Chilika Lagoon

Experience and Lessons Learned Brief

*Asish K. Ghosh**, Center for Environment and Development, Calcutta, India, cedkolkata@sify.com
Ajit K. Pattnaik, Chilika Development Authority, Bhubaneshwar, India, ajitpattnaik@hotmail.com

* Corresponding author

1. Introduction

The Chilika Lagoon (also referred to here as Lake Chilika, Chilika Lake, or simply "Chilika") is the biggest lagoon on India's eastern coast (see Figure 1). Its size fluctuates substantially within the course of a year, with a maximum area of 1,165 km² during the monsoon season and a minimum of 906 km² during the dry season. It is of relatively recent origin, being formed several thousand years ago. Freshwater runoff from the drainage basin, combined with saline water inflows from the ocean, result in a wide range of fresh, brackish and saline water environments within the lagoon, with this spatially and temporally diverse water environment supporting an exceptionally productive ecosystem.

The lagoon is a well-known wintering site for migrating birds; approximately half of the over 211 species recorded at Chilika are intercontinental migrants from far parts of Asia, including the Caspian Sea, Lake Baikal and Siberia. The lagoon is also only one of two lagoons in the world that is home to the Irrawady dolphin (the other being the Songkhla Lagoon in Thailand). Its rich biodiversity, along with the beautiful scenery of the area, attracts many bird watchers and ecotourists. The lagoon is also extremely important for the local population, not only as a source of livelihoods (mainly though its fisheries) but also as a focus for cultural, religious and spiritual activities.

Unfortunately, Chilika was facing a series of problems by the 1990s that impaired many of its uses. Major problems were related to a decreased salinity in the lagoon, caused by a narrowing of the lagoon mouth. The gradual choking of this outlet to (and *inlet from*) the sea was a result of the accumulation of sediment entering the lagoon from the drainage basin. Because the tidal flux was disturbed, the lagoon's salinity decreased, thereby altering the natural

Figure 1. The Chilika Lagoon Basin.

ecosystem. The area and depth of the lagoon decreased; the area covered by freshwater macrophytes increased; biodiversity decreased; and fish catches declined. Some lands near the lakeshore also were waterlogged at certain times because the natural release of floodwaters through the lagoon mouth was constrained. In addition to the clogging of the lagoon mouth and the salinity-related problems, there also have been changes in the quantities and timing of freshwater flows because of upstream riverine impoundments for irrigation and flood control. There also has been a general increase in pollution from agricultural, aquacultural and domestic sources in the drainage basin.

Traditional fisherfolk were particularly hard hit by these problems. The decline in fish catches led many to use a smaller mesh size, thereby putting even greater pressure on the fisheries and further complicating the problems. Pressure to maintain livelihoods seems to have contributed to poaching of migratory birds and logging activities in the watershed. Compounding the difficult situation was a change in government policy regarding the lease of fishing grounds (that affected fishing rights), resulting in the loss of access by traditional fisherfolk to many fishing grounds and a rise of commercial prawn culturing. Conflicts over this issue resulted in violent clashes and several deaths.

The Chilika Development Authority (CDA) was created in 1992 as a coordinating body between the wide range of institutions and people with a stake in the lagoon and its basin. The CDA has worked closely with departments of the State Government of Orissa to improve conditions in the lagoon. The most noticeable decision to date under the guidance of the CDA was cutting of a new opening in 2000 to the Bay of Bengal, and dredging the channel between the outer channel and the rest of the lagoon. The result was a restoration of the flow regime, leading to a dramatic improvement in the lagoon's salinity conditions and amelioration of many problems caused by the declining salinity. As examples, fish and crab catches (and income for fisherfolk) have markedly increased; macrophyte coverage has declined; and some rare and endangered fish species have returned. A monitoring program was instituted, a management plan was drawn up and environmental flow releases are being negotiated from the upstream irrigation impoundments. It is notable that the decision to open the new mouth and dredge the channel was based on both scientific studies and extensive stakeholder consultations.

Challenges undoubtedly remain. Addressing upstream problems (e.g., siltation, untreated sewage, changes in the hydrological regime) will require much effort. However, conflicts over fishing have abated mainly due to enhancement of the fishery resource. Furthermore, it is encouraging to note that the Chilika Lagoon, after being placed on the Montreux Record (Ramsar's list of sites undergoing ecological degradation) in 1993, was awarded the prestigious Ramsar Wetland Award in 2002 in recognition of the improvements and was removed from the Montreux Record due to the successful restoration of the lagoon ecosystem by the CDA.

2. Background

2.1 Biophysical Features

The Chilika Lagoon, (19°28'–19°54' N latitude and 85°05'–85°38' E longitude), located in the east coast of the State of Orissa, India, is the largest lagoon in Asia (see Figure 1). It is separated from the Bay of Bengal by a sandbar whose width varies between 100 m to 1.5 km; a long outer 32 km channel connects the main lagoon with the Bay of Bengal near the village of Arakhukuda. The pear shaped lagoon has a maximum linear axis of 64.3 km, with an average mean width of 20.1 km.

The lagoon is spread over three coastal districts of the State: Puri, Khurda and Ganjam. In the early 20th century, the lagoon area is reported to have varied between 1,165 km^2 in the monsoon season and 906 km^2 in summer (Annandale 1915–1924); however, land reclamation for agriculture, aquaculture and human settlements, along with sediment inflow from the catchment, had reduced the average lagoon area to 760 km^2, based on late-1990s satellite images. Figure 1 depicts the lagoon at its lower level.

Hydrologically, Chilika is influenced by three subsystems, including the Mahanadi river system (See Figure 4 on the last page of this brief), rivers flowing in the lagoon from the western catchment, and the Bay of Bengal. The lagoon receives freshwater from a series of 52 channels, the larger ones being depicted in Figure 1. The Chilika drainage basin, including the lagoon itself, covers an area of over 4,300 km^2 (Das and Samal 1988). The watershed boundaries lie between water flowing into the Mahanadi and Chilika in the north, while areas draining into the Bhargavi River make up the northeast watershed; in the west and southwest, the watershed boundary lies between streams flowing into the Rushikulya River and those flowing into Chilika (Ram *et al.* 1994).

The long shore sediment transport (littoral drift) along the coast of the Bay of Bengal is estimated to be 0.1 million metric tons annually and tends to shift the lagoon mouth opening to the sea every year, thereby adversely affecting tidal exchange. Although this phenomenon used to significantly affect the salinity regime, flushing pattern and consequent natural recruitment of biological species, a new mouth to the ocean has since been created, ameliorating the situation. The spatial and temporal salinity gradients, due to freshwater flows from the riverine system and seasonal seawater influx, have given Chilika unique characteristics of an estuarine ecosystem, and exercised a continuous, selective influence on the biota.

The drainage basin in the northeast consists of a large tract of alluvial land with elevations less than 30 m above sea level (asl). An area of rolling plains, located 30–150 m asl lies in the north. Some higher hills, reaching up to 600 m, also are recorded in the northern and western parts. In this area of predominantly laterite soil, hill streams formed deep gullies and ravines, often interspersed with depressions filled with alluvium. The Eastern Ghat mountain range forms a part of

the west and southwest drainage area, with an elevation of over 600 m and strands of forests of Sal (Shorea), Dillenia and Pterospermum spp. These hilly tracts serve as the headwater region of several streams flowing into the lagoon (Asthana, 1979). Along with the natural forest plantations of cashews, casuarinas and eucalyptus are found around parts of the lagoon; the remaining catchment land is covered by human settlements or cultivated land (www.chilika.com).

The catchment has a tropical climate, with average maximum and minimum annual temperatures of 39°C and 14°C, respectively. The southwest monsoon brings much rain during June–September, while the northeast monsoon brings some rain during November–December. December–February is the winter season and March–May is the hot season. The average annual rainfall is over 1,200 mm (www.chilika.com). The geophysical location of the lagoon dictates that the eastern periphery of the lagoon is exposed to the vagaries of the Bay of Bengal; the lagoon experiences the impacts of trade winds, as well as "Southeasters" and "Nor'westers", and the occasional cyclonic depression from the sea. The wind usually blows from the south and southwest directions from February to September, and from the north and northwest during October to January. The southwest winds generate a clockwise circulation at the lagoon, whereas the northwest wind creates a counter clockwise circulation in the lagoon. The winds act as the dominant mixing force, with the tidal effects apparently negligible.

The salinity level in the lagoon is dictated by river discharges during different seasons, wind action, and the extent of tidal influx carrying marine water from the Bay of Bengal. Before the new mouth was opened, the average salinity had been reduced by a third by late 1995–1996 (see section 3.1.2), severely affecting the biota of this saline ecosystem. The seasonality of rainfall also leads to large fluctuations in the size of the lagoon. Data from 1992–1997 on the maximum and minimum depths of the lagoon are presented in Table 1, and demonstrate the wide range of depths seen throughout the year, as well as inter-annual changes reflecting rainfall fluctuations between years.

Lagoons generally are highly productive ecosystems, due to large nutrient inputs from their drainage basins, as well as high nutrient cycling and a wide range of habitats supported by the salinity gradient. Chilika is no exception and, in reflection of its important biodiversity, the lagoon was declared a wetland of international importance in 1981, thereby becoming a Ramsar site. Nalabana Island was declared a bird sanctuary in 1973.

Table 1. Average Depth of Chilika Lagoon (1992-1997).

Year	**Maximum** (cm)	**Minimum** (cm)
1992–93	340	74
1993–94	210	65
1994–95	332	58
1995–96	382	60
1996–97	142	42

Source: Orissa Remote Sensing Agency (ORSAC).

The lagoon system now hosts over 211 species of birds in the peak migratory season, with 97 being intercontinental migrants from the Caspian Sea, Baikal, Aral Sea, remote parts of Russia, Kirghiz Steppes of Mognolia, Central and Southeast Asia, Ladakh and the great Himalayas (Dev 1990). Because it is in the central Asia flyway, this list includes some rare birds. The important bird species of the lagoon are *Anser clypeata, Aythya ferina, Anas querquedula, Anas penelope, Anas fuligula, Anser strepera, Limnodromus semipalmatus* and *Eurynorhynchus pygmeus*. Other interesting and threatened species include the spoon-billed sandpiper *(Eurynorhynchus pygmeus)*, Asian Dowithcher *(Limnodromus semipalmatus)*, spot-billed pelican *(Pelecanus philippensis)*, dalmatian pelican *(Pelecanus crispus)*, and pallas fishing eagle *(Haliaeetus leucoryphus)*.

The most recent account of the flora was made by Pattnaik (2003), who reported the existence of 726 species of angiosperms, belonging to 496 genera under 120 families from the lagoon and its immediate neighborhood, including its islands, sandbar and shorelines, which represents about one-fourth of the flora of the State of Orissa (estimated at 2,900 species). The predominance of members of Leguminosae, Poaceae and Cyperaceae was a striking feature of the flora. The occurrence of an apparent endemic species *(Cassipourea ceylanica)* was recorded (in badly degraded condition) from Barkuda and Sanakuda Islands, which is also known to occur in the coast of Madras and Sri Lanka.

A few mangrove associates, such as *Aegiceras corniculatum, Excoecaria agallocha, Salvadora persica, Pongamia pinnata,* and *Cassipourea ceylanica* have been recorded by Pattnaik (2003). The plant species recorded from Chilika during the present CDA study under the category of rare, vulnerable or threatened plants include *Cassipourea ceylanica* (Rhizophoraceae), *Colubrina asiatica* (Rhamnaceae), *Capparis roxburghii* (Capparaceae), *Maerua oblongifolia* (Capparaceae), *Macrotyloma ciliatum* (Fabaceae), *Indigofera aspalathoides* (Fabaceae), and *Halophila beccarii* (Hydrocharitaceae).

Pattnaik (2003) enumerated the economic and useful plants of the lagoon and its environ, including medicinal and aromatic plants, wild relatives of cultivated species, wild plants of horticultural importance and interesting plant groups like insectivorous plants, epiphytes, parasites, and lithophytes, among others.

The diversity and extent of seagrass distribution in Chilika Lagoon has been assessed by Pattnaik (2003) and the occurrence of five species of seagrass in their true sense (*Halodule uninervis, Halodule pinifolia, Halophila ovalis, Halophila ovata, Halophila beccarii*) have been reported. The occurrence of *Halodule uninervis, Halodule pinifolia* and *Halophila ovata* from the lagoon were new distributional records.

2.2 Political and Socio-Economic Features

The lagoon has a history spanning more than five thousand years, during which it provided livelihoods for local inhabitants, as well as inspiration for philosophers, poets and naturalists with its picturesque beauty and panoramic view of the Eastern Ghats (hills) in the background. Tourists are drawn by the thousands every year. The lagoon was once a part of the Bay of Bengal and was created through the process of embayment due to the long shore sediment transport. The lagoon mouth used to serve as an excellent port. Commercial boats used to sail from the lagoon to Cambodia and Indonesia. To this day, the villagers around Chilika observe an annual festival ("Bali Yatra", which means "Journey to Bali" in Indonesian). A place called Manikpatna is considered as the port.

The local community also has deep religious attachments, with the Kalijai temple situated on yet another island at the middle of the lagoon; the goddess Kalijai is venerated in folklore and legend. Ancient deities (e.g., Nabagraha located near the village Berhampur along the lagoon's outer channel; the Shiva temple in the village Alupatna in the same area) also are venerated.

The Chilika Lagoon remains a vital lifeline for more than 200,000 people who live around the lagoon in 141 villages. The historical records indicate the use of the lagoon system for capture fisheries through the formation of 92 primary fishery cooperatives. Six types of traditional fishing methods used in practice (Table 2). The steady fish landing records provide evidence of a sustainable fishing strategy, using ecological zones, different contraptions and traditional experience.

In early 1990 the non-fishermen communities of Chilika filed a petition in the High Court of Orissa to recognize their fishing rights in Chilika, challenging the principle of the State of Orissa's Revenue Department which used to lease out the fishing rights only to the traditional fishermen. The high court in a 1992 verdict, directed the state government to settle 30% of the fishery sources of the lagoon with the non fishermen communities and 70% with the fishermen communities. The local fishermen resented this as the non-fishermen introduced shrimp culture by virtue of this order. However in the mean time the Supreme Court of India (the apex court) imposed a complete ban on ban on shrimp culture in the lagoon and within 1000 meters periphery in 1996.

2.3 Institutional and Management Features

Until 1992, management of Chilika Lagoon was basically related to the activities of two major stakeholder departments, namely, the State Fisheries and the State Tourism Departments. In addition, the State Forest (Wildlife) Division was entrusted with responsibility for the Nalabana Sanctuary within Chilika. The lagoon was included in Ramsar's Montreux Record due to change in the ecological character and degradation of the lagoon ecosystem. In response, the Government of Orissa created the Chilika Development Authority in 1992. CDA is a registered society borne under the administrative jurisdiction of the Forest and Environment Department of the Government of Orissa. It is governed by a governing body chaired by the Chief Minister of the State. Secretaries from the key departments, experts, eminent scientists, people's representatives (members of parliament and legislative assembly) and representative of fisherfolk communities are members of the governing body. The CDA's mandate includes:

- To protect the lagoon ecosystem and its genetic biodiversity;
- To survey, plan and prepare a proposal for integrated resource management in, and around, the lagoon;
- To understand multi-dimensional and multi-disciplinary development activities;
- To cooperate and collaborate with other institutions for development of the lagoon; and,

Table 2. Traditional Fishery Methods in Chilika.

Name	Method	Period
"Bahani"	Net fishing	Throughout year
"Jano"	Enclosure in shallow region by spilt bamboo and net	September–October (Leased August–February)
Trap fishery "Dhaudi" & "Baja"	Box-type bamboo basket with or without lead line; Dhaudi is a large box; Baja is a small box.	Throughout year
"Dian"	Upland near Jano areas (for non-fishermen communities), 100–200 yards from the shore.	June–July
"Uthapani"	Near shore; in shallow water both by fishers and non-fishers.	June–July
Prawn Khatties	For capturing prawns; a total of 70 were operative	March–August

Notes: "Jano" and "Dhaudi-Baja" have been replaced by "Khonda", popularly called "Disco-nets, "Khonda" has a "Barh" (wing) 20–60 cm length net of 20–25 mm mesh that meet Bichni — a ten meter semi-circular net area with "zero-mesh" (very fine size) net with two box type trap or puda (2 m x 1.5 m x 1.5m) with net of 10–15 mm mesh. The Bahani method also is being displaced by gill–cum–drag netting.

- To restore the lagoon and its catchment with active community participation.

Though created in 1992, CDA was almost in a moribund condition due to lack of effective networking, partnership and coordinated action. To make more flexible procedures and quicker decisions, an executive committee was constituted in 1998 with adequate delegation of financial power. The CDA is headed by a Chief Executive Officer (CEO) nominated by the authorities for a fixed-term period; the current CEO (as of September 2005) is on deputation from the State Forest Department, having served in the position since from November 1997. This institutional structure has facilitated integration and coordination between the stakeholder departments and organizations.

The CDA executive body currently is delegated with adequate financial power to make quick decisions. The institutional development was facilitated with additional funding support received from the National Government's 10th and 11th Finance Commissions (see sections 4.1 and 4.7). The restoration was carried out through an adaptive planning process with active community participation. This was achieved through a strategic framework for organizing existing scientific information and knowledge about the lagoon ecosystem for its incorporation into the planning of the restoration process. The adaptive management planning process for developing a management plan was based on an explicit set of assumptions and hypothesis about the elements and components of the lagoon ecosystem as well as man-made systems and how they function and interact. The flexible adaptive management plan provided an opportunity for learning by doing instead of waiting for the outputs from long-term scientific studies, which are both time and cost intensive. The CDA achievements to date are discussed in Sections 4.1 and 4.2.

3. Biophysical Environment

3.1 Past and the Present Conditions

3.1.1 Biodiversity

Chilika Lagoon's faunal diversity was first studied between 1915-1924 by Annandale and his colleagues from the Indian Museum and Zoological Survey of India. Their study results indicate nearly 600 species exist in the aquatic, island and shore areas of the lagoon; the past records of 428 species

Table 3. Faunal Diversity in Lagoon Chilika: A Changing Profile (1914-15 to 1985-87).

Type	Annandale (ed.) (1915–1924)	Ghosh (ed.) (1995)	Comments
Protozoa	Few	61	
Porifera	7	2	Due to decline in salinity
Coelenterate	6	7	
Platyhelminthes Digenia	N.A.	29	2 new genera, 8 new species
Nematode	4	37	5 new species
Polychaetes	N.A.	31	
Crustacea Stmatopod	3	2	Due to decline in salinity
Crustecea Brachyura	36*	28	*[29 described as new by Kemp, 1915]
Crustacea Decapoda (Prawn & Shrimps)	30	17	
Animuran (Hermit Crabs)	N.A.	8	
Mollusks	74	87	Type locality for 60 species; 3 freshwater mollusks not present in 1995 due to declining salinity; 50 species recorded in 1916 not found now.
Sipuncula	N.A.	1	
Echiura	1	3	
Echinodermata	5 [other study]	1	
Protochordate	N.A.	1	
Pisces	217 [all sources]	69*	[*24 freshwater species]
Amphibian & Reptiles Amphibia	4	7	
Reptilia	22	23*	*8 species of 1915-24 not found in 1995
Birds	N.A.	156	
Mammals	18	18*	[*5 new entrant in place of 5 earlier records]

Sources: Annandale (1915-1924) and Ghosh (1995).

shows a positive trend of species diversity, although earlier investigations on Platyhelminthes, Polychaetes, and birds have never been carried out systematically. At least 3 species of brackish water porifera and a number of crustaceans (Brachyura, Decapods) have disappeared over the past 60 years. Of 74 species of mollusks, at least 50 species could not be traced during these year-long surveys, even though the total number of species increased to 87. Of the 69 species of fishes noted in the lagoon during the 1980s, 24 species were freshwater fishes — the decline in total fish diversity from the earlier-recorded 217 species to 69 is perhaps most startling. While the lagoon generally has been known as a type locality (the place where a given species was first discovered) for nearly 30 species of crustaceans, and 60 species of mollusks (besides others in the past that are no longer present), the profile of species diversity has clearly changed over 60 years. It may be noteworthy that, even in the 1980s, 8 new species of Platyhelminthes and 5 species of Nematode have been discovered in the lagoon (see Table 3). It also should be noted that the Irrawady dolphin *(Orcaella brevirostris)* is found in the lagoon and is considered a "flagship" species.

Similar accounts of flora over time unfortunately are not available. However, the most recent account (Roy 2001) of floral diversity (before the new mouth was opened in September 2000) provides a listing of 72 phytoplankton genera and 8 seaweed genera from different sectors of the lagoon in different seasons, which plays a key role in the food chain of the lagoon ecosystem. The phytoplankton genera include Bacillariophyceae (35), Chlorophyceae (20), Myxophyceae (12), Dinophyceae (3) and Xanthophyceae (1). The seaweeds comprise 12 species under 8 genera belonging to Chlorophyceae (7 spp), Charophyceae (1 spp) and Rhodophyceae (7 spp) located only in the marine and brackish water zone. The seagrasses include Halophila and Ruppia. Aquatic macrophytes comprise Vittate (9), Rosulate (1), Ptenstophyte (12), Epihydate (6), Hyperhydate (6) and Helophyte (33) growth classes, a total of 67 species. Macrophyte concentration seems to be most dense in the northern sector, followed by the outer channel and southern sector.

It is further reported (Roy 2001) that the Chilika Lagoon system harbors at least 185 species of plants in the aquatic and terrestrial islands of known medicinal properties. Of the total floral diversity in the lagoon area, at least 10 species are used as local vegetables, 15 as fodder, 6 for thatching, 12 as fish food, 56 for bird feeding and nesting, in addition to the 185 for medicinal purposes. Such use plant resources provide a vital resource base for the local community, as well as for birds, fishes and other biota.

In summary, of 389 species of flora, (Dicots – 288, Monocots – 80, Pterydophytes – 9, Seaweeds – 12), 84 species belong strictly to aquatic plant categories. Of the aquatic plants, 5 species of sea grasses (*Halophila becarii, Halophila minor, Halophila ovalis, Ramamurtiaoa, Ruppia maritima*) are considered threatened from extensive prawn culture and habitat change. At least 1 species of algae (Rosenvingea) and a species of mangrove Aegiceras corriculatum also are considered threatened.

At least 63 species and sub-species of plants reported between 1913–1988, could not be traced during the 1996–2000 period, with at least 15 being aquatic or semi-aquatic plants. The impact of opening the mouth and increasing the salinity is likely to cause some changes in the aquatic vegetation of the lagoon; only future research can provide information on the changing profile. Because of the increasing salinity, the area occupied by freshwater invasive species in the northern sector is declining. Similarly, smaller fluctuations in salinity favored the growth of seagrass in the central sector.

The lagoon also provided a unique habitat for both resident and migratory avian fauna, which led to establishing the Nalabana Sanctuary. The peak bird population varied between 447,511 (1985) to 756,396 (in 1993); according to Wetlands International, it reached 1,454,186 in 1996 (noting that the arrival of the migratory species is determined by many factors starting from their home land that it is not wise to draw a conclusion based on their number during a particular season). The tourists visiting the lagoon during the same period obtained the greatest benefit from the vast wetland habitat, as did the waterfowl. At least 20 species of reptiles, birds and mammals recorded in Chilika, however, are considered threatened or vulnerable.

3.1.2 Salinity

Salinity is the most dominant factor determining the lagoon's ecology. As mentioned earlier, the lagoon is connected to the Bay of Bengal by a narrow inlet and constricted outer channel. In the past, the inlet frequently tended to shift to the north, affecting the tidal influx into the main lagoon. The mean surface salinity is affected by an influx of freshwater from the western catchment (approximate average of 536 m^3/s) and from the distributaries of the Mahanadi River (mainly the Daya, Nuna, Bhargavi Rivers; approximately average of 850 m^3/s). The sediment buildup at the mouth of Chilika and the Palur Canal in the Ganjam District connecting the lagoon with the ocean had reduced the saline water influx over time, as illustrated in Table 4.

The reduced salinity has caused a significant change in the fish catch composition and quantity (see section 4.2.2). Such changes can be attributed to the gradual decline in the

Table 4. Overall Average Salinity for the Whole of Chilika Lagoon.

Year	Salinity (ppt, parts per thousand)
1957-58	22.3 ppt
1960-61	13.2 ppt
1961-64	9.4–11.8 ppt
1995	1.4–6.3 ppt

Source: Chilika Development Authority.

recruitment rate of marine elements, due to blockade at the mouth and the inhospitable habitat of lower salinity.

3.1.3 Sedimentation

The major silt load to the lagoon is carried by the Daya, Bhargavi and Nuna Rivers, distributaries of the Mahanadi River system. A sediment flow monitoring program initiated by the Department of Water Resources in five rivers (Bhargavi, Daya and Malaguni in the northern sector; Kusumi and Salia in the western sector) showed that approximately 1.5 million tons/year of sediment enters the lagoon in the north from the distributaries of the Mahanadi River and 0.3 million tons/year enter the lagoon from the Western Catchment (Pattnaik 2002). The vertical accumulation of sediment has exceeded the relative sea level (RSL) rise. The fate of the lagoon depends on a combination of accretion and the local RSL rise, which determines the lagoon's volumetric capacity.

The upstream erosion and sedimentation process in the lagoon directly contributed to the loss of lagoon bed depth, as well as the choking of the mouth. In turn, this led to a declining salinity. Further, introduction of prawn culture, gheri or bund fishery in 1991 led the process of changes in hydrology and sediment transport, due largely to the use of split bamboo and very fine mesh nets, encircling the culture area, which prevented free sediment flow.

The siltation and reduced salinity resulted in rapid growth of the invasive weed species in the northern sector, and restricted the free movement of juveniles of prawns and mullets from the sea into the lagoon. The breeding and spawning grounds of many important fishes, mollusks and paenid prawns have been affected due to siltation.

3.1.4 Other Issues

High nitrate concentrations are observed in winter months, resulting from land drainage carrying agricultural fertilizers. Data collected at 8 monitoring stations for the years 1986–87 to 1997–98 indicate that the use of fertilizer has nearly doubled within a decade. Agriculture runoff became severe, due to lack of adequate soil conservation measures. Additionally, untreated wastewater from the capital city in Bhubaneshwar finds its way to the lagoon. However, as with agricultural runoff, it is difficult to estimate how much of the amount generated makes it to the lagoon and how much is settled out or otherwise transformed along the way.

Siltation, declining salinity and nutrient inflows led to extensive macrophyte growth. Free-floating invasive species (e.g., Azolla, Eichhornia, Pistia) and emerging species (e.g., Ipomea) have become a common sight. Weed infestation increased from 20 km^2 in 1973 to 440 km^2 in 1998. *Paspalum vaginatum, Paspalidium punctatum, Potamogetom nodosus,* and *Potamogeton pectinatus* dominate the macrophyte community; Potamogeton alone accounts for 78% of the invasion. A Utkal University study (1998) indicated that, while a positive correlation can be established between macrophyte growth and total phosphorus and nitrate-nitrogen concentrations, the pH level had no apparent influence on macrophyte growths (CDA monitoring shows that the nitrate-nitrogen concentration is 0.0062 to 1.321 mg/L and orthophosphate is 0.003 to 0.533 mg/L (CDA 2005)).

Finally, to make an assessment of the impact of the proposed Naraj barrage upstream of the River Kathajuri, an environmental flow assessment study is being carried out to assess the amount of fresh water essential to maintain the ecological integrity of the lagoon.

3.2 Lake and Drainage Basin Resource Conflicts

A major conflict in the Chilika Lagoon resulted from a reallocation of fishing rights from traditional fishermen to include the local non-fishermen. Table 5 summarizes four main phases of allocation of the fishing rights at Chilika. Before the change in the allocation of the fishery sources (1990s), traditional fisherfolk had developed a complex system of rights and restrictions (on techniques, gear, etc.) that led to more-or-less sustainable fishing in the lagoon. Over time, however, prawn farming became more and more lucrative because of the significant increase of the price of the tiger prawn in the international market, attracting the interest of outsiders. In the lagoon area itself, conflict began with a change in basic policy, entitling the non-fishermen community to use water-spread areas for traditional culture fishery. Major conflicts began when large investments poured in from other parts of the State of Orissa and even outside the State. The functioning of the Primary Fishermen Co-operative Societies gradually deceased, almost ceasing to work.

The agitated fishermen made writ petition, organized themselves under the banner of "The Chilika Matsyajibi Mahasangh", submitted a memorandum to the government demanding abolition of unauthorized shrimp culture within the water-spread area of the lagoon. The national Supreme

Table 5. Major Changes in Fishery Rights in Chilika.

Period	System
Zamindar & Jagirdary period (British colonial rule)	Royalty to Raja of Purikud, Raja of Kalikote, Jagirdars.
Anchal Adhikari of Chilika (1953–1959)	Open auction lease mostly to fishermen.
Central Fishermen Cooperative Marketing Society (CFCMS) (1959–1988)	Lease out to Primary Fishermen Co-operative Societies; Limited access to non-fishermen.
Orissa High Court verdict in 1992	30% of rights to non-fishermen.

Source: Ghosh (1999b).

Court (through their 1996 verdict) banned the shrimp culture in the lagoon and within 1,000 meters from the high water line of Chilika; however, the State Government unfortunately could not implement the courts order effectively. Implementation of this restriction could have stopped all prawn culture activities. This brewed discontent among the fishermen as the unauthorized shrimp culture is mostly carried out by the non-fishermen. Two incidences of police firing leading to loss of life (the last one in May 1999), led the Government to issue an executive instruction banning all culture fishery in the lagoon in 1999. During this period (in early 1990s), the house of Tata's, one of the top three industrial houses, had proposed a large aquaculture project. Local agitation, however, forced the government and the investor to withdraw. The conversion of capture fishery (locally called "Jano") in fringe areas of the lagoon in Puri district during 1988–92 led to 61 new culture ponds; the district administration in Puri allowed 30% of the area to be changed to culture fisheries, which also fuelled agitation by traditional fishermen.

Overall, the repetitive administrative failure to arrive at a firm policy decision, alleged nexus between politicians and prawn culturists, and denial of rights to the traditional fishermen community for their livelihood sustenance, led to gunfire on 29 May 1999, resulting in the death of 4 fishermen.

Finally, several upstream-downstream issues also may be seen as "resource conflicts". For example, land-use practices in the upper catchment that lead to high sedimentation rates in the lagoon adversely affected the direct uses of the lagoon. Additionally, changes in the hydrological regime, due to barrages on upstream rivers, also have an impact on the natural lagoon ecosystem. Although these issues have not caused bloody conflicts, like the fishing rights issue, they nevertheless represent different users impacting each other in unfavorable ways. Due to land degradation and the change in the land use pattern in the drainage basin, productivity had declined significantly, adversely affecting the livelihood of the local communities.

4. Management Environment

4.1 Lake Management Programs and Processes

Management issues associated with restoration of this complex ecosystem were so vast in scale ecologically, hydrologically and socio-economically, that meticulous integrated planning was necessary to address them. Until the mid-1990s, lagoon management activities were limited and fragmented. To address this, CDA facilitated a consultation process at national and international level with an objective to initiate key targeted studies essential to a management-directed understanding of the ecosystem and to trace out the root cause of its degradation, and appropriate corrective measures to restore the ecological integrity and functionality of the lagoon and its drainage basin.

An integrated management plan was formulated with wide stakeholder consultation with an adaptive approach. It relied heavily on the participation of stakeholders to establish goals and targets, to manage competing objectives, and to weigh options and tradeoffs. Formulation of a credible management plan paved the way for funding support from the Government of India. CDA received an amount of 270 million INR from a "special problem grant" from the Ministry of Finance, Government of India under the 10th Finance Commission (1996-2000) for restoration of the lagoon. This was followed up by a further grant of 300 million INR from the 11th Finance Commission for consolidation of the activities carried out with the support from the 10th Finance Commission. The strategy adopted was for a more ecologically beneficial hydrologic regime to improve water quality, recovery of the lost habitat of the important species, enhancement of the productivity and controlling the invasive species in the lagoon and an integrated

Table 6. Consolidated Plan of Action for Chilika Lagoon as per Recommendation of the 10th Finance Commission (1996–2000).

No.	Activities	**Cost** (10^6 Indian Rupees)
1	Catchment area treatment; Control of silt-load by plantations and soil moisture conservation measure with the active participation of local community.	24.78
2	Improvement of water exchange and salinity gradient including cost of dredging equipment.	151.24
3	Restoration of ecosystem of Nalabana Island for migratory birds.	4.68
4	Creation of mass awareness and publicity program including environmental education.	5.00
5	Improvement of socio-economic condition and allied economic activities by providing communication facilities.	10.00
6	Improvement of road network and construction of bridges.	47.00
7	Fishery development including training for avoiding gherries and prawn culture.	4.30
8	Research Center of Wetland Management at Balugaon near Chilika shore.	21.00
9	Weed management.	2.00
	Total	270.00 (approx. US$6.0 million at 1 US$ = 45 INR)

water resource management practice in the drainage basin. The results of these programs are presented in Section 4.2. Details of activities carried out under these two major grants can be found in Table 6 and Table 7, respectively.

Additionally, the World Bank-supported Orissa Water Resource Consolidation Project (OWRCP) recognized "Lake Chilika" as a component of the OWRCP, allocating funds for hydrobiological monitoring of the lagoon with an objective to assess the impact of the Naraj barrage by the water Resource Department with the funding. In addition to this, a specialist consultancy to prepare an "Integrated Management Action Plan for Chilika Lagoon" was also supported. Although that plan was not formally adopted, many of its components were nevertheless taken up.

The restoration strategy adopted by CDA derives its uniqueness from the strong participation by local communities, grassroot-level NGOs, Community Based Organizations, strategic partnerships with various national and international organizations and experts, government agencies and stakeholder government institutions. The key to the success has been strategic partnership built up through networking, consultation and coordination with the stakeholders. For example, Chilika Development Authority maintains institutional linkages with 7 state government organizations, 33 NGOs and CBOs, 3 national government ministries, 6 other national

Table 7. Consolidated Plan of Action for Chilika Lagoon as per Recommendation of the 11th Finance Commission (2001–2004).

No.	Activities	**Cost** (10^6 Indian Rupees)
1	Catchment area treatment; Control of silt-load by plantations and soil moisture conservation measure with the active participation of local community.	47.29
2	Desiltation of the outer channel of the lagoon for improvement of the Water Exchange and Salinity gradient including excavation of Palur Canal and procurement of dredging equipment.	180.33
3	Restoration of Nalabana (Chilika) Sanctuary.	6.77
4	Creation of mass awareness and publicity program including environmental education.	11.15
5	Socio-economic development; Construction of salinity embankment, jetties, fish-landing centers etc.	15.05
6	Weed management through remote sensing application studies in collaboration with NRSA, Hyderabad and SAC, Ahmedabad.	2.95
7	Fishery resources development; Fish stock assessment study and carrying capacity through CIFRI, Barrakpore; Removal of illegal prawn gherries through district administration.	7.55
8	Communication network; Provision of ferry services between Satapada and Janhikuda.	9.86
9	Center for Wetland Management; Completion of the Wetland Research and Training Center and installation of laboratory in situ research.	19.05
	Total	300.00 (approx. US$6.7 million at 1 US$ = 45 INR)

Table 8. Activities of the Chilika Development Authority in Collaboration with Other Organizations.

Activities	Groups Engaged
Improvement of water exchange and salinity gradient by dredging, with support of mathematical model and bathymetry data	Central Water and Power Research Station–Pune (CWPRS–Pune), Ocean Engineering Center, IIT Chennai, CDA
Environmental Impact Assessment of Chilika Lagoon for dredging of outer channel by water and sediment quantity study, eco-biological quality study and circulation of siltation process	National Institute of Oceanography in Goa (NIO), CDA
Weed Management and Eutrophication study	RRL (Regional Research Laboratory) (CSIR), Bhubaneshwar
Catchment area afforestation and soil conservation	State Forest Department, Soil Conservation Department, Watershed associations
Public Awareness, eco-development in peripheral areas	CDA/CEE (Center for Environment Education), Community Based organizations, NGOs
Research and training	CDA
Fisheries development	Fisheries Department, stakeholders, CIFRI (Central Inland Fishery Research Institute)
Bird sanctuary management	Forest Department, Bombay Natural History Society

organizations, 11 international organizations, 13 research institutions, and 55 different categories of community groups. This difficult task of coordinating and strategic partnership could be accomplished through strong net working. Table 8 identifies some major groups involved in different activities.

Additionally, an innovative participatory micro-watershed management concept was adopted with a "sustainable rural livelihood" approach for holistic management of natural resources. The drainage basin of the lagoon that spreads over 4,100 km² was the logical starting point for planning and management actions for sustainable management. The objective of this concept was to facilitate the community through empowerment to take decisions and build capacity to work collectively. The participation of local communities and stakeholders in planning and implementing management of natural resources and in sharing the responsibilities of decision-making is a key feature of the ecosystem approach adopted by CDA for management of the drainage basin. The local community has considerable, relevant knowledge of the ecosystem and ways in which it can be sustainably managed. The basic approach was to create an enabling environment, through capacity building of the community, community-based organizations and NGOs at the outset, and a series of need-based training programs to facilitate an integrated and holistic management of micro-watersheds by the community. The goal was to facilitate the community to manage and reverse degradation of life support systems within the watershed, particularly land and water, to enhance the productivity, resulting in alleviation of poverty and promoting improvements in livelihood of agricultural communities. To achieve this, an innovative grassroots approach was adopted by the CDA, by formulating a micro-plan, blended with indigenous knowledge and appropriate experts' input, for optimum utilization of the natural resources in a sustainable manner and to increase productivity and provide equal opportunity for livelihood for the landless, marginal farmers and women.

CDA also addressed the issue of illegal bird hunting by working with local NGOs and CBOs and the wildlife wing of the Forest Department of Orissa to form "Bird Protection Committees" which has assisted in developing alternative economic activities through soft loans. The current CDA policy to link socio-economic activities in support of local communities has been commended by a Ramsar Mission visiting Chilika from 9–13 December 2001, which stated "CDA has developed

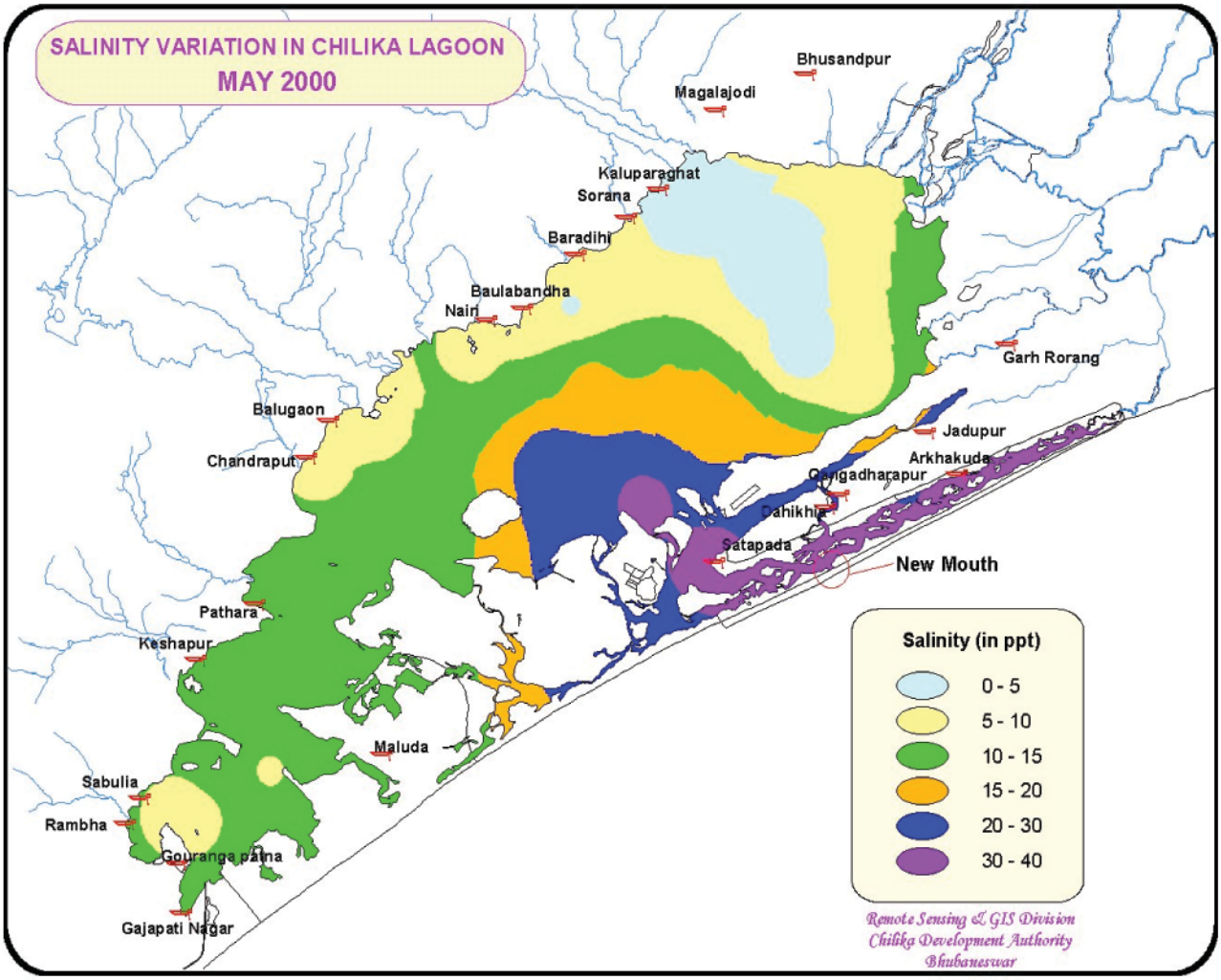

Figure 2a. Salinity Variation in Chilika Lagoon in May 2000 (Source: Chilika Development Authority).

an integrated approach to managing the lagoon which can be regarded as an excellent example of the whole ecosystem approach." The previously discussed participatory micro-watershed management is one such program.

4.2 Reduction in Stressed and Lake Environment Improvements

The basic program of opening a new lagoon mouth, a major recommendation from studies by the National Institute of Oceanography (NIO) and Central Water and Power Research Station (CWPRS), can be considered a first step in improving the lagoon environment. Interestingly, this was also a long-standing demand of the local communities, reflecting the value of local knowledge. Environmental Impact Assessments, undertaken before and after the artificial mouth was opened, showed marked improvement in terms of salinity flux, weed-free areas, recruitment of marine elements, flushing of silts and, finally, increasing productivity for both fish and shellfish. The new mouth also reduced the distance between the lagoon and the sea by 18 km, facilitating migration of both catadromous species (fish that migrate from fresh to saline water to spawn) and anadromous species (fish that migrate from saline to fresh water to spawn) (Pattnaik 2000). Detailed improvements in the lagoon environment are discussed below.

4.2.1 Improved Flow Regime

Dredging of the lead channel, and opening the new mouth on 23 September 2000, have significantly changed the lagoon's hydrology, returning it to a more natural state than existed before excessive siltation affected the tidal flows in and out of the lagoon. The management intervention to improve the tidal influx and salinity in the lagoon can be assessed by the remarkable change in salinity between May 2000 (shown in Figure 2a) and May 2001 (in Figure 2b).

Furthermore, the opening of the mouth, and consequent changes in tidal flux, led to significant flushing of sediment from the channel, thereby increasing its depth to the 30–45 cm level. The newly-restored hydrological system also led to rapid freshwater discharges through the new mouth. Consequently, peripheral and island villages were not affected by floods and water-logged land after 2001. Before the intervention, the peripheral villages suffered from inundation, especially in the

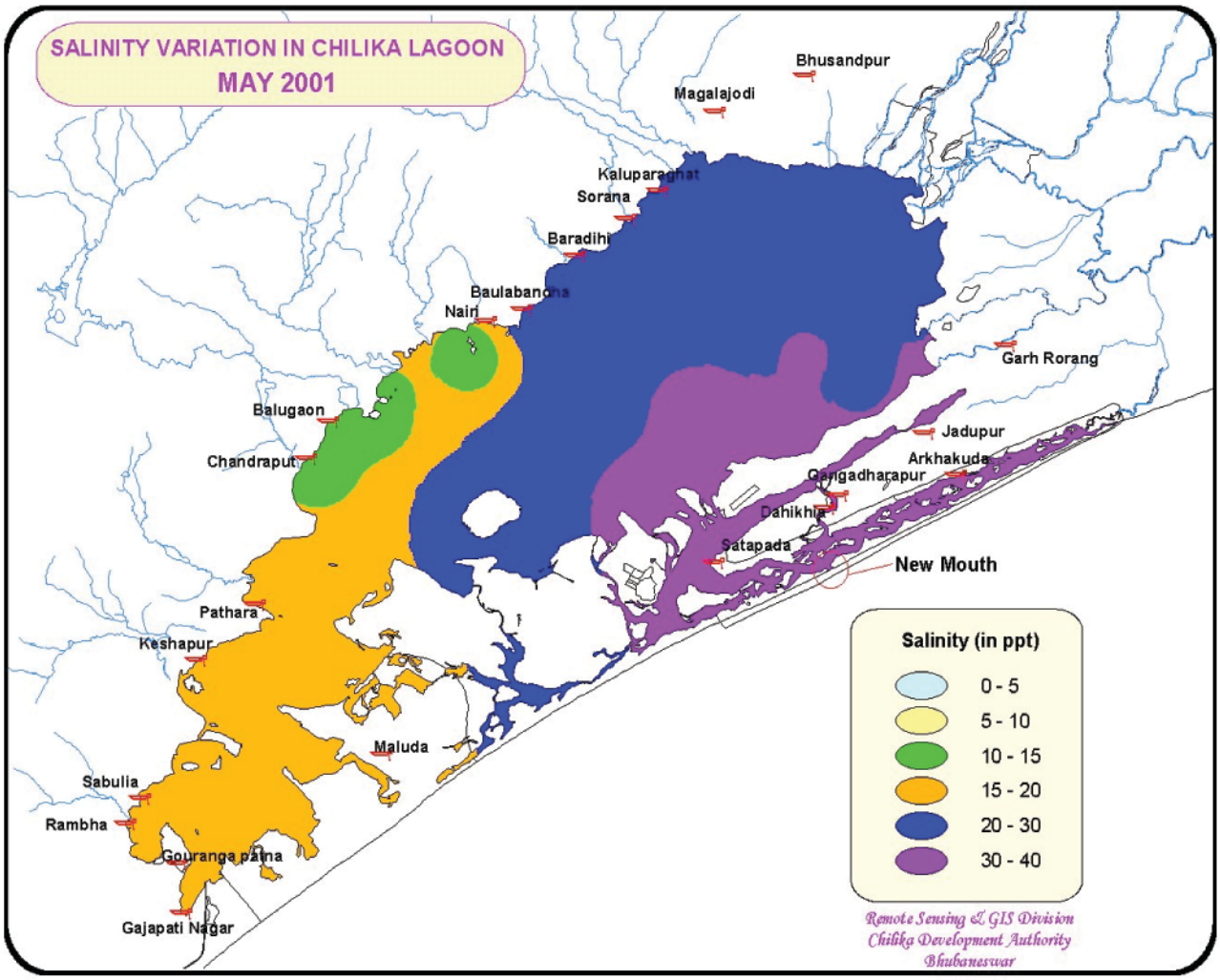

Figure 2b. Salinity Variation in Chilika Lagoon in May 2001 (Source: Chilika Development Authority).

Kanas and Bramhagri Development Block areas, leading to crop loss of over more than 50,000 hectares of paddy fields.

4.2.2 Improved Fish Catches and Recruitment of Marine Species

Opening of the new mouth had a dramatically positive effect on fish catches and, therefore, on fisherfolk's incomes. Figure 3 shows how fish, prawn and crab catches declined, but then made a dramatic comeback after the hydrological intervention of 2000. The main reasons for this occurrence have been the restoration of salinity regime improved autorecruitment from the ocean and free breeding migration. More than 75% economic species of the lagoon maintain a phased life cycle The fish landing data reached an all-time low at the most degraded lagoon condition in 1997–1998 (1,600 metric tons (Mt)); after the intervention, a record yield of 11,878 Mt was attained in 2001-2002. The crab landing data also showed a 10-fold increase, from 10 Mt to 111.07 Mt.

The recruitment of marine species, especially *Mugil cephalus* and *Liza macrolepes*, which became increasingly rare during the lagoon's degraded period, has markedly increased. About 40% of the typical fish catch originally had depended on seawater migration; this proportion has been reportedly restored after the intervention. Recruitment during February to May became highest, because of the opening of the outlet. The seaward migration of prawn and lakeward migration of mullet fingerlings are now ensured through the Muggermukh area because of dredging and de-siltation. The fish and crab landing data further indicate a significant level of increase in auto-recruitment from the sea into the lagoon after intervention. The shrimp species *(Paenaus indicus)* alone showed a record yield of 438 Mt, higher than any other figure in the previous decade.

Important for the local economy, the total financial return due to enhanced fish, prawn and crab yield, based on average weighted price, increased by nearly INR 680 million (approximately US$15.1 million). The average annual income per family increased by INR 50,000 (approximately US$1,100).

4.2.3 Decrease in Weed Coverage

Improved salinity conditions resulted in a significant decrease in the coverage of invasive freshwater weeds, with the infested area declining from 523.01 km² in October 2000 (just before opening of the new mouth), to 351.01 km² by May 2001. The reason is because the freshwater macrophytes have difficulty existing in the higher-salinity water (details provided in Table 9).

Table 9. Declining Weed Cover in Chilika.

Weed Category	October 2000 (Area in km²)	May 2001 (Area in km²)
Emergent weeds	86.07	71.62
Free floating weeds *(Eichhornia, Salvinia, Nymphea)*	110.74	51.81
Submerged weeds *(Potamogeton, Hydilla)*	170.76	122.24
Other submerged weeds *(Najas, Hydrilla)*	155.44	105.34
Weed-free area	333.82	505.82
Total	856.83	856.83

Source: CDA database — www.chilika.com.

4.2.4 Improved Biodiversity and Return of Threatened Species

The lagoon system hosts over 160 species of birds in the peak migratory season, with at least 97 being inter-continental migrants (Ram et al., 1994). The Bombay Natural History Society has been conducting a study since December 2001, using birds as a bioindicator. After implementation of the restoration program, the Society's team recorded nesting colonies of Gull-billed Tern in Nalabana, establishing its southern breeding range extension. During the same period (2002), the Indian River Tern, a lesser-studied group, was found to nest on Nalabana Island (540 nest records). These records further established the significant positive changes in the lagoon's environment, illustrating that the management program's component on Nalabana Bird Sanctuary Habitat Improvement Program yielded some positive results within a short period of time.

In addition to the return of flagship mullet species, a shrimp species *(Paenaeus indicus)* reappeared in the lagoon system because of environmental improvement, constituting nearly 50% of the total shrimp landing. The crustacean species, which were rare during the period of degradation,

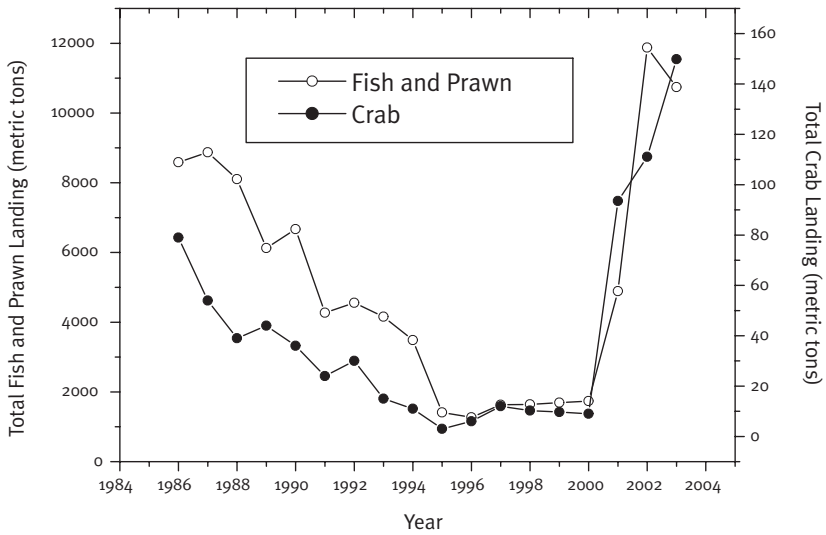

Figure 3. Changes in Fish, Prawn and Crab Landings.

comprised 2,486 Mt (20.51%) of the total catch of 11,989 Mt in 2001. The crustacean landings further increased to 2,629 Mt during 2002-2003, accounting for 24.13% of the total landings. It also is noteworthy that six other fish species once considered threatened have reappeared in the lagoon during the post-intervention period, including *Hilsa (Tenuealosa) ilisha, Chanos chanos, Megalops cyprinoids, Elops machnata, Rhabdosargus berda* and *Rhinomugil corsula*.

The restoration process helped improve seagrass meadows and their species diversity, with improved water level variations during tidal cycle turning the lagoon into a pulsating mode. Finally, Irrawady dolphins have again become well distributed in the central and southern sectors of the lagoon, while they were previously mainly reported only in the outer channel.

4.2.5 Reduction in Silt Loading from Catchment

The lagoon environment is also directly linked with the land-use patterns and agricultural practices in the basin area. The drainage basin is delineated into micro-watershed based on the latest satellite imagery. The most degraded micro-watershed are treated based on the experience from a participatory micro-watershed management which was initiated on a pilot basis in three villages, covering 640.45 ha, with the objective of capacity-building at the community level through a series of training programs directed toward integrated and holistic management of micro-watersheds. This model is already providing encouraging results, in terms of effective training for income generation activities through proper water resource management. In conjunction with trapping of significant silt loads at the Naraj Barrage, this will likely reduce the annual silt flow into the lagoon.

4.3 Remaining Problems

While the above story clearly shows that the management interventions at Chilika have had much success, resulting in direct improvements in the lagoon environment and local economy, it is incorrect to assume that all problems have been successfully addressed. Some remaining issues are discussed below.

4.3.1 Wastewater Treatment and Pollution Control

An important area requiring attention is the prevention of inflow of untreated domestic wastewater from each of the 5 sewage discharge zones of the capital city, Bhubaneshwar (approximately 25 million gallons/day), as well as untreated domestic wastewater from the 141 villages around the lagoon. A positive suggestion in this regard was given in OWRCP plan; namely, a possible linkage with the Bhubaneshwar Development Authority and Orissa State Pollution Control Board. Analysis of the capital city's wastewater indicates suspended solids (SS) concentrations of roughly 275 mg/L, well over the permissible limit of 30 mg/L; the BOD likewise shows an average value of 110 mg/L, well over the permissible limit of 20 mg/L (OSPCB 1998). "Project Water" is currently being launched with Indo Canadian Environment Facility (ICEF) funding for treating wastewater of the capital city, although only on a limited scale.

The Orissa Water Supply and Sewage Board, Government of Orissa, has formulated a proposal for the Integrated Sewage and Waste Disposal scheme for abatement of pollution in the River Kuakhai and Daya, draining into Chilika at Bhubaneswar City, at a cost of US$108 million.

4.3.2 Runoff from Upstream Lands

Despite plans within the Agricultural Intensification Program (AIP) and OWRCP, fertilizer-laden runoff water still flows into the lagoon from the basin, as pointed out in Chilika Report under OWRCP (1998; 1999). The interest of drainage basin inhabitants in the delta, especially agricultural farmers, is apparently not high because it is difficult to highlight their linkage to lagoon-related resource management. The current efforts to involve NGOs (e.g., "Campaign for Conservation of Chilika Lagoon" and Pallishree), however, may help motivate upstream people to adopt sustainable agricultural practices.

4.3.3 Palur Canal restoration

The OWRCP plan not only recommended dredging of the mouth, but also 17 km Palur Canal, a connecting link from the Ganjam side (see Figure 1), which is now under control of the Minor Port and Harbour Department. The canal provides an extra inlet both for saline water intrusion into the lagoon and recruitment of marine species. Due to siltation of the canal bed and extensive interventions along the entire canal length, the dynamics of the system had reached a moribund condition. The Palur Canal was renovated in 2004 which is likely to improve the fishery resources of the southern sector of the lagoon.

4.3.4 Eco-tourism

The present tourism activity at Chilika is focused around Rambha, Barkul and Satpada. During the OWRCP study, a tourism growth rate of nearly 30% was recorded between 1987–1997. Introduction of motorized boats in the lagoon (in contrast to conventional sail boats), and lack of a specifically-demarcated channel to Nalabana Island, has led to uncontrolled tourist activity. A report on tourism development, prepared by Tata Consultancy Services (TCS) in 1993, focused on eco-tourism. Wetland International also subsequently prepared a document on ecotourism in Chilika. More meaningful dialogue must be established between the CDA and the State Tourism Department, in order to implement a community-based ecotourism program at Chilika (Lenka 2002). The Tourism Department of the Government of Orissa commissioned the services of a consultant for developing an ecotourism master plan, and an orientation/training program for boatmen transporting tourists in the lagoon has been started.

4.3.5 Environmental Flows

The total impact of the projected 49 irrigation projects, involving dams and barrage constructions in the Mahanadi basin of Chilika, has not been linked with the Chilika Management Plan,

even though it was mentioned in the 2nd Technical Report on Chilika Lagoon under OWRCP (Ghosh 1999a).

In particular, the construction of the Naraj barrage upstream has the definite potential to affect the hydrology of the lagoon. To determine the optimum flow allocations and other key ecological functions, an environmental flow assessment supported by the World Bank has been initiated and is currently underway (as of September 2005). For arriving at different flow scenarios due to the construction of the Naraj barrage, hydrological, hydrodynamic, biological, and socioeconomic modeling as well as stakeholder consultation was carried out involving the Water Resource Department, Wetlands International South Asia, Central Water and Power Research Station, Department of Fishery Resources, World Bank, Center for Water Resources Development and Management (CWRDM), a number of NGOs, CBOs and an expert from CSIRO Australia (William Young), with extensive stakeholder consultation.

4.4 The Critical Policy and Institutional Framework for Management

The institutional framework for Chilika is based on a principle of multi-sectoral collaboration, with the CDA playing the role of central coordinating authority. The earlier problem of overlapping areas of authority, and the conflicts arising thereof, will be further addressed with the newly-proposed bill of Government of Orissa, "The Orissa Fishing in Chilika (Regulation) Bill". While acknowledging the right of the District Collector to grant leases to the Orissa State Fishermen Cooperative Federation Ltd. in regard to the entire leasable area, the bill also made it mandatory to communicate the details of such leases or sub-leases to the CDA. The bill identified the CDA as the central authority for all other matters, empowering it to make regular inspections, demolish illegal structures, search and seize any article of objection, and seek the help of the police wherever needed. The present CDA activities show a clear perception about the importance of functioning with civil society organizations, both in the basin and the lagoon area, ensuring a positive role of the CDA as an institution.

The policies and laws that can be correlated with the administration of Chilika include:

- Indian Wildlife Protection Act, 1972;
- Water Act, 1974;
- Forest (Conservation) Act, 1980;
- Coastal Zone Regulation Rules, 1991;
- National Water Policy, 2002;
- Biological Diversity Act, 2003.

These federal acts and policies, along with the State Marine Fisheries Act and Fishing in the 2002 Chilika Bill, provide a strong foundation for implementing a process of conservation and sustainable use.

4.5 Stakeholder Involvement, Awareness and Access to Information

After the hydrological intervention there has been a steady increase in the fish landing which facilitated self initiated good practices (e.g., regulation of mesh size, discouraging juvenile catches) propagated by the fisher community using a public address system. A better linkage has been established between CDA and the fisherfolk following implementation of the action plan.

A network of the NGOs and CBOs working in and around Chilika has been developed, and an outreach program is carried out through this network. The work of 'Pallishree', a grassroots-level NGO working with the support of the Japan Fund for Global Environment, Ramsar Center Japan–Asia and Chilika Development Authority, can be cited as a good example of creating public awareness. The NGO has established 10 small centers, one for four villages in and around the Chilika area. These centers (called "Center for Environment Awareness and Education"; CEAE) provide both non-formal education through trained facilitators and formal education through school-level textbooks in the local language on the Chilika Lagoon environment, Birds of Chilika, Fishes of Chilika and Plants of Chilika. Each center has a small museum and library, audio-visual material, facilities for environmental games, etc. A quarterly newsletter in the local language also is published regularly, with most of the articles contributed by the local stakeholders.

The launch of Chilika website (www.chilika.com) provided a new source for detailed information on wetland studies sponsored by the CDA; restoration history, ecological characteristics, socioeconomic features, forests and agriculture in the basin area, physical characteristics, and a special focus on birds and dolphins. The website www.chilika.com could be used as a vehicle to keep other organizations and the public aware of progress with Chilika restoration and protection. A visitor's center has been established at Satapada, a major entry point to the lagoon. The entire Chilika ecosystem is showcased at the center, via interactive exhibits. Wetland education programs also are presented in the center for school children and stakeholders.

4.6 Linkages with Other Programs

Management of Chilika Lagoon is dependent on a successful partnership between at least 8 government departments. Thus, while coordination by the CDA for acceptance by each stakeholder may appear time consuming, it is nevertheless essential.

4.7 Past and Ongoing Financial Investments

The largest investment to date has been the Special Problem Grants of the National Government's 10th and 11th Finance Commissions, as described in Tables 6 and 7. The total amount of money was approximately INR 570 million (or US$12.7 million). Furthermore, the Orissa Water Resource Consolidation Project (OWRCP) made INR 10 million (US$0.22 million) available to the CDA for the hydrobiological monitoring of the lagoon.

A major key to achieving complete success of the planned activities is the timely flow of funds and availability of resources. Thus, while the success of many of the management plan components can be lauded, failure to implement some vital components indicates the need for more concerted efforts, with the failure likely due more to lack of financial resources, rather than lack of concept and willingness by the executing agency. To this end, it would be worthwhile to determine the feasibility of undertaking work through self-financing from fisheries and eco-tourism.

The CDA itself is supported by funding from both the State and Central Government. The human resource and institutional development aspect can be judged from the existing staff component of the CDA at the capital city of Bhubaneshwar, which does not exceed 10 at any given time. The linkages with more than 40 national and regional institutions is a clear example of an integrated collaborative approach. The emerging results are encouraging. This process of multi-institutional involvement can be sustained only through a well-planned program and funding support. However, since each department has its own agenda and annual work plan, the expectations from these agencies for carrying out work relevant to lake management can only be realized through annual budgetary allocations for outsourcing work.

5. Lessons Learned

5.1 Danger of Unilateral Decisions on Established Rights of Stakeholders

Unless the government is well-informed about the existing lagoon management, and takes account of the interests of local communities and their informal management methods, it can cause biophysical and social destruction. The history of management of Chilika Lagoon clearly shows that clear perception and strong political will ensure better management results. Effective and strong coordination could be possible because of the governing body headed by the Chief Minister. Some of the bold decisions like the ban on shrimp farming and strong commitment of the state government for sustainable management of the lagoon resources is possible because of strong political commitment.

The fisher community traditionally had a positive role in managing the lagoon, through indigenous and sustainable fishing systems. The fishermen co-operatives further ensured a mechanism of equitable benefit sharing. The decision of the Supreme Court to change the fishing rights led to the loss of some rights held by traditional fisherfolk. The opinion of the traditional communities was ignored, with the Fishery Department of the State Government forced to play a minor side role as well. The earlier reports showed the involvement of the Fishery Department in lagoon management had a positive effect on fish yields.

5.2 Vital Role of Science

One of the most significant lessons learned from the Chilika experience was the vital role scientific information can play toward achieving the goal. The data generated on the freshwater flow, silt load, nature and characteristics of weed infestation, salinity and nutrients, depth and possible impacts of dredging constitute a vital research output. For effective management of the drainage basin, delineation of the most degraded micro-watershed was done based on the satellite imagery. The application of remote sensing and GIS has been used as an important management and monitoring tool. Scientific results obtained from the targeted studies and the modeling provide vital clues for restoring the salinity gradient. The prediction of a rapid salinity return was then put to test, demonstrating the connection between research and the management initiative.

The post-operative phase already has resulted in significant changes in the lagoon environment, increasing prawn and fish yields, and the active participation of stakeholders. The lesson learned from this exercise illustrates how scientific research can lead to better management of wetland ecosystems. Amelioration of the ecosystem, both in the lagoon and in the basin, resulted in enhancement of lagoon productivity, thereby leading to poverty alleviation as well.

5.3 Importance of Coordination and Diverse Funding

Despite the ineffectiveness of the CDA in the early-1990s, attempts to establish sustainable institutions to address multi-sectoral issues and multi-stakeholder interests finally seemed to succeed during the post-1997 period. That lack of coordination can create more chaos is a positive lesson learned. Thus, strong linkages and scheduled monitoring are most welcome.

It is worthwhile to mention here that the Chilika Lagoon is located in a province of a developing country with a severe resource crunch. With appropriate entrepreneurial skill and strategic partnership, the huge restoration task could be accomplished with the limited resource available. It will not be out of place to mention here that this could be achieved without any overseas funding or loan from any financial institutions. With the strategic planning and sound financial management and the very limited available resources available in from of grant from the government of India, the entire restoration task could be accomplished.

5.4 Need for Long-term Policies

No comprehensive "lagoon management policy" for Chilika has yet been publicly announced. That the absence of a lagoon management policy can create a crisis, even in the future, should be a lesson learned from the immediate past. Thus, it is essential to formulate a long-term policy on Chilika to ensure its sustainable management. The management program since 1999–2000 emphasized stakeholder participation in major decision-making. Indeed, a key lesson from the conflict in 1999 was that unilateral decision can create serious problems for both people and the lagoon. The changed policy emphasizing stakeholder involvement and agreement led to recovery of the lagoon, thereby ensuring benefits to the stakeholders. The "Chilika Fishery Regulation Act" is now under the active consideration of select committees of the Orissa Legislative Assembly. The Act prohibits culture fisheries in Chilika and, if approved, will further reinforce the executive instruction by the Revenue Authority of Orissa banning shrimp culture, in effect from the year 2000.

5.5 Stakeholder Participation Can Lead to Self-Initiated Good Practices

The network of the NGOs and CBOs, widespread stakeholder consultation, and watershed associations are some of the positive elements in the participatory management approach adopted by the CDA. Due to very good rapport with the local communities and the community-based organizations, the restoration activities carried out by CDA were strongly supported and endorsed by the community as they are consulted and taken in to confidence at all stages. Communication, education and public awareness were used as tools for enhancing the knowledge and thereby empowering them. To achieve community participation, exchange of information, mutual enhanced understanding, and facilitation of cooperation between different users groups were ensured through the outreach program. The self-initiated good practices (e.g., mesh-size restrictions) are indications of the confidence stakeholders have regained regarding the lagoon ecosystem.

5.6 Links between Poverty Alleviation and Ecosystem Restoration

Investments for the restoration of the Chilika ecosystem also provide a lesson of positive return, in terms of fishery productivity and poverty alleviation. In addition to the benefits from the fishery sector, tourism for Chilika Lagoon is expected to exhibit an upwardly mobile trend from 3 different streams of visitors; namely, winter tourism in the Nalabana Sanctuary for viewing migratory birds, tourists coming from other states round the year for aesthetic and recreational purposes, and local pilgrims visiting Kaliaji Temple and other places of worship. Investments for promoting eco-tourism, by training local boatmen, would be a worthwhile venture. Investments from the private sector on boats, nets, ice factories and transportation of produce is likely to increase with the increasing lagoon productivity. However, no quantified data is available, and an investigation regarding this topic would be worthwhile.

Although the process of good management for the Chilika Lagoon has been started, it still has "miles to go." Much remains to be done, particularly in the area of basin management, ecotourism and installing mechanisms of self-financing. Nevertheless, the Chilika story shows how effective the application of scientific and technological methods can be in the context of a well-financed management intervention process, especially when they are supported by local participation.

6. Acknowledgements

The authors are grateful to Dr. Masahisa Nakamura, Project Manager, and Dr. Thomas Ballatore of ILEC for providing this opportunity to share experiences on Chilika Lagoon. Thanks also are due to the Chilika Development Authority for readily supplying data on recent developments and other courtesies. The authors also are thankful to all the participants at the Asian Regional Experience Sharing and Review Workshop held at Manila (September 2003) for their valuable comments.

7. References and Further Reading

Annandale, N. (ed.). 1915-1924. "The fauna of Chilika lake." *Mem. Ind. Mus*. 5(1-13): 1-1003.

Asthana, V. 1979. *Limnological studies on Chilika Lake: Final Project Report*. MAB-India, Project No. 112, Department of Science and Technology: New Delhi.

Bandyopadhyay, S. and B. Gopal. 1991. "Ecosystem studies and management problem of a coastal lagoon, the lake Chilika." In B. Gopal and V. Asthana (eds). *Aquatic Sciences in India*. Indian Association for Limnology and Oceanography.

Das, N.K. and R.C. Das. 1998. "Environmental Survey of Chilika." In S.N. Patro (ed.). *Chilika, The Pride of our Wetland Heritage*. Orissa Environmental Society: Bhubaneshwar.

Ghosh, A.K. (ed.). 1995. "Fauna of Chilika Lake." *Wetland Ecosystem Services, Zoological Survey of India* 1: 1-672.

Ghosh, A.K. 1998. *Interim Technical Report on Chilika Lake under Orissa Water Resources Consolidation Project, 30 November 1998*. Water Resource Department, Government of Orissa.

Ghosh, A.K. 1999a. *Second Technical Report on Chilika Lake under OWRCP, April 1999*. Water Resource Department, Government of Orissa.

Ghosh, A.K. 1999b. *Integrated Management Action Plan for Chilika Lake under World Bank aided Orissa Water*

Resources Consolidation Project. Water Resource Department, Government of Orissa.

Lenka, S.K. 2002. "An approach to community based ecotourism planning for Chilika lagoon." In the *Proceedings of International Workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority.

Nayak, B.U., L.K. Ghosh, S.K. Roy and R.S. Kankara. 2002. "A Study on Hydrodynamics and Salinity of Chilika Lagoon." In the *Proceedings of International Workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority.

Panda, P.C. and S.N. Patnaik. 2002. "An enumeration of the flowering plants of Chilika lagoon and its immediate neighbourhood." In the *Proceedings of International Workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority.

Patnaik, S. 1978. "Distribution and abundance of some algal forms in Chilika lake." *J. Inland Fisheries. Soc. India* 10: 56-67.

Pattnaik, A.K. 2000. "Opening of a new mouth – A step to restore the ecosystem of Chilika lagoon – A Ramsar site of India." In the *Proceedings of the Workshop on Environmental Management and Wise Use of Brackish Water Lakes, Lagoons and Shallow Bays: 9th International Conference on the Conservation and Management of Lakes*. ILEC: Otsu, Japan.

Pattnaik, A.K. 2003. *Phytodiversity of Chilika lake, Orissa, India*. Ph.D. Thesis, Utkal University.

Pattnaik, S.S. 2002. "Estimation of sediment flow into Chilika Lake." In the *Proceedings of International Workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority.

Ram, R. et al. 1994. *Ramsar Sites of India: Chilika Lake*. World Wide Fund for Nature: New Delhi.

Ramsar Bureau. 2001. *Removal of Chilika Lake Ramsar Site, India from Montreux Record*. Ramsar Advisory Mission, No. 50.

Roy, A. 2001. *Ecological Investigations on the plant resources of the Lake Chilika, Orissa, India*. Ph.D. Thesis, Botanical Survey of India, University of Calcutta.

Unpublished Reports

CDA. 1991. Sustainable Development of Chilika Lake, Orissa.

CDA. 2005. Monitoring Reports.

CWPRS. 1992. Mathematical Model Studies for Chilika Lake.

CWPRS. 1995. Mathematical Model Studies to assess the effect of proposed channel on flow circulation and salinity in Chilika Lake.

CWPRS. 1997. 2-D Mathematical Model Studies to assess the effect of proposed channel on salinity improvement in Chilika Lake.

CWPRS. 1998. Mathematical Model Studies to assess the effect of proposed channel on flow circulation and salinity in Chilika Lake, Orissa.

Das, G. S. 1993. Report of the fact finding committee on Chilika Fisheries submitted to the Honorable High Court, Orissa on 16th August, 1993.

DOWR. 1998. Report on Naraj Barrage.

NIO. 1992. Studies on waves and long shore sediment transport along coastline of Chilika Lake.

NIO. 1994. Characteristic of existing Chilika Lake Inlet Channel.

NIO. 1996. Studies on volume of Dredging of Chilika Lake.

ORSAC. 1992–1996. Report on Chilika Database for the year 1991–92, 1994–95, 1995–96.

ORSAC. 1994–1996. Environmental Monitoring of Chilika Lagoon, 1994, 1995, 1996.

RRL. 1994. Investigation on Eutrophication problems in Lake Chilika.

Utkal University. 1996. A Socio-Economic study of peripheral villages of Chilika Lake — A Preliminary Report. Anthropology Department.

Utkal University. 1998. A Report on present status of Weeds in Chilika Lagoon, Botany Department.

Disclaimer

The findings, interpretations and conclusions expressed in this report are the views of the authors and do not necessarily represent the views of The World Bank and its Board of Directors, or the countries they represent, nor do they necessarily represent the view of the organizations, agencies or governments to which any of the authors are associated. Also, the colors, boundaries, denominations, and classifications in this report do not imply, on the part of The World Bank and its Board of Directors, or the countries they represent, and the organizations, agencies or governments to

Figure 4. The Mahanadi River Basin.