwide has led to habitat loss, changes in species composition, loss of biodiversity and shifts in dominance and survival ability. Worldwide, about half of the mangroves have been destroyed. For that matter India has reduced from 6000 km^2 in 1953 to 2000–3000 km^2 in 1989. These forests now occupy an area of about only 4871 km^2 area. The Indian mangrove biodiversity is rather high. The increased anthropogenic pressure on mangroves in India has been mainly due to land use changes and on account of multiple uses such as for fodder, fuel wood, fibre, timber, alcohol, paper, charcoal and medicine. A larger area of approximately 40% of the coastal land in the west coast has been converted to agriculture and urban development. Environmental awareness, proper management plan and greater thrust on ecological research on mangrove ecosystems may help save and restore these unique ecosystems. In order to conserve these fragile ecosystems the following strategies may be implemented. 1) The local governments should formulate proper management policy by involving local people who have a stake in the conservation and management of mangrove forests in their areas. 2) Efforts should be made at village, district and state levels by the policy makers and NGOs, to educate the local people about the economic and ecological values and functions of mangrove forests, and the negative results of their mismanagement. There is a need to involve people at the grassroots level, in protection of these forests. 3) The government should also encourage and involve ecologists, researchers and specialists to work on various aspects of ecological management of this resource. 4) Long-term research activities should be undertaken in collaboration with various premier organizations to increase the productivity of mangrove forests and also to develop various management models which can give added benefits to local communities involved in protection and conservation. 5) Added to these, the local educational institutions should chalk out the programme with the students and their parents to create an awareness on the ecological significance of these fragile and sensitive ecosystems and the prime necessity of their conservation.

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Integrating Sustainable Coastal Development Initiatives along Maharashtra Coast, using ICM Guidelines

R. Dhiman, J. Tirodkar and A. B. Inamdar

Indian Institute of Technology, Bombay, Mumbai – 400076, India

Abstract– Around 250 million of India's population reside within 50 km of the 7500 km coastline that is shared by 9 states and 2 union territories comprising 77 towns and cities including 3 megacities viz. Mumbai, Calcutta and Chennai. The coastline supports several economic activities that are vital for India's economy like oil & gas, ports & harbors, power plants, fishing, tourism and mining that keep affecting our coastal ecology and environment. Same time, it is important to note that Indian coastal stretches are well endowed with highly productive ecosystems that support coastal human population in numerous ways, ranging from alleviating their poverty by offering variety of coastal resources, to protecting them from natural and manmade hazards like erosion, cyclones, storm surges, tsunamis, pollution etc. Healthy coastal ecosystems are also considered as an effective and inexpensive defense against coastal hazards, besides being helpful in offering multiple options of livelihood for the coastal population. In the light of these facts, it is but natural to adopt an approach that balances between development and environmental wellbeing. But, of late, it is observed, that climatic change and anthropogenic stresses resulting from over-urbanization, ill-planned development, habitat fragmentation, overexploitation of resources, pollution from industry as well as anthropogenic sources are adversely affecting the ecological balance and the services being offered by the coastal ecosystems all along the Indian coast, thereby exacerbating vulnerability of the coastal population to various hazards. Hence, in order to improve the adaptive capacity of the coastal population, it is felt essential to restore the ecological balance by including ecological considerations into coastal planning and governance that can lead to enhancement of the resilience of the natural coastal ecosystem and thereby, increase the diversity of coastal livelihood. The best way to do this is by adopting the principles and practices of Integrated Coastal Management while aiming at sustainable development goals. This paper explains 2 major initiatives in this direction, one headed by the Maharashtra Maritime Board (MMB) viz. 'Sustainable Protection and Development of Coastal Maharashtra' and the other one, from Ministry of Environment and Forests (MoEF) viz. 'Enhancing Climate Resilience of India's Coastal Communities', that are aimed at restoring the coastal ecological balance through 2 separate eco-friendly interventions covering Maharashtra state. Further, the ways of harmonizing/integrating these activities with each other are also indicated in order to achieve best results from all, in the context of the current coastal status and laws.

1. Introduction

India is exposed on all fronts to the impacts of climate change due to its unique geographical features like a long coastline of 7500kms (5,423 km in peninsular India and 2,094 km in the Andaman, Nicobar land Lakshadweep Islands), Himalayan mountain ranges and vast desert stretches. These impacts include melting glaciers, accelerated desertification, sea level rise and intense storm surges. According to the Inter-governmental panel on Climate Change (IPCC, 2013), by 2030s, temperatures are expected to increase in India by 1-4° c, with maximum increase in coastal regions. About 250 million people reside within 50 km of India's coast, which accounts for approx. 3.5 percent of the world's population. India's coastline covers nine states and two union territories with 77 towns and cities located along the coast, including megacities like Mumbai, Chennai and Kolkata, and 75 coastal districts. India's coastline supports a number of economically important infrastructure such as oil and gas, power plants, ports and harbors, aquaculture, agriculture, marine fishing, tourism, mining, reclamation, etc. Currently, there are 12 major ports and 187 minor ports, several industries including power plants and urban sprawl occupying 43 per cent of the coast. These activities contribute significantly to the country's economy, which accounts for one of the largest in the South Asian Region. The coast also harbors rich ecosystems with extensive mangroves, seaweed beds, salt marshes and coral reefs that provide ecosystem services and contribute significantly to poverty reduction. For example, the ecosystem services in Odisha coast contribute to approximately 60 per cent of the rural economy. Conservation and effective management of these ecosystems are also a part of important climate change mitigation strategies, as they contain rich carbon reservoirs. Degradation of coastal and

marine ecosystems has a direct impact on the marginalized communities which are already vulnerable to climate change related impacts. The National Disaster Management Authority states that the Indian coastline is amongst the most affected regions in the world and exposed to almost 10 per cent of the world's tropical cyclones. It is estimated that the Bay of Bengal and the Arabian Sea are likely to experience strong climate vagaries over the coming years. India has already experienced many instances of extremes of temperature, rainfall and tropical cyclones in the period2009-2016, resulting in enhanced exposure to multi-hazard vulnerability with adverse impact on natural resources, agriculture and related livelihoods. Climate change and human induced drivers of environmental degradation pose significant long term risks to the country's economic growth and could undermine India's efforts to achieve the Sustainable Development Goals. There is increasing evidence of coastal India being exposed to human-induced pressures from poorly planned developmental activities, land reclamation, habitat fragmentation, exploitation of resources, invasive alien species, pollution from urban and industrial effluents, and increased occurrence of Industrial disasters. These anthropogenic stresses further exacerbate the vulnerability of India's coastal areas to climate change impacts discussed above.

On the backdrop of the aforementioned facts, it is utmost essential to see that the ecofriendly initiatives in the region are well planned to support sustainable development, in order to strike a balance between our developmental needs and environmental aspirations. This paper discusses the methodology being adopted in 2 such initiatives along Maharashtra coast along with a comment on the possibilities how they can complement each other. The paper also provides results obtained from applying the proposed methodology for Shoreline Management Plan to the available data from Mumbai coast.

2. Literature Review

Integrated Coastal Management is a continuous process of rational decision making with concern of conservation and sustainable use of coastal space and resources (Cicin-Sain and Knecht 1998). It requires the mediation of conflicts for allocation of resources with active involvement of interested stakeholders and public (GSAMP, 1996). ICM has distinct characteristics of balanced development, conservation, multisectoral planning with an added advantage of conflict mediation and participation. Fundamental purpose of ICM is to accomplish, "a sustained effort whose goal is to structure the allocation of coastal resources", the rate in which coastal resources are used and "how conflicts among stakeholders are resolved" (Olsen et. al., 1998).

A comprehensive definition, provided by Knecht and Archer (1993) defines ICZM as:

"A dynamic and continuous process of administering the use, development and protection of the coastal zone and its resources towards common objectives of national and local authorities and the aspiration of different resource user groups".

Sorenson (1993) gives a definition of ICZM as:

"Integrated management provides policy direction and a process for defining objectives and priorities and planning development beyond sectorial activities. It adopts a systems perspective and multi sectorial approach which takes into account all sectorial interests and stakeholder interests, and deals with economic and social issues as well as environmental and economic issues".

Table 1 Existing research on specific mechanisms of ICZM and the corresponding emphasis. Indicated by an X in the appropriate column

Mechanisms	Source	Emphasis on	
		Institutional success	Sustainable management
Public participation	Anker et al. 2004	X	
Co-management task force	Crean 2000	X	
Consistency review	Portman 2007		X
Capacity building	Garriga and Losada 2010	X	X
Planning hierarchy	Allmendinger et al. 2002		X
Setback lines	Bernd-Cohen and Gordan 1999		X

Environmental impact assessment	Budd 1999		X
Statutory management	Enemark 2005		X
Social impact assessment	Sievanen et al. 2005		X

3. Methodology

Coastal adaptation solutions include developing adaptive capacity of communities to diverse coastal livelihoods, enhancing the resilience of natural ecosystems, and including climate change considerations into coastal planning and governance. Barriers to addressing such adaptation solutions include poor inter-sectorial coordination and land use planning, promotion of unsustainable technologies, failure to integrate environmental and climate change concerns into development planning, poor enforcement, lack of alternative livelihood options, low adaptive capacity and poor preparedness. A necessary response to this challenge is to strengthen capacities of communities, local and state authorities and decision-makers to understand and harness the enormous value of ecosystems to local livelihoods and economy and in reducing climate change impacts through a well-planned growth.

The 2 major eco-friendly idea being attemptedalong Maharashtra coast, in line with the aforementioned goals are:

i. 'The Shoreline Management Plan' by Maharashtra Maritime Board (MMB)
ii. 'Enhancing Climate Resilience of India's Coastal Communities' by the MoEF through Maharashtra State Forest Department.

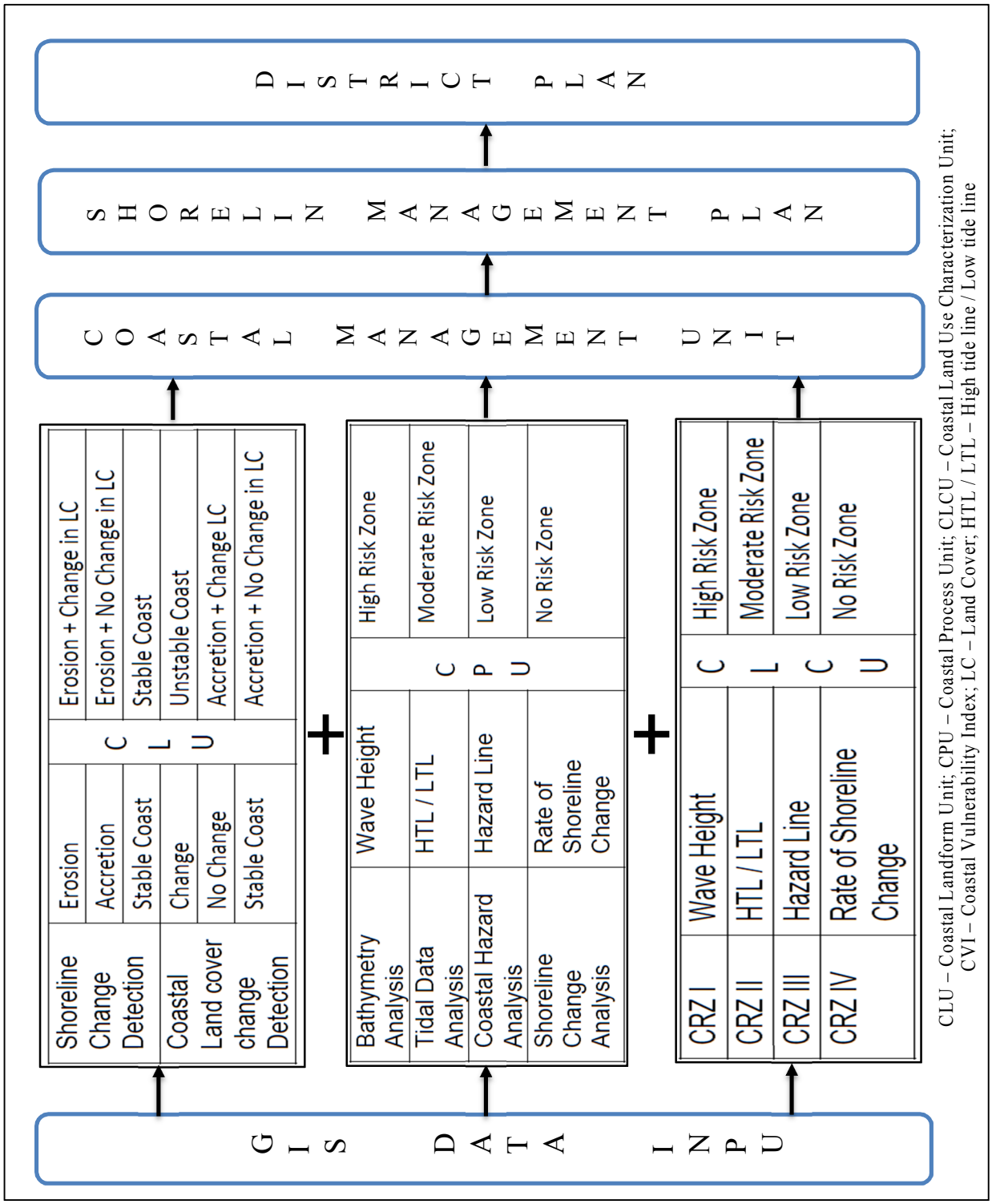
3.1. Shoreline Management Plan

The preparation of a Shoreline Management Plan (SMP) revolves around identifying land cover units that are vulnerable to shoreline erosion and deciding the future development plan based on the permissible land use under the law of the land, like CRZ Laws as well as the vulnerability status of the coastal land covers. The data requirements for this exercise are: Topographic Maps, Satellite Data, Digital Elevation Models, Tidal Data, Bathymetry, Historical Hazard Data, Wave Run-Up Data, CRZ Maps, Population Growth Data.

Proposed methodology for Shoreline Development & Planning can be divided in 2 major parts such as Coastal Managing Unit & Coast Protective Measures. Coastal Managing Unit is combination of Coastal Landforms Units (CLU), Shoreline retreat, Coastal Processes Units (CPU) & Coastal rules & regulations. Whereas Coast Protective measure Unit is combination of Population growth rate & Risk associated with coastal processes. This methodology not only addresses Sustainable Development but also performs risk assessment of Coastal zone.

The Shoreline Management Plan (SMP) methodology forthe Coastal Cityof Mumbai is provided in Fig 1. Output of CLU, CPU, Coastal Land use Characterization Units (CLUCU) in combination with each other forms Coastal Managing Unit. Coast protection Measures are suggested based on the analysis of Population Growth Rate & Coastal Process Unit. A Shoreline Management Plan decides Development & Non Development zone on the basis of CMU & Coast Protective Measures. This SMP not only preserves Ecological balance of Coastal zone but also addresses social & economic balance of the region.

The SMP is best executed with the help of GIS where various layers of information can be effectively stored, co-registered, scientifically manipulated and retrieved as per the needs of planners and decision makers.



CLU – Coastal Landform Unit; CPU – Coastal Process Unit; CLCU – Coastal Land Use Characterization Unit; CVI – Coastal Vulnerability Index; LC – Land Cover; HTL / LTL – High tide line / Low tide line

Fig 1 System architecture of shoreline management plan

3.2. 'Enhancing Climate Resilience of India's Coastal Communities'- Ecosystem based adaptation in coastal India:

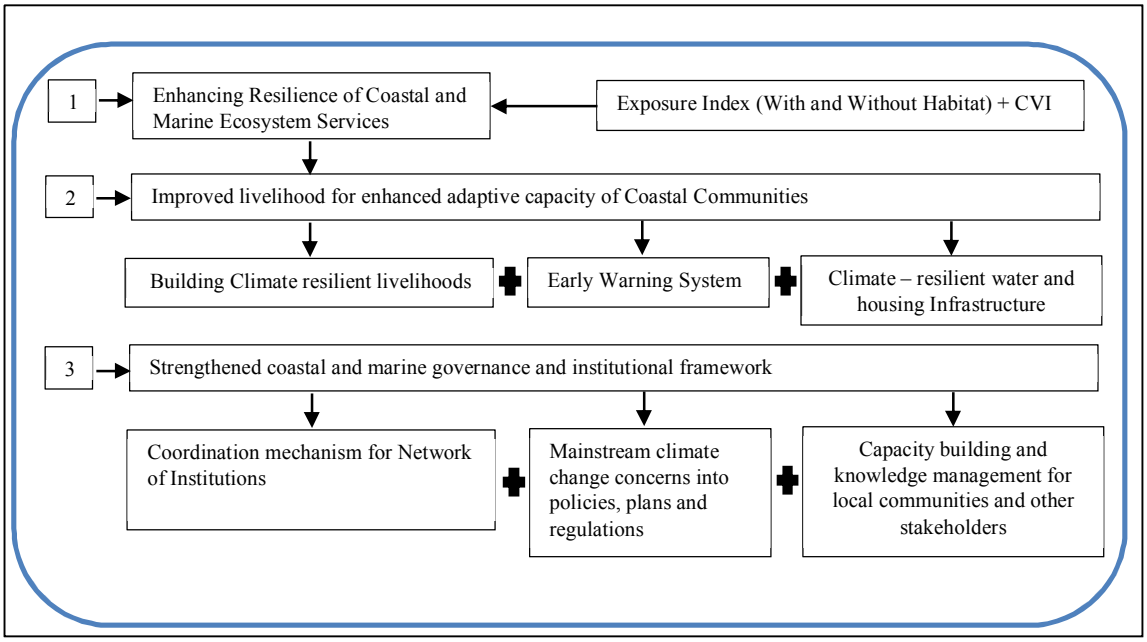
Coastal ecosystems have proven to be effective buffers and a good first line of defence against the impacts of extreme weather events and disasters like providing essential goods and services to local people. Consequently, the sustainable management and maintenance of coastal ecosystems is considered to be a cost effective and essential strategy in support of climate change adaptation. The UNFCCC recognizes that ecosystems play a crucial role in adapting to climate change at all levels. In effect, ecosystem based approaches address both climate change mitigation and adaptation efforts and provide multiple benefits. Though in India, the conservation of coastal habitats has been accorded high priority, its potential in supporting communities in adapting to climate change impacts is yet to be assessed comprehensively. Studies have shown that mangroves can reduce the impacts of cyclones and tsunami while also providing essential goods and services for coastal communities. This initiative will adopt an ecosystems based adaptation approach including the conservation, restoration or introduction of vegetated coastal ecosystems as a cost-effective option for addressing the increased risk from flooding and erosion caused by climate change in vulnerable areas.

3.2.1. Proposed Objectives

The objective of this project is to enhance the resilience of the lives and livelihoods of the most vulnerable populations, particularly women, in the coastal areas of India to climate change and extreme events. The expected key Fund level impacts are increased resilience and enhanced livelihoods of the most vulnerable people, communities and regions as well as the ecosystems and ecosystem services. The key component of the project is enhancing climate resilience in the coastal areas of India through a landscape based ecosystem centric approach. The component comprises three inter-linked outputs-

1) Enhanced resilience of coastal and marine ecosystems and their services.
2) Improved livelihoods for enhanced adaptive capacities of coastal communities;
3) Strengthened coastal and marine governance and institutional framework.

Fig 2 Proposed methodology for enhancing climate resilient of coastal and marine ecosystem services (MoEFCC)



- Integration of SMP and proposed methods of enhancing climate resilience

Inputs from detailed shoreline management plan can be an input for coastal vulnerability index which can serve as an indicator to identify and prioritize the regional locations for implementation of climate resilience actions. Multiple scenarios with habitat and without habitat can give an estimation of the extent under stress for decision making. Exposure index is directly dependent on coastal vulnerability which can be estimated using GIS data coupled with shoreline management plan. Furthermore, SMP driven hotspots will act as an identifier for implementation of climate resilient plan at various stages as mentioned in the proposed methodology for improvement of livelihood of coastal communities and strengthening of institutional framework.

4. Results for Shoreline Management Plan

4.1. CLU for Mumbai Coast

Mumbai Coast Topographic map of Year 1955 & remotely sensed satellite images of year 1999 & 2012 were used for this purpose. Landsat 5,4 and 3 band image combinations are considered. By visual interpretation, shoreline has been mapped for years 1999 & 2012.

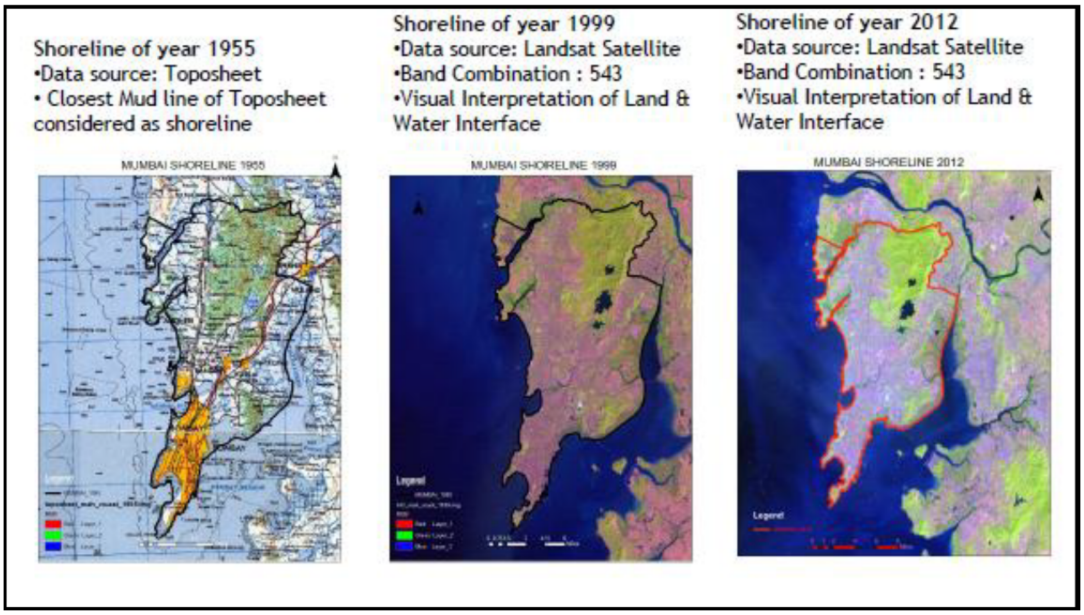


Fig 3 Shoreline Maps of Mumbai Coast for year 1955, 1999, and 2012

4.2. Shoreline Management Plan for Mumbai Coast

Shoreline Management Plan comprising CPM & CMU, formulated with help of Remote Sensing & GIS divides whole coastal zone in development zone & Non development zone along with suggestion of construction of coastal protective measures.

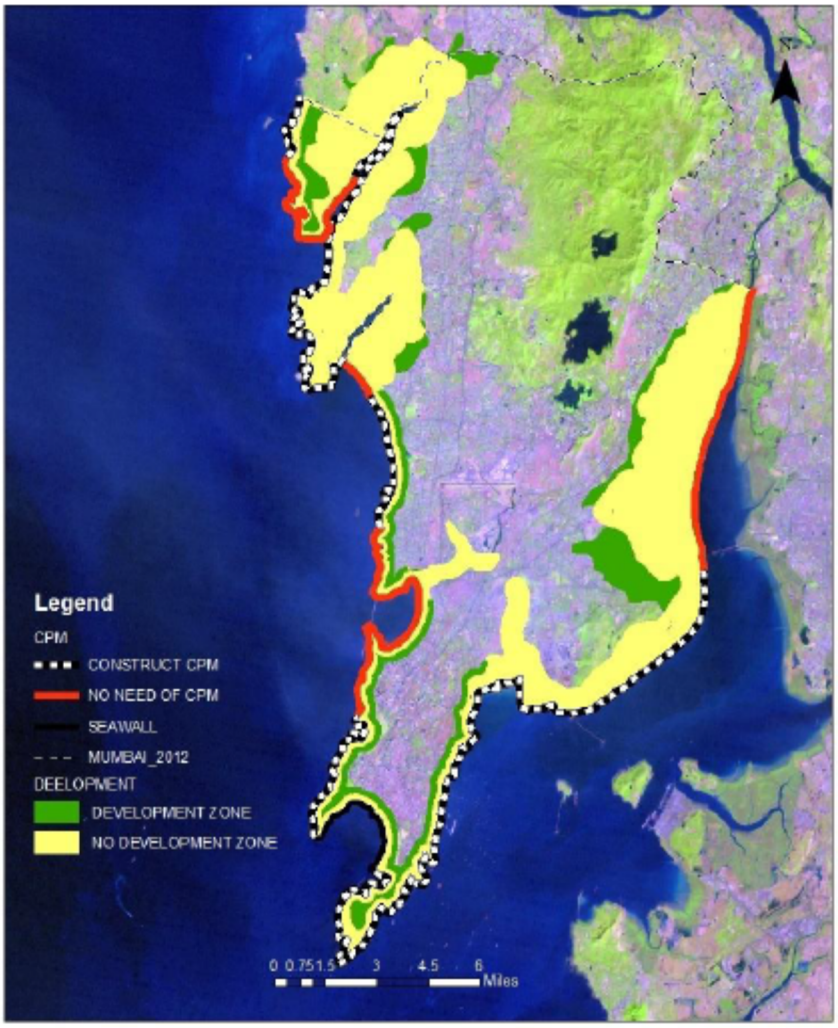


Fig 3 Shoreline Maps of Mumbai Coast for year 1955, 1999, and 2012

5. Results for ICM Initiatives

5.1. Enhanced Resilience of Coastal and Marine Ecosystems and their Services:

- Comprehensive climate vulnerability assessment to prioritize vulnerable stretches for ecosystems based interventions

An initial vulnerability assessment of coastal communities, towns and ecosystems will be undertaken as part of the feasibility study during proposal development, in order to ensure a solid evidence base for the activities and scope of the full project proposal. In the project itself, a comprehensive coastal climate vulnerability map of the whole of India will be prepared, and highly vulnerable coastal stretches will be identified. A detailed methodology based on the existing IPCC method will be developed for Indian conditions. This addresses the barrier posed by the incomplete state of information on vulnerability to climate change impacts along the whole of India's coastline, and information on specific local scale potential for ecosystem-based adaptation interventions.

- Conservation and restoration of coastal ecosystems for increasing ecosystem resilience.

Ecosystems based interventions will be conducted in the form of conservation and restoration of ecosystems (mangroves, corals, marshes, sea grass, etc.) in identified coastal stretches. Vegetated coastal ecosystems are important in protecting the coast against flooding and erosion due to waves and storm surges under mean and extreme conditions, including hurricanes whose intensity is predicted to increase with climate change. Recent findings on the remarkable capacity of vegetated coastal ecosystems for CO_2 sequestration and storage, and their capacity for sediment accretion and coastal protection, have converged to identify these habitats as essential elements of a strategy that combines both climate change adaptation and mitigation. The eco-engineering approach could become socially and economically efficient and may offer greater opportunities for countries-especially developing ones-to achieve sustainable targets even under limited financial resources and capacity.

- Monitoring blue carbon storage and sequestration to mitigate climate change

The use of vegetated coastal ecosystems to protect and restore lost CO_2 sink capacity and prevent the loss of deposits to mitigate climate change is not widely understood amongst decision-makers in India, posing a barrier to maximizing the use of natural ecosystems as part of managing multiple climate risks. "Blue Carbon" initiatives to maximize and monitor the contribution of coastal and marine ecosystems to avoided emissions of GHGs were first discussed in India in 2009. The project will assess the potential of blue carbon sequestration for coastal areas of India and monitor and report on quantities carbon sequestered through specific interventions in three target states, using standardized global methods.

5.2. Improved livelihoods for enhanced adaptive capacities of coastal communities

- Building climate resilient livelihoods

The project will combine government co-financing for livelihood support with GCF resources to address the incremental costs of incorporating climate change adaptation concerns. The lack of technical capacity will be addressed by undertaking extension and technical support, focusing on a) livelihoods that are linked to ecosystems and the services provided by them, such as fishing, aquaculture, mariculture, apiculture, pisciculture, eco-tourism, coastal agriculture etc., b) alternative livelihood opportunities through skill development to reduce dependence on ecosystems, and c) developing work opportunities for coastal ecosystem based activities like mangrove protection and restoration, coral reef enhancement, reducing erosion in estuary mouths, etc. Local communities and CBOs will be involved in the planning and implementation phase of the ecosystem enhancement. The feasibility study will explore opportunities along the coasts of the three target states, including potential for new market linkages and value chain development.

- Improving capacities of local communities on climate resilient planning and early warning systems

Through trained community members, climate change messages will be communicated to coastal communities and stakeholders of the coastal areas for efficient adaptation and mitigation. These trained community members will also share the message of successful livelihood related interventions to other villages. This has been found to be effective in Wadatar village in Sindhudurg, Maharashtra, where the local women were trained in mussel and oyster culture, an important livelihood activity which has now spread to other villages.

- Climate-resilient water and housing infrastructure for coastal villages and towns

When considering climate related risks, it is essential to ensure provision of basic development needs such as housing and water supply, while ensuring integrated approaches by all sectors. The project will support the existing government schemes

and program to integrate climate change adaptation into processes to create new and/or strengthen existing amenities related to essential needs of communities, with special reference to water infrastructure and human settlements.

5.3. Strengthened coastal and marine governance and institutional framework:

- Network of institutions for enhanced climate resilience and integrated planning in coastal states

Partnership and cooperation amongst the institutions would be established by mainstreaming climate under the UNDP Government of India Coastal and Marine Programme-Mangrove and Marine Biodiversity Conservation Foundation, in Maharashtra and the East Godavari River Estuarine Ecosystem Foundation in Andhra Pradesh. Similarly, the Gulf of Mannar Biosphere Reserve Trust was established as a coordination body under a UNDP supported project. Climate resilience will further be incorporated into the mandate of these existing institutions.

- Mainstream climate change concerns into policies, plans and regulations related to coastal governance and strengthen their enforcement across sectors.
- Capacity building and knowledge management for reduced vulnerability.

6. Conclusion

Multiple initiatives highlighting the need for adherence to ICM principles and practices in developmental activities is the need of the hour and is being reflected in the recently proposed endeavors. It is however essential to see that such activities complement each other in order to draw maximum benefits out of them in terms of economic as well as ecological needs of the region.

Many risk assessment methodologies, rules and regulations are in use in India to prevent loss of life in coastal region. Most of the methodologies have attached more importance to economy of the region. However, natural hazard events occur due to disturbance in ecological balance &uncontrolled land reclamation in coastal zone. Exploitation of natural coastal resources beyond the optimum limit is expected to lead to scarcity in future. For developing country like India, it is equally important to fulfil needs of population & maintain social as well as economic balance during development phase. Adoption of Sustainable Development practices is hence the only solution that can strike a balance between ecology, economy and social aspects. Shoreline Management and Planning is one of the major parts of Sustainable Development. Along with SMP, we need to train population residing in coastal zone for social awareness during hazardous event.

In order to achieve resilience, effective multi stakeholder governance of India's coast for adaptation to climate change needs to be combined with well managed coastal ecosystems maximizing the delivery of ecosystem goods(such as harvested products), and services (such as buffering extreme events). A number of barriers to achieving these outcomes are currently in place. There is currently a lack of understanding of the effectiveness of coastal ecosystems as natural buffers during extreme events. Limited evidence is available on the importance of coastal ecosystems as carbon sinks for India. Technical capacity of coastal communities and governance institutions is also currently limited, both for effective co-management to maximize ecosystem-based livelihoods and for making coastal infrastructure, such as housing and water services, resilient to climate change impacts. There is a need for detailed information on vulnerability to these impacts along the whole of India's coastline, including analysis of socio-ecological sensitivity and adaptive capacity, as well as detailed information on potential for ecosystem-based adaptation investments and comprehensive systems for making early warning information accessible to all.

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Lake 2016: Conference on Conservation and Sustainable Management of Ecologically Sensitive Regions in Western Ghats
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Lessons from Phewa lake and Phusre river of Nepal to mitigate landslides, floods, etc.

Niwas Singh, Brajesh Pratap Singh and Gautam*
Baba Raghav Das Post-Graduate College, Deoria, U.P. – 274001; *

Abstract

Landslides, floods and earthquakes are common natural disasters that are, some or other way, associated with water. Landslides and earthquakes are common features of the youngest and the most fragile Himalayan ecosystem whereas the floods are the common features of the Himalayan rivers, foothills, terai regions and the Indo-Gangetic plains. In fact, the Gangetic plain is a flood-plain where we human-beings are learning to live with floods and drought as well. If water is managed properly, both the floods and droughts could be handled well. We need to understand these phenomena in their great details and look for steps where suitable human interventions could be taken as diagnostic and preventive measures to fight with these so-called natural calamities. Our narrow vested interests might be aggravating the situation because of our ignorance. Here in this study, we look at Phewa lake and Phusre river of Nepal and suggest how these might be managed to control natural disasters.

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Integrated municipal water resources management within the North American Great Lakes.

Rajasekara Murthy
Visiting Professor, Centre for Ecological Sciences
Indian Institute of science, Bangalore

Abstract–
The North American Great Lakes is the source of drinking water for over forty million inhabitants around the perimeter of the Great Lakes system both in Canada and USA. The waters of the Great Lakes are interconnected and part of a single hydrologic system. The multiple uses of these resources for municipal, industrial and agricultural water supply, mining, navigation, hydroelectric power and energy production, recreation, and the maintenance of fish and wildlife habitat and a balanced ecosystem are interdependent. Many of these source waters face several threats. Municipal wastewater is a complex mixture of human waste, suspended solids, debris and a variety of chemicals derived from residential, commercial, and industrial sources. The volume of the wastes, the pollutants they contain, and potential for impacts to water quality make municipal wastewater a concern. For example, waterborne pathogens can pose a problem to drinking water supplies and recreational waters. Taste and odour in drinking water is another example that can be man-made (industrial, municipal, etc.) or biogenic. However, the recent occurrences in the Great Lakes come at a time where nutrient levels have reached their lowest levels in decades. Until recently, these source waters were taken for granted and little attention paid for their long term sustainable management. Recent severe outbreaks of waterborne diseases pointed to a risk of outdated infrastructure and emerging chemical and biological threats. Because of these concerns an integrated multi-barrier approach (MBA) was developed by Federal-Provincial-Regional governments to protect the source water supply from the Great Lakes. It is an integrated system of procedures, processes and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health. In this process the source protection authorities and municipalities will be able to complete the required science-based assessment of threats to drinking water sources. Municipalities would be able to act on significant threats around municipal wells or surface water. In this paper we will discuss the population pressure and associated environmental issues in the western Lake Ontario. This paper presents examples of source water characteristics of the Great Lakes and long-term management strategies in the basin.

WETLANDS, RIVERS , FISH, PLANKTON RESOURCES AND AQUACULTURE IN NORTH- EAST INDIA: AN OVERVIEW

Devashish Kar

Division of Wetlands, Fishery Science and Aquaculture, Department of Life Science and Bioinformatics, School of Life Sciences, Assam (Central) University, Silchar-788 011, India

Conservation Forum, 39, Public School Road, Silchar-5, India

devashishkar@yahoo.com Cell: +91-9435070519

Abstract– India is blessed with myriads of water resources in the form of numerous rivers, streams, wetlands, lakes, etc. India has c 67,429 number of wetlands covering an area of *c* 4.1 million ha. Besides lotic territories, the lentic water bodies having 0.72 x 10^6 ha lake coverage in India, constitute great potential of fishery resources. The NE region is blessed with a number of lentic systems, locally called `Beel, Haor, Anua, Hola, Doloni, Jalah, etc., which alone constitute *c* 81 % of the total lentic area (0.12 x 10^6 ha) in Assam. These lentic systems are generally shallow and open, ranging in size from 35 to 3458.12 ha and with depth ranging from 0.25 to 3.0 m (in some, however, the maximum depth may exceed 6.0 m) at FSL. Further, in Assam, there are *c*1392 number of wetlands having a total of *c* 22,896 number of fisheries of different categories; out of which, the number of registered wetlands is only 394 (30.38 %) covering an area of *c* 70,000 ha. Out of this, *c* 19,000 ha is in good condition; *c* 15,000 ha is in semi-derelict condition and *c* 35,000 ha is in derelict condition (Govt. of Assam, 2006). Incidentally, on the basis of the research findings of the present author, Sone Beel was declared as a `Wetland of National Importance' by the Ministry of Environment and Forests, Government of India on 16 October, 2008 (*vide* Resolution No. 11 dt. 16.10.2008, of MOEF Expert Group Meeting; and, also, Letter No. FRM 41/2008/63-A dt. 8.9.2008 from Commissioner and Secretary to the Govt. of Assam, Department of Forests).

The meandering rivers, which criss-cross the NE Provinces, have, through the ages, played a dominant role in shaping its history. The most striking feature of the Region's drainage is the magnificent flow of the mighty Brahmaputra and the Barak reckoned amongst the world's most majestic rivers. Both these mighty rivers have a number of tributaries forming an intricate network of Brahmaputra and Barak drainages. The former includes the rivers like Subansiri, Dhansiri, Kopili, Puthimari, Beki, Manas, Aai, etc.; while the latter includes tributaries like Jiri, Chiri, Madhura, Jatinga, Ghagra, Dhaleswari, etc.

Extensive ichthyological field survey conducted from 1996 to 2006 in the major rivers of Mizoram, Tripura and Barak drainage (in Assam and partly in Manipur) revealed the occurrence of bewildering diversity of fishes. Of these, the rivers in Mizoram revealed 42 species in river Tuirial, 42 species in river Kolodyne, 31 species in river Karnafuli, 25 species in river Mat, 36 species in river Tlawng, nine species in river Tuirini, 14 species in river Serlui and 23 species in river Tuivai. The rivers in Tripura reflected 28 species in Manu, 22 species in Khowai, 53 species in Gomati, and 22 species in Feni. In Barak drainage, river

Barak portrayed 65 species (including collections from the proximity of its origin in Karong, Manipur), river Jatinga 61 species, river Sonai 54 species and river Dhaleswari 32 species. Declaration of 'aquatic sanctuaries' for the conservation of rare and endangered fishes like the mahseers have been strongly suggested in the paper. Further, the dreadful fish disease, called Epizootic Ulcerative Syndrome (EUS) has been causing large-scale mortality among the freshwater fishes since 1988 initially affecting four species of fishes very widely. Our study (Kar, 1988, 1989, 1990, 1993, 1995a, b, 2000, 2003, 2004, 2006, 2007a, b, 2010, 2012, 2013, 2014, 2015) revealed fluctuations in the intensity of disease in relation to species affected. Our further studies related to aspects like Limnology, chemistry, physics, bacteriology, mycology, and virology along with tissue culture and electron microscopy, revealed interesting findings including isolation of a virus. Details of the EUS in wetland fishes have been discussed in the communication. Our study had portrayed 25 species of fishes in Dolu lake, 34 species in Chatla Haor, 40 species in Karbhala lake, 31 species each in Awangsoi lake and Oinam lake , 33 species in Loktak lake and 32 species in Utra lake have been recorded during the study period. Study revealed that 22.72% of the fishes of Dolu lake, 5.76 % of Chatla Haor, 19.16 % of Karbhala lake, 23.83 % of Awangsoi lake, 33.86 % of Oinam lake, 49.75 % of Loktak lake and 48.8 % of Utra lake were found to be parasitized.

The present level of Annual Fish Production (AFP) is 1.81 lac metric tonnes (mt) against estimated demand of 2.81 lac mt. annually. At present, the deficit is met partially by

importing fishes from other provinces. This is highly undesirable; because, it is not only rendering our resources uncared for; but also, at the same time, draining out a huge sum of capital from our province everyday; which, otherwise, could have been used for our own developmental purposes.

Hence, Integrated Fish Farming (IFF) Practice could be a promising method for reverting the situation. It is because the integration of Fish Culture with Livestock rearing holds great promise and potential for augmenting production of animal protein, betterment of economy and generation of employment in rural India.

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Keywords– Wetlands, Sone Beel, Rivers, Fishes, EUS, North-East India

INTRODUCTION

Principal wetlands in Barak valley region of Assam: Sone Beel (Biggest) (3458.12 ha), Rata Beel, Sagar Beel, Rani-Meghna Beel, Angang Beel, Medha Beel, Tapang, Duberi Beel, Bishali Beel, Dholi Beel, Gudi Beel, Lora Beel, Narapati Beel, Jabhda Beel, Karkari Beel, Jonamara Beel, Sushka Beel, Charua Beel, Auti Bauti Beel, Raua Beel, Petua Beel, Atoa Beel, Sundarkuri, Mahishatal, Deochhara Beel, Asinia Beel, Dhalchhara Beel, Hatichhara Beel, Doloo Beel, Chatla Haor, Bakri Haor, Puneer Haor, Baskandi Anua, Rupairbala Anua, Dungripar-Kaptanpur Anua, Satkarakandi Anua, Ram Nagar Anua, Baraknadi-Salchapra Anua, Fulbari Anua, Sibnarayanpur Anua (Kar, 2007, 2013).

A detailed account of the biggest wetland in Assam, *viz.,* the Sone is given below as a typical example of a wetland in this region.

Sone Beel: Sone Beel, situated at 23 m MSL, between 92 º 24' 50" – 92º 28' 25 " E and 24º 36' 40" – 24º 44' 30" N within Karimganj district of Assam, is the biggest wetland in Assam and falls in a valley geologically called syncline.

The physiography of the district consists of small hillocks intervened by wide low valleys. The hillocks have NE-SW and NE-SSW trend near the Barail range and N-S trend towards south away from the Barail range. Notably, Sone Beel, the biggest `Beel' (wetland) in Assam is situated in between two hill ranges, viz., the Badarpur-Saraspur range and the Chowkirmukh-Dohalia range. In the East, the neighbouring structure is the the Badarpur line of folding; while, there is the Chargola anticline towards the west. A typical geomorphological feature is the tight folded-ness of the anticlines represented by hillocks having very high dips of the sedimentary beds. Information obtained from ONGC and GSI (Personal communication) reveal that, Cachar represents a type area of Surma sediments exhibiting only Tertiary deposits (70 million years old). Investigations into the rock samples of this wetland revealed that the hillocks around the wetland were, probably, formed after Tipam sedimentation. Most of the wetlands in this region, including the mighty Sone Beel , might have been originated after the Dupitila sedimentation during the Mio-Pliocene period.

The principal feeder of Sone Beel is the major inflow, the river Singla which drains a total catchment area of *c* 46,105 ha. The wetland also receives water from 12 minor inlets and many other canals flowing from both hills and plains, all of which together drain a total of *c* 18,941.9 ha of the catchment area of the wetland.

The maximum length (L) and breadth (B) of the wetland at Full Storage Level (FSL) were measured as 12.5 km and 3.9 km respectively. Interestingly, these values were found to shrink (reduce) to 4.07 km and 2.22 km respectively at its Dead Storage Level (DSL).

The area of Sone Beel at FSL was measured as 3458.12 ha; while, at DSL, the area diminished to only 409.37 ha. The length of the shoreline was measured as 35.4 km while the shore and volume

developments were recorded as 1.69 and 0.15 respectively with mean depth of 0.29 m. The gross volume of the wetland was found to be 101.54 x 10^6 m^3.

The major outflow (there being no minor outflow) of the wetland, the river Kachua originates from the northern-most end of the wetland. It drains out the wetland water into the mighty river Kushiara after covering a length of *c* 19.30 km.

Although the river Kachua was blocked by a blind dam constructed by the Government of Assam in 1950-51, the dam was replaced by a lock gate in 1964 after experiencing navigational and fishery problems. The maximum outflow of the wetland was found to be 87.03 m^3 sec^{-1} in Aug 2008; while, the maximum inflow was recorded to be 33.91 m^3 sec^{-1} in July 2008. Concomitantly, the minimum inflow and outflow of the wetland were recorded as 0.0027 m^3 sec^{-1} and 0.087 m^3 sec^{-1} (both in Feb 2008).

Aquatic Macrophytes (AM): AM was found to exhibit a heterogeneous assemblage of 23 species in Sone Beel. Association of different species of AM, forming phyto-social units, are generally encountered in Sone Beel. the wetlands. In Sone Beel, among the floating varieties, *S.cucullata* and *A.pinnata;* and, *N.cristatum* and *N.indicum* were found to form distinct phyto-social units. Among the emergent varieties, *E.acutangula* and *S.trifolia;* and, *S.eriophorum* and *E.stagnina* were found to be associated together. Among the submerged types, *H.verticillata, V.spiralis* and *N. alternifolia* were found to make an association. Interestingly, *T. bispinosa,* the floating form, also, exhibited association with this group. Further, *E.crassipes* and *E.ferox* were found to remain solitary and thus formed mono-specific unit.

PLANKTON COMMUNITIES: Plankton, the living fraction of material, found in water and move passively by wind or current, is composed of bewildering varieties of microscopic organisms. The `phytoplankton', are predominantly autotrophic, are the primary producers of organic matters in the aquatic habitats. The nutritionally dependent animal component constitutes the `zooplankton'.

Phytoplankton: The phytoplankton, though stands on the baseline of many food webs, in the aquatic environment, is, in turn, dependent on the activities of other microbial organisms, notably bacteria, which convert organic material into inorganic nutrients required by the plants. The phytoplankton, found in this region, could, broadly, be classified into the following groups:

i. Cyanophyta
ii. Euglenophyta
iii. Chlorophyta
iv. Chrysophyta (which includes the Diatomes)
v. Pyrrophyta

Zooplankton: The zooplankton, which are the primary consumers in the ecosystem, include many varieties. While some spend only a part of their lives drifting at the surface, others are found to extend to the deeper waters than the phytoplankton do. Many of them make daily sojourns between layers.

The zooplankton, which occur in this region, could broadly be classified into the following groups:

i. Protozoa
ii. Rotifera
iii. Cladocera
iv. Copepoda
v. Ostracoda

The NE-region in general and Assam in particular, is gifted with a bewildering diversity of limnoplankton distributed spatially and vertically in enormous number of lentic and lotic systems, spread across the length and breadth of the region. The limnoplankton serve as potential food and nutritional supplement for the fishes of the region.

Studies conducted extensively and intensively in the region covering approx. 270 wetlands and 58 rivers, covering the provinces of Assam, Meghalaya, Mizoram, Tripura, Manipur, Nagaland, Arunachal Pradesh and Sikkim (Kar, 2007, 2013) revealed general abundance of *Brachionus* sp., *Lecane* sp., *Trichocerca* sp., *Filinia* sp., among the Rotifers; *Bosmina* sp., *Bosminopsis* sp., *Moina* sp., *Alona* sp., *Chydorus* sp., *Dadaya* sp., *Pleuroxus* sp., *Ceriodaphnia* sp. among the Cledocerans; *Cyclops* sp., *Diaptomus* sp., among the Copepods. However, plankton in few wetlands have been discussed in the present communication with the aim of brevity.

Limnoplankton of Sone Beel: 47 different forms of phytoplankton belonging to five groups, as indicated above, have been recorded, till date, in Sone Beel. Of these, the Chrysophyta included the maximum number and Pyrrophyta, the least. The phytoplankton density in the Beel varied from 48-5308 (average 1027) units/lit. 19 different forms of zooplankton, belonging to five groups, have been recorded in Sone Beel. The zooplankton density varied from 6-380 (average 49) units/lit. Low density is generally recorded during February-March and high density during November-December. (Dey and Kar, 1994).

There is a bewildering diversity of fishes in the lentic systems of this region.The data for annual fish yield were extrapolated from daily catch statistics recorded at all the landing stations of the Beel (FAO, 1974) while the trend and cyclic variations were constructed by applying 12 month's moving average method (Coxton and Cowden, 1950).

An account of Zooplankton of Chatla Haor Wetland (Kar and Barbhuiya, 2004): Studies conducted in *c* 1600 ha Chatla Haor in Cachar district revealed the occurrence of 18 species of zooplankton consisting of 2 species each of Protozoa and Copepoda, 6 species of Rotifera and 8 species of Cladocera. Occurrence of *Arcella* sp among the protozoans and *Brachionus calyciflorus* among the rotifers, indicate eutrophy of the wetland. Two protozoans, viz., *Arcella* sp and *Paramoecium* sp, represented *c* 11.11 % of the total zooplanktonic taxa in the wetland. Verma and Dalela (1975) had reported *Arcella* sp in eutrophic waters. Six rotifers constituting 33.33 % of the total zooplanktonic taxa were also identified; of which, *Filinia* sp and *Lecane* sp were found to be abundant. The identified Copepods included the *Cyclops* sp and the *Diaptomus* sp and they represented 11.11 % of the total zooplanktonic taxa. The total zooplanktoumc count was found to be 68± 45 units/litre (Kar and Barbhuiya, 2004)..

Ichthyospecies of Sone Beel: Of the 70 ichthyospecies, 84.2 % belong to the Primary FW group while the rest are of peripheral class. The annual fish yield from the Beel was determined as 358.21 mt during 1979-80 and 312.16 mt during 1980-81 having an annual average yield of 355.18 mt. Per hectare fish yield was determined as 103.5 and 90.26 kg respectively during the investigating years (Kar, 1990). The present data show a declining trend revealing an annual average yield of *c* 315.0 mt (Kar, 2003 a). Inconsistent trend of natural recruitment in such water bodies (Dey, 1981) coupled with higher catches in the turbid water might be the causative factor for higher yield during the first year. The forage fish containing mainly the cyprinids and chandids which constitute the bulk landing, could have gained ascendance over the predatory catfish to add further reasons to such propositions. The fish yield from Sone Beel appeared to be low as compared to 250 kg/ha obtained by Vaas and Schurman (1949) in some tropical FWs of Java. Further, Jhingran and Tripathi (1969) had recorded the range of fish yield from the Indian reservoirs to be as low as 6-7 kg/ha/year.

The constant deposition of silt reduces the living space of fish and fishes in the shallower areas become vulnerable (Welcomme, 1979). This has impacts on the production through an eventual diminution of the water spread area (Kar, 1990). Moreover, the lake soil with pH 5.0 to 5.9, organic carbon 0.25 to 1.74%, available phosphorus 0.15 to 1.93 %; and, water with pH 6.0 to 7.9 and dissolved oxygen 2,4 to 5,9 mg/lit were not very suitable for fish production (Banerjea, 1967; Michael, 1969). Also, dense strands of aquatic macrophytes, often known to bind up nutrient materials, thus, could result in reduction of natural food availability for the fish and lead to poor fish yield (Bennet, 1962). Further, as an attempt to increase fish yield (Fernando and Furtado, 1975) by introduction of *Cyprinus carpio* into the Beel, there have been adverse effect on the autochthonous ichthyodenizens of the Beel which could well account for overall poor yield from Sone Beel (Dey and Kar, 1990). On the basis of the earlier research findings, Sone Beel (Kar, 2007, 2013) was declared as a **`Wetland of National Importance'** by the Ministry of Environment and Forests, Government of India on 16 October, 2008 (*vide* Resolution No. 11 dt. 16.10.2008, of MOEF Expert Group Meeting; and, also, Letter No. FRM 41/2008/63-A dt. 8.9.2008 from Commissioner and Secretary to the Govt. of Assam, Department of Forests).

Potentials of Sone Beel: i).Very big size; ii).Continuous inlet and outlet; iii).High fish yield, IMC naturally growing, also could be cultured;

iv).Occurrence of Hilsa; v. Ideal site for rehabilitation of fishermen.

Major Problems of Sone Beel in Assam: (a) Inlet(s) diversification; (b) Outlet(s) diversification; (c)Outlet(s) blockade(s) (d) Siltation; (e) Mahajal (enormous encircling gear) operation; (f) Paddy cultivation; (g)Big size carnivorous fishes; (h) Availability of exotic fishes; (i) Day-in and day-out fishing operations; (j) Fish disease, particularly Epizootic Ulcerative Syndrome (EUS).

(a) Problems with regard to siltation and shrinkage: As a typical example, study, using GIS Geomatica Version 10, showed that within a span of 100 years (approx) from 1880 to 1980, there is shrinkage of c 3,539.6 ha of the water spread area of Sone Beel (Kar, 2012), This is the fate of other wetlands as well. Extensive deforestation coupled with soil erosion had been leading to large scale siltation of the water bodies; thus, causing shrinkage in the water spread area. One can expect further diminution in the water spread area due to the siltation process, if it continues (Kar, 2007).

Deepor Beel: This is a perennial FW wetland, located between 26° 05'- 26° 09' N and 91 ° 36'- 91° 45' E, about 10 km SW of Guwahati city, in Kamrup district of Assam, India. It is situated at a surface elevation of 53 m MSL and has a total area (waterspread + others) of 4014 ha (40.1 km ^{2}) at FSL and 10.1 km^2 at DSL. However, an area of 414 ha has been declared as "Deepor Beel Sanctuary" by the Government of Assam . It has a maximum depth of 4 m at FSL about 1 m at DSL. It has been declared as a Ramsar wetland in November 2002. It is categorised as representative of the wetland type under the Burma Monsoon Forest biogeographic region. About 1200 families in 14 villages live around Deepor Beel.

The Beel is bounded by steep highlands on the north and south. The Beel, and its adjoining areas were, perhaps, abandoned channels of the Brahmaputra river system . The Beel soil represents recent alluvium consisting of clay, silt, and sand while the highlands around the Beel are made up of gneisses and schists of the Archaean age .

The Rivers of South Assam, Mizoram and Tripura in North-East India: The meandering rivers, which criss-cross the NE Provinces, have, through the ages, played a dominant role in shaping its history. The most striking feature of the Region's drainage is the magnificent flow of the mighty Brahmaputra and the Barak reckoned amongst the world's most majestic rivers. Originating in a Himalayan glacier, and after traversing *c* 1600 km in Tibet, the Tsangpo, as the Tibetans call the river, cuts the Himalayas and enter Arunachal Pradesh as Siang. Two other rivers, viz., Dibong and Lohit, join the river Brahmaputra; and, the main river, thus replenished, flows down the Assssam plains as the River Brahmaputra.

The river Barak originates from Japvo peak in Nagaland (*c*3353.65m MSL), and flows through Karang village along the Manipur-Nagaland border and drains almost the entire Manipur valley before entering Assam. It flows through the southern part of Assam (thus, forming the Barak valley); and, after traversing through a stretch of *c* 532 km from its origin, the River Barak bifurcates into two branches, viz.., the Surma and the Kushiara at village Harinagar (Haritikar) at the Indo-Bangladesh border. After flowing a short spell along the Indo-Bangla border, both these rivers flow into Bangladesh to join the Meghna basin before entering the Bay of Bengal. Barak has a number of tributaries joining it on both north and south banks, viz., Jiri, Chiri, Madhura, Jatinga, (north bank tributaries) and Sonai, Rukni, Dhaleswari, Ghagra (south bank tributaries). In addition to these, the River Shingla and the River Longai, both originating from the Mizo Hills, join the River Kushiara in Barak valley, the former flowing via Sone Beel , the biggest wetland in Assam. Also, the River Baleshwar joins River Surma in Barak valley.

The province of Mizoram is drained by eight major rivers belonging to three principal drainage systems as mentioned below:

1) River Tuirial, 2) River Tlawng, 3) River Serlui: Barak-Meghna drainage system: Indo-Bangladesh
4) River Tuivai; 5) River Mat; 6) River Kolodyne : Kolodyne drainage system: Indo-Myanmar
7) River Tuichong; 8) River Karnafuli : Tuichong-Karnafuli drainage system: Indo-Bangladesh

The province of Tripura is drained by four major rivers forming four independent basins as given below:

1) River Manu: Manu basin; 2) River Khowai: Khowai basin; 3) River Gomati: Gomati basin; 4) River Feni : Feni basin

All these rivers flow into Bangladesh independently.

In Assam

River Sonai: It is a 4th order stream which originates from Mizo Hills as river Tuirial. The study sites lied between geographical limits of 24° 34' 36.4" N and 92° 53' 47" E at altitude ranging from 25-39 m MSL. The rate of flow of the river varied from 15-37 rev/10 sec. However, the surface water depicted maximum flow of 47 rev/10 sec by the flow meter. The valley segment is of alluvial type while the reach is of regime type. As such, the river is generally highly turbid during the rainy season and fishes are sometimes found gulping due to little asphyxiation (Kar, 2003a, 2005a; Kar, *et al*., 2002 a).

The river Sonai is seasonally flooded due to intermittent rains. The river sometimes shows roots of plants along the bank. A peculiar feature portrays undercut banks on the outside of the curves and sand bars on the inner side. Patches of overhanging vegetation provides shelter for fishes. Reaches were selected both in the plainwater downstream region as well as in the rheophilic little upstream region.

More recent studies (Kar, 2005a) revealed small rivulets, viz., Jorkhal and Nagakhal, joining the main river Sonai from the surrounding catchment. Gravels and cobbles formed the principal component of the substratum of these rivulets; which, along with higher transparency (as compared to the main river Sonai) and faster flow of water, probably, paved the way for some fishes to migrate locally from the main river to these rivulets.

The river Sonai joins the **river Rukni** (flowing down from Mizo Hills as River Serlui) around the village Palonghat and the combined flow, as river Sonai, joins the river Barak around the village Kaptanpur in Sonai Revenue Circle in Cachar.

River Jatinga: It is a 2nd order stream which originates from the North Cachar (NC or Dima Hasao) Hills in Assam and flows down the side of Jatinga village. It is one of the North bank tributaries of river Barak. The reach type is mainly pool-riffle to braided-type; while, the valley segment of the river is colluvial to alluvial type. Bedrocks, boulders, cobbles, gravels and fine sand form the main components of the river substratum. The study spots (selected reaches) of the river were situated within the geographical limits of 24° 57' 49.4" N and 92° 45' 41.3" E having an altitude of 19 m MSL on the average. The river is less entrenched (E/R : 3.06) possibly because the valley segment is V-shaped. Turbulence is the principal fish cover; while, small woody debris, overhanging vegetation and depth was also found to serve as fish cover. River Jatinga is of hydroriparian type having riparian vegetation consisting mainly of herbs, shrubs and trees. There is an abundant population of *Polygonum* spp. , *Sesbania* spp., and *Bambusa* spp. Dominant land use pattern includes human habitation, some amount of agriculture (mostly `Jhum' or shifting cultivation) and some tea gardens, many of which are abandoned today mainly due to transportation problems. It is remarkable to note here that, not much soil erosion has been observed, which could be because of deforestation to a little lesser extent. However, recent earth-cuttings going-on in the gauge-conversion of the Indian Railways, from MG to BG is causing a lot of soil being deposited into the river bed sliding down from the surrouonding hills leading to changes in the riverine habitat. Also, undercut banks are sometimes seen. Dominant riparian texture includes boulders and gravels. Flow rate of the river was found to be 56 rev/10 sec at the surface level and 23 rev/10 sec at a little deeper level; while, it was found to be 5 rev/10 sec at the deepest point (Kar, 2003a, 2005a; Kar, *et al*., 2002 a).

In river Jatinga, vegetation, depth and bottom types vary according to gradient. The river is braided-type at some spots mainly because of accumulation of sand bars and boulders by the water current. The river has many logs and fallen trees which provide excellent shelter for fishes. Also, there are spots where the banks are deeply undercut and soil has eroded from the bank.

River Dhaleswari: This river is a 4th order river,

which originates, as river Tlawng, from the Mizo Hills, around Lunglei. After flowing through a tortuous course through the Mizo Hills, this river enters the Barak valley region of Assam around a place called Ramnathpur (Gharmura), situated at a distance of *c* 30 km down from Bhairabi in Mizoram. The river is called Dhaleswari from the point it enters Barak Valley region of Assam. After flowing for about 25 km in Barak valley of Assam, the river had been blocked by a blind dam and the main flow of the river had been diverted at a village called Karichhara (near Katlichhara) as river Katakhal which joins the River Barak, on its south bank, after passing through villages Matijuri, Mohanpur, etc. The original river Dhaleswari, as a dead river from village Karichhara, also joins the river Barak, on its south bank, around the place called Panchgram where the Cachar Paper Mill (of the Hindustan Paper Corporation) is situated. Incidentally, the Hailakandi town is situated on the bank of (now) dead river Dhaleswari. The study sites in these rivers were situated between the geographical limits of 24° 57' 48.9" N and 92° 45' 41.1" E having an altitude of 16 m MSL on the average. The reach type is regime while the valley segment type is alluvial. `Run' and `mid-channel type' pools were the dominant micro-habitat types. The E/R is generally 2.27. The river is of riparian type with riparian vegetation type varying from herbs, shrubs and tress including grasses and quite a dense population of bamboos. The riparian soil texture is largely silt and clay on both the banks while the riparian land use pattern is mainly human habitation, agriculture and tea gardens. The river substratum consists mostly of silt and fine sand with a large amount of clay. Signs of erosion are seen quite frequently. The water current was measured as 5.0 rev/10 sec on the average. There is not much natural fish cover and consisted mainly of turbulence, undercut banks and depth; but, not much overhanging vegetation. The total cover was estimated to be *c* 10 % (Kar, 2003a, 2005a; Kar, *et al.*, 2002 a).

Mizoram: The province of Mizoram (area 21,081 km^2) is a beautiful terrain (maximum height *c* 2,743.90 m MSL) situated in the southern part of NE India bordering Bangladesh in the SW and Myanmar in the East having the Tropic of Cancer passing through it. Inhabited by a population of *c* 8,91,058 (2001 census), growth rate was found to be *c* 21.18 % (1991-2001); while, density/ km^2 was found to be *c* 42. *c* 85 % of the rural mass are engaged in various kinds of agricultural practices including fisheries. The province has *c* 24,000 ha of cultural fishery resources and *c* 6000 ha of riverine water spread area which is spread over *c* 1100 km^2 of riverine stretches. *Per capita* availability of fish per annum is only *c* 3.01 kg. The major rivers of Mizoram are the Tuirial, Tlawng, Tuirini, Tuivai, Mat, Kolodyne (Chhimtuipui), Tuichong, Karnafuli and Serlui. Of these, the rivers Tuirial, Tlawng, Tuivai and Serlui join the Barak drainage at different points of their course. A small river, called, Tuirini, also joins the river Tuirial. The river Chhimtuipui originates in Myanmar, flows northward along the Indo-Myanmar border for some distance, then, takes turn towards south to flow back to Myanmar again. This river, further, as river Kaladan, is said to have joined the the river Karnafuli in Chittogong district of Bangladesh after flowing through Indo-Myanmar-Bangladesh border The river Mat joins the river Chhimtuipui in Mizoram. The river Karnafuli, after originating from around Marpara region in the Mizoram-Tripura border, flows along the Mizoram-Bangladesh border; and, ultimately, joins the Bay of Bengal in Bangladesh. In addition to the lotic systems, there are few lentic bodies in Mizoram. The prominent among those are the following:

Lentic bodies

(a) Tum Dil Lake near Saitual; (b) Rih Dil Lake near Champhai along Indo-Myanmar border; (c) Palak Dil Lake near Tuipang along Indo-Myanmar border; (d) Rengtlang Dil Lake near Parva along Indo-Bangladesh border

An account of Tumdil Lake is briefly given below:

Tum Dil: It is one of the very few perennial wetlands in Mizoram situated at a distance of *c* 40 km away from Aizawl city. It lies between the geographical limits of 92-93° N and 22-24° E. It has a maximum length, breadth and depth of 0.73 km, 0.10 km and 6.5 m respectively. It has a water spread area of *c* 12.0 ha at FSL . It receives water mainly during the monsoon months from the surrounding catchment. There is no major inlet or outlet of the lake except few drains. This lake is under the joint management of departments of Fisheries and Tourism of the Govt.

of Mizoram. In Tum Dil, the land use pattern involves mainly pisciculture and horticulture. Among the practices in Animal Husbandry, it is mainly poultry farming with little amount of cattle farming. There is much amount of naturally-occurring farm forestry as well as much amount of support area of forests around these wetlands. However, there is not enough of grazing in view of not a big population of cattle being available. Concomitantly, the amount of pasture land is also limited. The source of pollutants in these wetlands is mainly horticultural wastes and refuges as well as domestic sewage and effluents from the surrounding human habitations (Kar, 1998).

Lotic systems: Among the many rivers, an account of river Tuirial is given below:

River Tuirial: It is a 3rd order stream which originates from around Serchip region of Mizo Hills and is formed by the union of two 2nd order streams, viz., Chite and Zelphui. After following a tortuous course in Mizo Hills, it enters the Barak valley region of Assam as river Sonai and merges with another river called Rukni (river Serlui in Mizoram) around village Palonghat. The combined flow joins the river Barak in its south bank near the village Sonaimukh (Kar, 2003a, 2005a; Kar, *et al.*, 2002 a).

The study spots in this typical hill stream are situated in Mizoram between the geographical limits of 22° 23' 45.5" N and 92° 57' 59.9" E and at altitude ranging from 500 m to 920 m MSL. The reach type is cascade to pool-riffle type. The valley segment is mostly of colluvial type. Falls, cascades, riffles, eddy pools and mid-channel pools constitute the diversity of micro-habitat types in this river. The E/R of the river is, generally, 8.35. Tuirial is a mesoriparian type of river with riparian vegetation consisting of herbs, shrubs and trees. Herbs include different types of grasses and a rich population of bamboos; while, teak (*Tectona grandis)* forms a rich component of bank vegetation. There is also a very big abundance of *Saccharum* spp. almost all along the river bank. The riparian soil texture is generally dominated by gravels and cobbles with some amount of boulders and few bedrocks. The riparian land use pattern consists mainly of human habitation, agriculture (`Jhum') and plantations. The water current is generally 28 rev/10 sec on the average. Fish covers include mostly turbulence and undercut bank; while, depth and vegetations also serve as fish covers in some spots. The total cover in some area could be *c* 30 %. The river substratum was found to consist mostly of gravels and cobbles and also some boulders and few bedrocks. Signs of soil erosion was seen to be quite significant in some portions with accumulation of heaps of silt and sand on the river bank (Kar, 2007).

Tripura: The province of Tripura is flanked by both hills and plains having four principal rivers flowing through its terrains, viz., (a) River Monu, (b) River Khowai, (c) River Gomati, (d) River Feni. In addition to above, there are other little smaller rivers, *viz.,*(e) River Howrah, (f) River Deo, (g) River Muhuri. Of these, the rivers Monu and Gomati originate from the Longtarai Hills while the river Khowai originates from the Atharamura Hill ranges. The river Feni is said to also originate from the escarp of the Chittagong Hill tracts and flows down beside the village Shilachhari along the Indo-Bangladesh border. The river Howrah originates from the Baramura Hill ranges.

Notwithstanding the lotic systems mentioned above, there are a number of lentic bodies in Tripura. Some of these lentic bodies are called by the word `Sagar', meaning `tank', which are said to have been constructed by the Monarchs who had ruled Tripura (Tiperrah) once upon a time. Some of the lentic bodies are cited below:

Kurti Beel: This wetland is situated within the geographic boundary of 92° 15' E to 24° 45' N in the Kadamtala Block of North Tripura near Churaibari on the Inter-state border of Assam and Tripura. It could be regarded as a classic example of a wetland which has reached almost the climax of siltation and eutrophication. It is situated *c* 30 km away from Dharmanagar town and *c* 110 km away from Silchar city along NH 44. The Beel has a maximum length, breadth and depth of 0.6 m, 0.3 m and 2.8 m respectively; and, a waterspread area of *c* 93.67 ha at FSL. Kurtichhara is the main inlet of the of the Beel while Kalanadi drains into the Thal river as the major outlet. The Beel also receives water from the surrounding catchment and domestic sewage through a number of small drains (Kar,1998) .

Lotic bodies: An account of river Gomati, as one of the principal rivers of Tripura, is given below:

River Gomati: It is a 3rd order river which originates from Tirthamukh-Mandirghat Hills of South Tripura district and is one of the biggest rivers in Tripura. After flowing a tortuous course through Jatanbari, Natun Bazar, Amarpur Udaipur and Melagarh, it enters Bangladesh. Our study sites in this river are located between the geographical limits of 23° 30' 32" N and 91° 28' 38" E at an altitude of 41 m MSL on the average. The reach type is regime while the valley segment is mostly alluvial. The micro-habitat types include riffles, runs, eddy pools and debris pools. Nevertheless, cascades are seen in a small stretch of the upstream portion. There is quite a rich amount of overhanging vegetation. The total cover is generally *c* 20 % of the area of the habitat. Signs of erosion is significant at some spots with accumulation of silt and sand (Kar, 2003a, 2005a; Kar, *et al.*, 2002 a) .

Awangsoi lake (24° 39'48"N and 93°46'90"E) is situated south of Keinou village in Bishnupur District , Manipur, about 22 km. away from Imphal city. It contains about 31 species of fishes belonging to 20 genera, 5 orders and 14 families**.**

An account of Disease and Health status of fishes with particular reference to EUS

EUS has been causing large-scale mortality among the freshwater fishes since 1988, initially affecting four species of fishes very widely. Our study revealed fluctuation in the intensity of the disease in relation to species affected. Large haemorrhagic cutaneous ulcers, epidermal degeneration and necrosis followed by sloughing of scales are the principal symptoms of EUS. Low total alkalinity (TA) could be pre-disposing `Stress factor'. Sick fishes show low haemoglobin and polymorphs, but high ESR and lymphocytes. Communicative nature of EUS revealed variation in time gap between fish and infection in different species. Inoculation of microbes in the test animals did not reveal of any sign of ulcerations for two years. Bacterial culture revealed occurrence of haemolytic *E. coli, Aeromonas hydrophila, Pseudomonas aeruginosa, Klebsiella* sp, *Staphylococcus epidermitis* in the surface lesions as well as in the gut , liver, gills, heart, kidney and gonads of sick fishes, all of which have been found to be sensitive to Chloramphenicol, Septran, Gentamycin, etc. Fungal isolation revealed the occurrence of *Aphanomyces* sp with concomitant occurrence of the same fungal genus in histological sections of EUS-affected fishes. Histopathological (HP) studies reveal focal areas of increased fibrosis and chronic inflammatory cell infiltration in muscles; and focal areas of fatty of deneeration of hepatocytes surrounding the portal triads in the liver. Preliminary Histochemical (HC) studies with regard to interruption in glycogen synthesis and blockade of respiratory pathways are being conducted. Similarly, preliminary enzymological studies are being conducted with regard to amount of Alkaline Phosphase, SGOT, SGPT, LDH. Inoculation of 10 % tissue homogenate of EUS-affected *Clarias batrachus* into 80 % concfluend monolayer form BF2 fish cell line in Leiboitz L-15 medium, revealed progressinve CPE which was passable in subsequent cultures; thus, indicating the `isolation' of virus (Kar, 2007, 2015).

Electron Microscopic studies with the ultra-thin sections of still-occurring EUS-affected fish, tissues, revealed the presence of virus-like particles (inclusion bodies); and, preliminarily, the picobirna virus has been electron microscopically identified as the primary aetiological agent of EUS. Further studies in this regard are being conducted.

The present level of Annual Fish Production (AFP) is 1.81 lac metric tonnes (mt) against estimated demand of 2.81 lac mt. annually. At present, the deficit is met partially by importing fishes from other provinces. This is highly undesirable; because, it is not only rendering our resources uncared for; but also, at the same time, draining out a huge sum of capital from our province everyday; which, otherwise, could have been used for our own developmental purposes.

Hence, Integrated Fish Farming (IFF) Practice could be a promising method to revert the situation. It is because the integration of Fish Culture with Livestock rearing holds great promise and potential for augmenting production of animal protein, betterment of economy and generation of employment in rural India. Vincke (1976) reported combined production of 8000 kg of Fish and 6000-9000 kg of pigs / ha / year in ponds stocked with

Tilapia niloticus @ 20000 fingerlings / ha in some African Countries. Chen and Li (1980) reported 3.5mt / ha / year of fish by raising 1500 ducks / ha in Taiwan. Ahmed *et al*. (1995) reported that several projects have been undertaken to assist farmers in fish culture in small water bodies in and around Bangladesh. Banerjee *et al.* (1979) reported a fish yield of 670 kg / ha / 90days from Poultry-cum-fish farming in India. Anon (1977) reported an average fish yield of 3,543 kg / ha / year from Integrated farms with intensive feeding and fertilization in Eastern India. Jhingran and Sharma (1980) reported a yield of 4,323 kg of fish / ha / year, 250 kg of ducks and 1,835 eggs from Integrated farms in India. The input consisted of 6,340 fingerlings/ ha of IMC and 100 ducks / ha in India. Edwards *et al*. (1983) reported that the highest production obtained so far in Integrated fish farming are with pigs, ducks and chicken, a very wide spread technique in India. Kar (2007) worked on various water bodies in North-East India with regard to their fish diversity and Fish yield. In Barpeta District of Assam, a common system among local tribals and fisherfolk for collecting fish and other aquatic resources from the paddies is in vogue. The yield of fish from such indigenous practice ranges from 25-280 Kg / ha / season, as reported by Das *et al*. (1996). Most of the rice farmers of Assam are small holders and have small ponds in their rice fields (measuring about 25-30 sq. m) locally called 'Pukhuris', as reported by Baruah (1999). According to the National Sample Survey Organisation, at present, only about 40 % of Indian population eat fish and the fish eating population is increasing slowly but steadily. About 8.5 million tonnes of fish are needed to meet the present demand but the production at present is 4.37 million tonnes from the marine and fresh water resources together. The domestic demand of fish, by the turn of this century, is projected to be 12.5 million tonnes, a half of which has to come from Inland Sector. However, the expected production of fish is only 6 million tonnes. To achieve this national goal, scientific understanding of all the water bodies supporting fisheries is imperative to back up their optimum exploitation. Integrated Fish Farming could also be a promising method to achieve this goal.

Integrated Fish Farming is a diversified and coordinated way of producing fish with non-fish such as crops, poultry, pigs, ducks etc. The wise integration of these items in a fish farm promotes the full utilization of its land area and recycling of wastes and by-products, minimizes the operation expenses in feeds and fertilizers, improves the living conditions of the workers due to the increase of income and maintains a balanced ecosystem (NACA, 1989). The recent surge of interest in Integrated fish farming is due to the growing concern to maximize productivity through optimum utilization of resources in a most dynamic world undergoing rapid increase in population growth and diminishing per capita availability of resources.

Types of Integrated Fish Farming

i) ***Aquaculture–Horticulture:*** Where there is sufficient water, the integration of aquaculture and forestry into agriculture based farms provides an appropriate starting point for the design of regenerative farming systems.

ii) ***Paddy–cum–Fish Culture:*** Fish Culture in paddy fields is common in parts of Italy, Japan, Taiwan, Malaysia, etc. and to some extent in India. Over 80 million ha of land produce the world's supply of rice and in favorable situations at the end of the season, paddy–cum–fish culture yields c 3 kg or more of fish per ha for an inundation period of 3 to 8 months.

iii) ***Fish Culture–cum–Duckery:*** Fish–cum–duck farming is very common in China, Hungary, East Germany, Polland etc. This type of integration has been found to be quite compatible as the ducks feed on miscellaneous items of biota like insects, tadpoles, mollusks, etc. The duck droppings act as excellent fertilizer and the dabbling of ducks in the pond water in search of feed releases nutrients from the soil which enhance the pond's biological productivity and consequently increases the fish yields.

iv) ***Fish Culture–cum–Poultry Rearing:*** Inland fish culture in conjunction with poultry rearing is a compatible business and can provide an aqua-culturist a ready source of manure to fertilize the fish pond. In a larger sense, fish and poultry are mutually complementary, the former providing fish meal, a protein rich poultry feed, and the latter, through its droppings, fertilize the aquaculture ponds on which depends the production of plankton to serve as natural fish food.

v) *Fish Culture–cum–Pig Farming:* Among the integrated fish culture system, pig–cum–fish culture is one of the most popular and profitable venture in our province. It is a fact that while fish fetches a good market price, there also exists a good pork market in our province. Pigsties are constructed either on the pond embankment or near the pond to facilitate easy drainage of waste directly into the pond, which acts as pond fertilizer and supports dense growth of natural fish food organisms. In case of indirect method of pig-cum–fish farming, there is no direct connection between pigsty and pond. In this case, pig dung are stored in a pit and applied as and when necessary. The size of the pond varies from 0.03 ha to 0.40 ha under integrated fish farming system organized by Assam Agricultural Competitive Project (AACP).

Three Integrated Pig-cum-fish farms of village Silcoorie namely Babul Saha's farm, Sudarson Das's farm and Hiralal Das's farm are not in practice now due to some unavoidable reasons. Recently, six Integrated Fish-cum-pig farms have been introduced in Village Dharamkhal under AACP scheme of Fishery Department in Cachar, Assam.

The Selected Integrated Fish Farms: A brief Profile

The works done were concentrated on Integrated Fish Farming around Silchar City. The area was chosen as least number of surveys had been done here. Eight Integrated Fish Farms were selected, four from village Silcoorie and other four from village Irongmara.

Silcoorie village is situated along the Assam University Road (Silchar)at an attitude of 39.6 m above Mean Sea Level (MSL). The annual rainfall is about 2728.07 mm. Maximum rainfall occurs during the period from May-September. The average maximum and minimum temperature are 30.63 ^{0}C and 20.02 ^{0}C respectively. Study revealed that more than 90 % of the inhabitants are fishermen belonging to the `Kaibarta' community.. In addition to this, more than 8 % is represented by others, notably the Tea garden workers. Study revealed that the fishery is an important source of livelihood in village Silcoorie. Fish ponds ranged in size from 1 Bigha to 2.5 Bigha (1 Bigha = 1338.0 m^2). The selected Integrated farms of Silcoorie rear poultry with fishery.

Integrated Farms in village Irongmara: *Irongmara village is situated in the Cachar District, 23 km away from Silchar City and 10 km away from village Silcoorie. It is located at an altitude of 39.7 m above mean seal level.* The annual rainfall is about 2,729.07mm. Maximum rainfall occurs during the period from May-September. The average maximum and minimum temperature are 30.74 ^{o}C and 20 ^{o}C respectively. Study revealed that more than 80 % of the inhabitants are fishermen belonging to the `Kaibarta' community. The fishery is an important source of livelihood in this village too. The selected Integrated farms in village Irongmara rear piggery with fishery. The area has a great market demand for pig meat as well as fishes.

The integrated farms of village Silcoorie cited above sell their poultry to Silcoorie market, Silchar market after achieving the marketable size (600-1.5 kg). The integrated farms of village Irongmara cited above sell their piggery to Irongmara market, Dwarband market etc. after reaching the marketable size (45 kg - 1.5 quintal). The information regarding different heads mentioned above of integrated farms of village Silcoorie and Irongmara was compiled basing on interviews with respective farm owners, Associates, fish farmers, local people and respected members of the Fishery Deptt. Cachar, Assam.

ECONOMIC ANALYSIS IN THE FARMS

The integration of fish culture with pig farming and poultry farming from the economic point of view is much more viable. The combined cultures are mutually beneficial and hence the profitability will also significantly increase to a large extent. In this project work, greater emphasis was given on potentialities and prospects of different selected Integrated Farms of village Irongmara and Silcoorie.

Expenditure under different heads in different selected farms

The capital investment of different integrated farms differ from place to place. The land as well as the construction expenses are the two most

important capital investments in the establishment of an Integrated fish farm. These costs are rapidly increasing and also other costs, such as, those for fish seeds, lime, piglets, chicks, pig-mash, poultry-feed etc. are also rising. But costs of production in Integrated Fish farming is less than simple fish farming as artificial fish feeds, fertilizers are not much required here.

The capital investment for selected Integrated farms in village Silcoorie consists of buying of fish seeds, lime, chicks, poultry feeds, medicine, labour cost, fish harvest cost, constructions cost, etc. The capital investment for selected Integrated farms in village Irongmara consists of buying of fish seeds, lime, piglets, pig-mash, medicine, labour cost, constructions cost, fish harvest cost, etc.

Annual fish and non-fish yield in different studied Integrated Farms

The mutual benefit of combined fish culture and non-fish (piggery, poultry etc.) raising is very difficult to assess with accuracy due to complex interaction in the pond ecosystem but the result has shown that this integration increases the production of both fish and non-fish and at the same time decreases the input cost of fish culture operations considerably. The selected integrated fish farms of Silcoorie rear poultry with fishery.

Each batch of chicks requires roughly 45 days for maturing. Thus, 8 batches of chicken can be reared along with one crop of fish during culture period of one year. The selected integrated fish farms of Irongmara rear piggery with fishery. The pigs attain slaughter maturity in about 6 months time. So, the system envisages harvest of two crops of pigs and one crop of fish during culture period of one year.

Expenditure and Income in different analysed Integrated Farms

Integrated Fish Farming is one of most popular and profitable ventures in Assam. It has become an important money-earning area where piscicultural and non-piscicultural works are done in a profitable manner minimizing cost of their production. Thus, it also helps to improve rural development and rural economy.

Expenditure and Profit of Different selected Integrated Farms.

Study revealed that Integrated Fish Farming is more profitable, being an efficient technology than that of Simple Fish Farming and its cost of production is also less. Profit of any farm is measured by deducting expenditure from total income.

Experiments on Integrated Livestock fish farming have opened up a new horizon of high animal protein production at very low cost. In addition to providing cheap protein–rich food, integrated farming has proven to be an efficient means of waste disposal and has allowed savings on the use of inorganic fertilizer and supplementary feeds in fish production.

Indian Fisheries Sector is of immense economic importance in view of its extensive resources potential, employment opportunities to improve the Socio-economic condition of fishermen, promising export growth and providing animal protein for growing population.

On Global level, 85 % of world fish production comes from marine resources and 15 % from freshwater, while in India, the contribution of FW fish production was 29.33 % in 1950–51 which increased to 40.99 % in the year 1992–93.

In India, efforts are made to develop low-cost farming systems for Indian condition based on the principles of productive utilization of farm wastes and full utilization of available resources and manpower. In some pockets in the Districts of Kamrup, Nagaon, Morigaon, Cachar, Karimganj, Darrang and Barpeta, fish farming projects have been taken up on commercial basis. The present study conducted in 8 Integrated Farms (IFs) in Silcoorie and Irongmara villages, indicated the total Fish yield (FY) to be 10, 10, 10 and 2 Qtls respectively in the four Farms in Silcoorie while those in the four farms in Irongmara were 5.7, 8.3, 10.4 and 9.3 Qtls respectively. The IFs in Silcoorie integrate only poultry with fish while those in

Irongmara integrate Fish with Piggery. As such, the poultry yields in the Silcoorie IFs were 137, 274, 48, 82 Qtls respectively while the yields of pigs in the Irongmara IFs were 4, 4.2, 5 and 4.2 Qtls respectively. The total annual recurring and non-recurring expenditure (in Rs/year) were 3,70,000; 7,95,000; 2,87,000 and 3,62,000 respectively in IFs in Silcoorie; while those in the Irongmara IFs were 47,966; 84,663.50, 84,529.50 and 67,238 respectively. The study further revealed that the total annual profit (in Rs/year) were 2,40,000; 3,85,000; 37,000 and 1,40,000 in Silcoorie IFs while those in the Irongmara IFs were 53,084; 36,486.50; 63,070.50 and 58,812 respectively.

The difference in fish yield in different Integrated Farms of village Irongmara and Silcoorie have been found to be largely dependent upon the physico-chemical characteristics of water. As fish growth depends greatly on the quality of the water used in the pond. And the quality of water depends upon factors like temperature, oxygen content, pH, turbidity, alkalinity etc. Study revealed that pond water having pH values from 6.5 to 8 is very suitable for fish culture. Study further revealed that ponds having depth range of 2-2.5 m , a temperature range of 20-30 ^{o}C and a DO value of 4.0 mg/lit are considered to be optimum for maximum productivity. In the present studies in the IFs in the two villages, turbidity of the pond water has been found to be a major problem. The farm owners take suitable steps to combat this problem

Differences in fish yield in different farms of Silcoorie and Irongmara was due to a variety of reasons, however, liming and fertilization with non-fish excreta should be perfect for better fish yield. Further, variation in piggery yield of different farms of village Irongmara could be due to various factors such as selection of variety of pigs to be reared, Feed quality, Rate of feeding etc. Hybrid variety (Hampshire, Yorkshire) of pigs having high growth rate are generally selected. They must be fed in the sty itself with balanced feed called pig-mash at the rate of 1-1.5 kg / pig / day.

Variation in poultry yield of different farms of village Silcoorie was due to different factors such as Improper housing, Feed quality, rate of feeding, lack of proper knowledge regarding various diseases etc. Success in broiler production depends mainly on the efficiency of the farmer, his experience, aptitude and ability in the management of flock. The difference in expenditure and in profit of different Integrated Farms of village Silcoorie and Irongmara were because of management techniques followed by owners of respective farms, their knowledge regarding physico-chemical characteristic of water etc.

The Integrated fish farming is a very useful technology for the backward areas of the country and is the most effective possible way to help economically, the small and marginal farmers and poor fishermen who has a small holdings for crop production and few heads of livestock but surplus family labour to diversify their farm production to increase cash income, improve quality and quantity of food produced and exploit unutilized resources particularly labour and wastes. Study revealed that out of four farms of village Silcoorie Gourhari Das's Farm has showed less profit where as in the case of IFs of village Irongmara, Arun Bhuiya's Farm had showed less profit; while, the other studied farms had depicted profits. The annual profit of farms of Silcoorie was less because most of the farms were affected by Bird flue disease during 2007. The success in Integrated farming depends upon proper liming, fertilization of ponds, selections of fish and non fish, proper feeding etc. The water quality of ponds of IFs should be maintained by controlling non-fish dung discharge.

Problems in Integrated System: Most of the current integrated farm in south East Asia are operated in the traditional way without proper planning, modern technology or modern farm management techniques and rely on personal experience. Marketing is therefore a recurrent problem in years where demand is sufficient. Fish disease, non-fish disease constitute a further major problem with the farmers cannot solve by themselves since they have inadequate experience and knowledge and such knowledge is not as readily accessible as with other farm animals integrated A further problem for farmer is the shortage of credit and working capital, which forces them to contact the middlemen for selling their products usually at losses. The selected integrated farms of village Silcoorie and

Irongmara, explained to operate their farming on small or large scale without proper knowledge regarding modern technology, diseases etc. which had resulted in the variation of their annual profits.

Future Trends: Fish is relatively cheaper than other animal protein sources. Increase of food supply is essential to feed the growing population.. But land is a limited resource and if more land is used for agriculture, the forestry will soon be reduced to a degree which will be harmful to the environment. Also, the cost of production could rise. Therefore, a method is needed to produce more food from existing agricultural land, and integrated farming offers a possible solution. Integrated farming will probably play a very important role in natural development, as well as in the national economy.

Research Needs: Although integrated farming has now been proved to be highly profitable, its practice remains very limited in scale. This is because the relevant scientific and technological information on diversification of methods in unavailable to farmers. To fill-in this gap, there must be a bridge between information sources and the farmers, perhaps through extension services. A multidisciplinary approach is needed, including technological, economic, social and political aspects, which are, interrelated. Any approach must, however, be relevant to national economic, social and environmental conditions and to the farmers' need.

Thus, investigations are required in rural areas of Assam where integrated fish farming is going on in a quite small scale without much knowledge of modern technology, etc. The selected areas around Silchar city need attention from people of modern civilization. To fight with world's 'Protein Hunger', Integrated Fish farming should be encouraged and managed on larger scale in a quite effective and profitable manner. The conclusions derived from the present study are briefly summarized below:

The current study revealed that the total annual recurring and non-recurrring expenditures of different IFs of village Silcoorie were Rs 3,70, 000.00, 7,95,000.00, 2,87,000.00 and 3,62,000.00 respectively; while those in the Irongmara IFs were Rs. 47,966.00, 84,663.50, 84,529.50 and 67,238.00 respectively.

The study indicated the total annual fish yield in the four farms in village Silcoorie were 10,10,10 and 2 Qtls respectively while those in the farms in village Irongmara were 5.7, 8.3, 10.4 and 9.3 Qtls respectively.

The study further revealed that the total annual non-fish (poultry)yield in four farms in village Silcoorie were 137, 274, 48 and 82 Qtls respectively while the non-fish (piggery)yield in four IFs in village Irongmara were 4, 4.2, 5, and 4.2 Qtls respectively.

The study displayed that the total annual profit in four IFs in village Silcoorie were Rs, 2, 40, 000.00; 3, 85, 000.00; 37,000.00 and 1, 40, 000.00 respectively while those in 4 IFs in village Irongmara were Rs 53,084.00; 36, 486.50; 63,070.50; and 58,812.00 respectively.

Notwithstanding the above, the NE India is very rich in diverse types of water bodies. And, the water bodies, both natural and man-made, could serve as potential habitats for aquaculture.

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