CHILIKA

An Integrated Management Planning Framework for Conservation and Wise Use

WETLANDS INTERNATIONAL

Chilika Development Authority

Wetlands International-South Asia

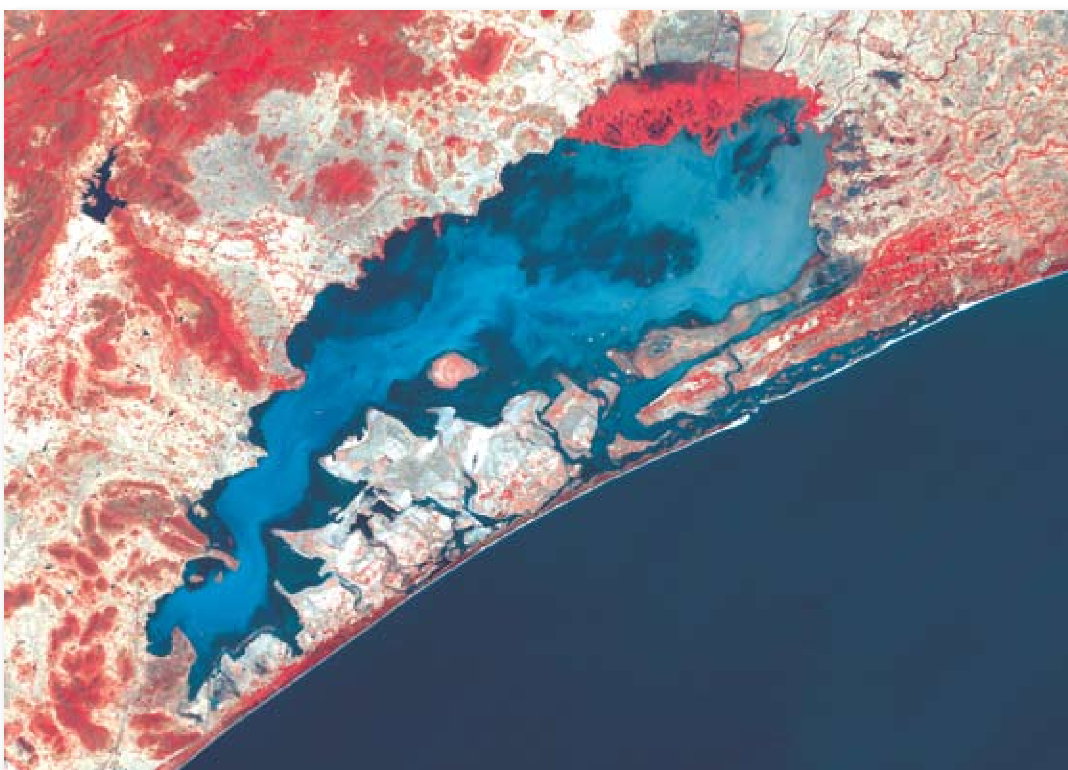
WISA is the South Asia Programme of Wetlands International, a global organization dedicated to conservation and wise use of wetlands. Its mission is to sustain and restore wetlands, their resources and biodiversity. WISA provides scientific and technical support to national governments, wetland authorities, non government organizations, and the private sector for wetland management planning and implementation in South Asia region. It is registered as a non government organization under the Societies Registration Act and steered by eminent conservation planners and wetland experts.

Chilika Development Authority

The Chilika Development Authority is the nodal agency of State Government of Odisha entrusted with conservation and sustainable management of Lake Chilika. It was created by the Forest and Environment Department, Government of Odisha vide Resolution No. 20389/ F&E dated 20.11.1991. The Authority is registered under the Orissa Societies Registration Act. Its Governing Body consists of the Chief Minister of Odisha as the Chairman and the Minister of Environment, Science and Technology as the working Chairman. The members are drawn from various state government departments, NGOs and technical experts besides elected representatives.

CHILIKA

An Integrated Management Planning Framework for Conservation and Wise Use



Wetlands International – South Asia ◆ Chilika Development Authority

Coordinating Authors
Dr. Ritesh Kumar, WISA
Dr. Ajit K. Pattnaik, CDA

Contributors
Dr. Pranati Patnaik, WISA
Mr. G. Rajesh, CDA
Dr. Nihar Das, Geoenvitech
Mr. Satish Kumar, WISA
Dr. Anita Chakraborty, WISA
Mr. Kamal Dalakoti, WISA
Ms. Usha Dangwal, WISA

Management Planning Advisory Team
Prof. E.J. James, Karunya University
Prof. N.K. Mahalik, Utkal University
Dr. B.C. Jha, Central Inland Fisheries Research Institute
Mr. S.K. Mohanty, Chilika Development Authority
Dr. S. Balachandran, Bombay Natural History Society
Prof. Niraj Kumar, Xavier Institute of Management, Bhubaneswar
Mr. D.P. Dash, Pallishree, Bhubaneswar

Peer Review
Prof. Max Finlayson
Institute of Land, Water & Society, Charles Sturt University, Australia

Publication Coordination
Ms. Meena Kumari, WISA
Mr. Bishnu Mohapatra, CDA

ISBN: 81-87408-05-7

Suggested Citation
Kumar, R. and Pattnaik, A.K. 2012. Chilika - An Integrated Management Planning Framework for Conservation and Wise Use. Wetlands International - South Asia, New Delhi, India and Chilika Development Authority, Bhubaneswar, India.

Printed on unbleached paper approved by FSC

Designed and printed by: Systems Visions
systemsvisions@gmail.com

Acknowledgement

Wetlands International - South Asia (WISA) and Chilika Development Authority (CDA) place on record their sincere gratitude to Mr. Naveen Patnaik (Chief Minister, Government of Odisha and Chairman, CDA), Mr. Bijayshree Routray (Minister, Forest and Environment, Government of Odisha) and Dr. Raj Kumar Sharma (Principal Secretary, Forest and Environment, Government of Odisha) for providing strong support and guidance to the management planning process.

The extensive support received from Dr. Sidharth Kaul (formerly Advisor, Ministry of Environment and Forests, Government of India and National Focal Point for the Ramsar Convention) is gratefully acknowledged.

The project has benefitted extensively from the reviews and inputs from the Management Planning Advisory team (names of the members listed on the left). Special mention is made of the support received from Prof. Max Finlayson (Charles Sturt University, Australia and former chair, Scientific and Technical Review Panel of Ramsar Convention) in shaping up the planning methodology and identifying intervention strategies.

Contributions received from participants of the consultation workshops held in October 2009 and January 2011 is gratefully acknowledged. Constant encouragement and support received from WISA Board Members, Dr. Ashok Kundra (President) and Mr. S.K. Pande (Treasurer) is acknowledged with thanks.

The project team expresses its heartfelt thanks to Chilika communities for willingly participating in the management planning exercise and contributing extensive insights. Mr. Durga Prasad Dash (Pallishree) coordinated community surveys and participatory appraisals in several villages of Chilika, in partnership with federation of NGOs. All contributions are acknowledged with thanks.

The work is dedicated to Late Dr. C.L. Trisal (Founder Director, WISA) who initiated this project along with several other initiatives for conservation of Lake Chilika. The financial support received from Ramsar Convention Secretariat and International Development Research Center is thankfully acknowledged.

सत्यमेव जयते
ODISHA STATE

NAVEEN PATNAIK
CHIEF MINISTER, ODISHA

MESSAGE

Lake Chilika is a pride of Odisha. This hotspot of biodiversity serves as natural habitat for a range of species, including over one million water birds that visit the wetland each year besides the charismatic Irrawaddy Dolphin. Chilika is also inextricably intertwined with culture and belief systems of the communities living in and around her, and depending on Lake resources for sustenance.

The Government of Odisha is committed to ensure the conservation and sustainable management of Chilika Lake. The rejuvenation of lake ecosystem since the bold and strategic hydrological intervention in the year 2000; the subsequent recovery of fishery resources immensely benefiting the fishers, increase in Irrawaddy Dolphin population, and the increasing sea grass meadows are some of the positive indicators of the effectiveness of restoration measures being undertaken by the Chilika Development Authority.

Given the dynamic nature of wetland ecosystems, Chilika is also open to influence from several natural and human factors taking place within the Mahanadi River Basin as well as the coastal processes within the Bay of Bengal. It is therefore important to lay down a comprehensive vision document on the way Chilika ecosystem needs to be managed. I am happy to note that an integrated management planning framework has been developed as a guiding strategy for ensuring wise use of Chilika with a long term perspective. Wetlands International – South Asia and Chilika Development Authority have intensively worked with a range of stakeholders, particularly the local communities to assess the status and trends of various wetland features and derive practical actions in order to ensure sustenance of the rich biodiversity and full range of ecosystem services of the wetland.

I congratulate the entire management planning team for bringing out this vision document, and underline the commitment and support of the Government of Odisha for implementation of the management plan.

(Naveen Patnaik)

CONVENTION ON WETLANDS
CONVENTION SUR LES ZONES HUMIDES
CONVENCIÓN SOBRE LOS HUMEDALES
(Ramsar, Iran, 1971)

PROF. NICK DAVIDSON

Deputy Secretary General
Ramsar Convention on Wetlands

MESSAGE

Wetlands, both coastal and inland, are a critical part of the world's natural infrastructure, supporting water and food security and human well-being through a range of ecosystem services. Yet unfortunately wetlands are the most rapidly degrading ecosystems on earth. Integrated management of wetlands, linked to developmental planning, is essential to ensure that wetlands continue to function within landscapes and thereby continue to secure human societies through their services.

Lake Chilika, a designated Wetland of International Importance under the Ramsar Convention, exemplifies the Convention's philosophy of "wise use", which emphasizes conservation and sustainable use of wetlands and their resources for the benefit of humankind. Participatory management approaches adopted by the Chilika Development Authority (CDA) have enabled effective redress of the rapidly degrading conditions of the wetland and removal of the site from the Montreux Record. By conferring the Ramsar Award for wetland management in 2002 to CDA, the Convention has strongly recognises their successful and ongoing efforts to deliver 'wise use' for the benefits to local communities, and intends to showcase the wetland restoration approach adopted at Chilika as exemplary good practice for application of various Ramsar guidelines and use of Convention's tools for addressing complex site management issues.

It gives me immense pleasure to see that Wetlands International – South Asia and Chilika Development Authority have developed a management planning framework for conservation and wise use of Chilika Lake. The planning process has been able to build on the several guidelines developed by the Convention, particularly those related to description of wetland ecological character, integrated river basin and coastal zone management and formulation of integrated management plans. Involvement of stakeholders, particularly local communities, in the planning process affirms adoption of a participatory approach by the planning team for formulation of the plan. The baseline on wetland features as outlined in this document will be immensely useful in monitoring and assessing changes in ecological character of the wetland system over a period of time.

On behalf of the Ramsar Convention, I congratulate Wetlands International – South Asia and Chilika Development Authority for this exemplary effort. I trust that this document will be used as a basis for organizing interventions and implementing action plans for the various components as identified in the framework.

(Nick Davidson)

BIJAYSHREE ROUTRAY
MINISTER
Forest & Environment, Labour & ESI
ODISHA

MESSAGE

Chilika Lake is a unique wetland ecosystem of State of Odisha. Every year more than a million migratory water birds descend on the lake making it an avian paradise. It is also one of the few lakes in the world which sustain habitat of Irrawaddy Dolphin. A diverse range of brackish and freshwater fishes make Chilika a very productive natural resource and source of livelihoods of over 0.2 million fishers living around the wetland.

Chilika Lake, a designated Ramsar Site has a complex ecosystem. The Government of Odisha is committed to ensuring wise use of the wetland system. This can only be achieved if the developmental activities within the river basin and coastal zone are coordinated in a way that Chilika's biodiversity as well as productive resources are maintained. A management planning framework is vital for ensuring the harmony of multi-sectoral development in Chilika.

It gives me pleasure to learn that Wetlands International – South Asia and Chilika Development Authority have developed such a framework based on extensive review of monitoring data and through the stakeholder consultations. The plan provides a basis for linking with broad-scale landscape and ecosystem planning, including the integrated river basin and coastal zone scales; as policy and planning decisions at these scales affect the conservation and wise use outcomes at site level. By setting the long term objective as "conservation and wise use of Lake Chilika integrating catchments and coastal zones for ecological security and livelihood improvement of local communities", the plan caters the need for biodiversity and livelihood linkages in an effective manner.

This plan will provide a very useful reference framework to guide interventions for maintaining the rich biodiversity and ecosystem services of Chilika Lake. I heartily congratulate the team which has worked towards drafting this plan and convey our commitment to support its implementation.

Bijayshree Routray

(Bijayshree Routray)

सत्यमेव जयते

RAJ KUMAR SHARMA

Principal Secretary to Government

Forest & Environment Department

MESSAGE

Chilika Lake was designated as Ramsar site in 1981 and was included in the Montreux Record in 1993 due to change in its ecological characters, by the Ramsar Convention Secretariat.

Strategic hydrological interventions in 2000 by the Chilika Development Authority has resulted in significant improvement of the Lake ecosystem. It has also improved the salinity levels and enhanced the fish landing which has benefitted the local communities. The ecosystem based management demonstrates how restoration of Chilika with active community participation not only has positive impact on the biodiversity but can significantly improve the livelihood of the local communities.

The restoration strategy adopted by Chilika Development Authority derives its uniqueness from the strong participation by local communities, linkage with various national and international institutions and intensive monitoring and assessment of the system. The key element of the restoration model is successful core partnership built up through networking, consultation and coordination. Due to successful restoration of the Lake ecosystem, it was removed from the Montreux Record in 2002.

I am glad to know that Chilika Development Authority in collaboration with Wetlands International – South Asia (WISA) has come up with a strategic management plan to address the key issues of water resources management for river basins, hydrological regimes of the lake, biodiversity conservation, community livelihoods and institutional development.

I am hopeful that the Chilika Development Authority with its existing linkages with National and International institutions would be able to execute the implementation of the management plan prescriptions in the right earnest. I congratulate the team for bringing out this much needed comprehensive management plan for the Chilika.

(Raj Kumar Sharma)

Preface

Wetlands in our region are placed within a complex development landscape marked with high economic growth, burgeoning population, exacerbating economic inequality, increasing food and water insecurity and more lately an unprecedented increase in number of disasters. Limited awareness about contribution that wetlands make to societal well-being had led to severe pressures on these ecosystems leading to their degradation, loss in biodiversity and decline in critical ecosystem services. Integrated management planning therefore is faced with the arduous task of recognizing and balancing tradeoffs that emerge from policies and development decisions primarily aimed at water and food security, and climate change adaptation.

Chilika is one of the most important natural asset endowments of the State of Odisha. Managing Chilika entails ensuring conserving its rich biodiversity as well as sustainable livelihoods for communities dependant on the wetland resource for sustenance. The management plan outlines a pathway for achieving wise use of Chilika. While identifying strategies for maintenance of ecological character, a focus is made on the social construct of wise use concept. This builds on a nested socio-ecological systems perspective wherein Chilika's ecological character stands influenced and in turn influences livelihood systems linked with the wetland, the choices and tradeoffs made by the resources users and governance system that is put in place. Analysis of wetland features and description of ecological character therefore includes an analysis of livelihood systems and institutional arrangements while identifying vulnerability contexts.

Lake Chilika is a highly complex ecosystem influenced by a diverse range of factors within its river basin and coastal zone. Management planning therefore cannot be prescriptive nature, but would need to be reviewed integrating new information or better understanding of the ecosystem linkages. The plan presents a description of ecological character based on interpretation of existing information base. The planning team has not only based its work on the published and unpublished outcomes of various assessments and research, but has also integrated the traditional knowledge available with the communities living around the wetland, which has evolved over ages based on observing and interacting the ecosystem closely. It is believed that the analysis presented in the report would be periodically reviewed and updated to inform management strategies. This is particularly important since the current wetland monitoring system is being gradually upgraded and research on coastal processes, ecosystem health and climate change commissioned in collaboration with international and national agencies.

Finally, management is about making informed choices and allocating scarce resources to their most productive use. Chilika Development Authority and Wetlands International – South Asia , in collaboration with the network of organizations are committed to implementing the management plan to ensure conservation of rich biodiversity as well as secure provision of ecosystem services. This plan would therefore serve as an instrument to guide future investment into the wetland system, and as a means to communicate with the diverse range of stakeholders. The plan also provides a basis for mainstreaming conservation and wise use of Chilika into developmental planning, particularly those addressing water-food and energy nexus.

Contents

Tables, Figures and Maps

Tables

Figures

Maps

Acronyms

°C	Degree Celsius
BNHS	Bombay Natural History Society
CAFL	Chilika Aquatic Farms Limited
CBO	Community Based Organization
CCCL	Campaign for Conservation of Chilika Lagoon
CDA	Chilika Development Authority
CEO	Chief Executive Officer
CFCCS	Chilika Fishermen Central Cooperative Society
CFCMS	Central Fishers Cooperative Marketing Society
CIFRI	Central Inland Fisheries Research Institute
cm	Centimeter
cm yr^{-1}	Centimeter per year
CPUE	Catch Per-Unit Effort
CR	Critically Endangered
CRZ	Coastal Regulation Zone
CS	Central Sector
CWRDM	Centre for Water Resources Development and Management
DD	Data Deficient
DO	Dissolved Oxygen
DoF	Department of Fisheries
EN	Endangered
FAO	Food and Agriculture Organization
FISHFED	Odisha State Fishermen's Cooperative Federation
FRMP	Fisheries Resource Management Plan
GHG	Green House Gas
GIS	Geographic Information System
Govt.	Government
ha	Hectare
IIASA	International Institute for Applied System Analysis
IRS	Indian Remote Sensing
ISRIC	International Soil Reference and Information Centre
ISSCAS	Institute of Soil Science-Chinese Academy of Sciences
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
JNU	Jawaharlal Nehru University
JRC	Joint Research Centre of the European Commission
kg/ha	Kilogram per hectare
km	Kilometer
km/hr	Kilometer per hour
km^2	Square kilometer
LC	Least Concern
LPG	Liquefied Petroleum Gas
m amsl	Meter above mean sea level
m^3	Cubic meter
m^3/s	Cubic meter per second
MCM	Million Cubic Meter
$mgC/m^3/hr$	Milligram carbon per cubic meter per hour
$Millimhos/cm^2$	Millimoles per cubic centimeter
MoEF	Ministry of Environment and Forests
MPEDA	Marine Products Export Development Authority
MSY	Maximum Sustainable Yield
MT	Metric tonne
MT/ha	Metric tonne per hectare
MT/month	Metric tonne per month
MT/year	Metric tonne per year
NE	Not Evaluated
NGO	Non Governmental Organization
no./l	Number per litre
$no./m^2$	Number per square meter
NS	Northern Sector
NT	Near Threatened
OC	Outer Channel
OMCAD	Odisha Maritime and Chilika Area Development
PFCS	Primary Fisher Cooperative Societies
ppm	Parts per million
ppt	Parts per thousand
Pvt.	Private
Rs.	Indian Rupee (Rs. 1 = US $ 0.02)
SGF	Small Grants Fund
SHG	Self Help Group
sp.	Species
ssp.	Sub-species
SS	Southern Sector
SWOT	Strength, Weakness, Opportunity and Threat
TERI	The Energy and Resource Institute
TM	Thematic Map
var.	Variety
VN	Vulnerable
WASH	Water, Sanitation and Hygiene
WCDS	Whale and Dolphin Conservation Society
WISA	Wetlands International-South Asia
ZSI	Zoological Survey of India

Ramsar Site Signage at Wetland Research and Training Centre, Chandraput

1. Introduction

1.1 Background

Lake Chilika, the largest coastal lagoon on the east coast of India and lifeline of the state of Odisha, is a designated Wetland of International Importance (Ramsar Site under the Convention on Wetlands) since 1981. Chilika went through a phase of rapid degradation during 1950-2000 owing to increasing sediment loads from catchments and reduced connectivity with the sea. Its fisheries underwent a major decline, invasive weeds proliferated and the wetland shrank in area and volume. This had tremendous impact on the livelihood of communities, especially fishers. Introduction of shrimp culture added further pressure on lagoon ecology and ultimately led to significant disruption of community institutions, which traditionally managed fisheries sustainably. This formed the background for inclusion of Chilika into the Montreux Record[1] of Ramsar Convention in 1993.

The Government of Odisha created the Chilika Development Authority (CDA) in 1991 for undertaking ecosystem restoration. With financial support of the state government and the Ministry of Environment and Forests, Government of India, CDA initiated several programmes including treatment of degraded catchments, hydrobiological monitoring, sustainable development of fisheries, wildlife conservation, ecotourism development, community participation and development and capacity building at various levels. In 2000, a major hydrological intervention was carried out in the form of opening a new mouth to the Bay of Bengal which helped improve salinity levels, enhance fish landing, decrease in area under invasive species and overall improvement of water quality. Recovery of resources led to significantly improvment in livelihoods of dependent communities.

Based on the impact of restoration measures, the Government of India requested the Ramsar Convention Bureau to consider removal of Chilika from the Montreux Record. This finally materialized in 2002 following recommendations of Ramsar Advisory Mission. The restoration was recognized with The Ramsar Wetland Conservation Award and Evian Special Prize conferred to the CDA in 2002. The Advisory Mission *inter alia* recommended that:

- Lake Chilika should be considered as an exemplary good practice case study by Ramsar Convention for the application of various Ramsar guidelines and use of Convention's tools and approaches

Opening of mouth to the sea in September 2000 helped rejuvenate Chilika

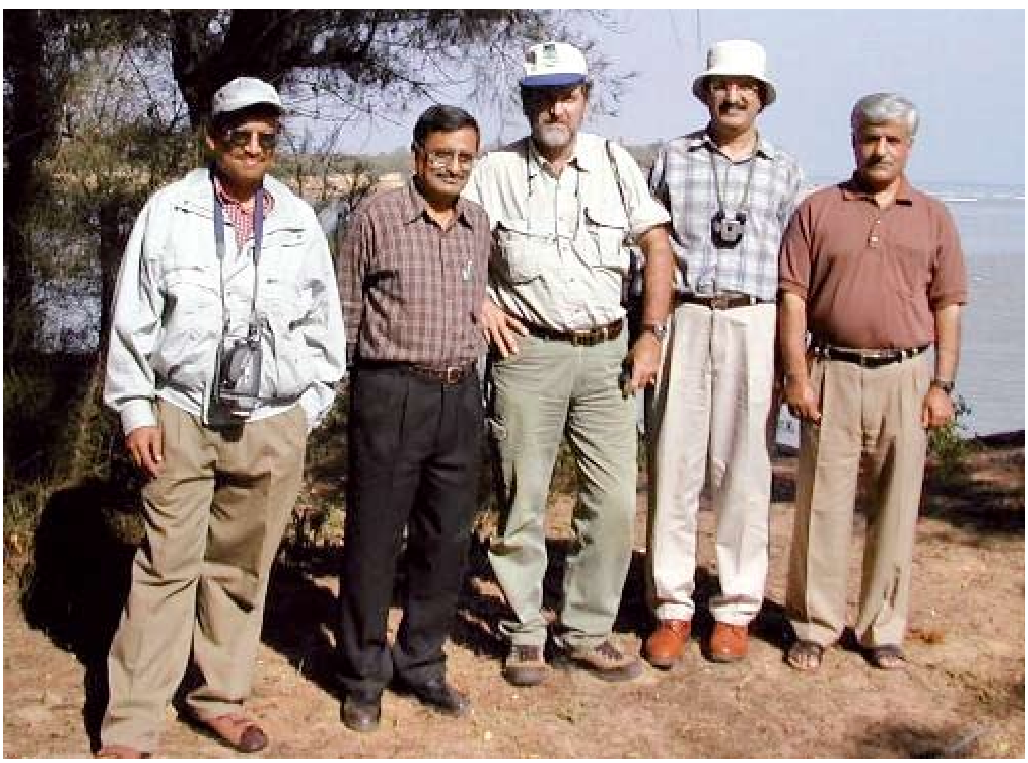
[1]Montreux Record is the list of Ramsar sites where change in ecological character has occurred, is occurring, or is likely to occur as a result of technological development, pollution, or other human interference (established by Resolution 5.4). Montreux Record sites require priority national and international conservation attention and receive preference for application of the Ramsar Advisory Mission.

to address the complex site and catchment management issues. This would assist the Convention to develop further guidance in support of the whole ecosystem approach to wetland management and provide an example of adaptive management practices for wetlands.
- Considering the inter-connectivity of several problems faced by Chilika Lake, a single management plan with widely agreed goals and objectives to restore ecological character of the lake while providing economic benefits to the local communities should be formulated.

The Governing Body of CDA, in its meeting held in May 2003 under the chairmanship of the Chief Minister, Government of Odisha also emphasized the need for an integrated management plan addressing ecological, economic and social dimensions.

Responding to these recommendations, Wetlands International–South Asia (WISA) and CDA formulated a proposal for integrated management planning for Chilika for financial support under the Small Grants Fund (SGF) for Wetland Conservation and Wise Use of the Ramsar Convention. The management planning framework presented in this report has been developed with Ramsar SGF support. Expert review and analysis of ecological character status and trends was carried under International Development Research Center (IDRC) supported climate vulnerability assessment project being currently implemented by WISA and CDA.

The Ramsar Advisory Mission at Chilika (January 2001) from Left – Dr. A.K. Pattnaik (CDA), Dr. S. Kaul (MoEF), Prof. Max Finlayson (then Chair, Ramsar STRP), Dr. Najam Khurshid (then Ramsar Regional Representative – Asia) and Dr. C.L. Trisal (WISA)



1.2 Integrated management planning: Purpose and Objectives

Designation of Chilika as a Ramsar Site commits the Government of India and Government of Odisha to take actions to ensure wise use of wetland ecosystem.

Wise use is the longest established example amongst intergovernmental processes, the implementation of which has become known as ecosystem approaches for conservation and sustainable development of natural resources, including wetlands. The wise use approach identifies the critical linkages that exist between people and sustainable development of wetlands; and encourages community engagement and transparency in negotiating trade-offs and determining equitable outcomes for conservation (Finlayson *et al.,* 2011). Wise use principle has also been emphasized in the National Environment Policy (2006) and as the primary objective of the National Wetland Conservation Programme of the Ministry of Environment and Forests, Government of India.

Wise use is defined within the Ramsar Convention text[2] as "the maintenance of their ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development". Maintenance of ecological character provides basis for management planning and management actions. Ecological character is further defined as "the combination of ecosystem components, processes and benefits / services that characterize the wetland at any given point of time".

The integrated management framework presented in this report represents the commitment of CDA, Government of Odisha, Government of India, WISA, and the Ramsar Convention on Wetlands

[2]Resolution IX.1 Annex A (2005)

to support conservation and wise use of Lake Chilika. The framework intends to:

- outline a management strategy to identify the objectives of site management;
- describe the management actions required to achieve the objectives;
- determine the factors that affect, or may affect, the various site features including functions;
- define monitoring requirements for detecting changes in ecological character;
- support obtaining of resources for implementation;
- enable communication within and between sites, organizations and stakeholders and,
- ensure compliance with local, national and international policies.

Site-based management planning is also recognized as one of the elements of a multi-scalar approach to wise use planning and management. The management plan aims to provide a basis for linking with broad-scale landscape and ecosystem planning, including at the integrated river basin and coastal zone scales, as policy and planning decisions at these scales affect the conservation and wise use outcomes at site level.

The long term objective of management planning is conservation and wise use of Lake Chilika integrating catchments and coastal zones for ecological security and livelihood improvement of local communities. The purpose is to establish effective management practices for management of Lake Chilika ecosystem at river basin and coastal zone levels for ecological and economic security of the people dependant on the wetland resources for sustenance.

1.3 Approach and Methodology

The ecological character of Chilika is influenced by hydrological regimes and is vulnerable to changes due to anthropogenic as well as natural factors. Management planning for Chilika therefore calls for an approach which recognizes the interconnectedness of coastal and freshwater processes taking into account the external, natural and induced factors. The approach also needs to address climate change which has direct and indirect implications for wetland features as well as factors governing three features. There is an underlying need to maintain ecological character while providing for sustainable utilization of lake resources for the benefit of stakeholders, particularly local communities. An Integrated Water Resources Management (IWRM) has therefore been adopted as the management planning approach.

IWRM is based on the concept of water being an integral part of an ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its use (Agenda 21, United Nations, 1992). The framework brings together stakeholders at all levels considering their needs and aspirations while ensuring conservation of the wetland ecosystem within the river basin. A critical requirement for IWRM at river basin level is introduction of land use and water planning and management mechanisms which focus at the river basin scale.

IWRM at river basin scale is also underlined in the New Guidelines for Management Planning as endorsed by the Eighth Meeting of Contracting Parties to the Ramsar Convention[3]. The need to integrate site management plans into public developmental planning system at local, regional and national levels is emphasized in the guidelines. In order to safeguard site and their features, the planning process recommends adoption of an adaptable management process which allows wetland managers to respond to the legitimate interest of others, adapt to ever-changing political climate, accommodate uncertain and variable resources, and survive the vagaries of the natural resources.

IWRM at river basin level is also recommended as a conservation approach in several national policy documents. The National Environment Policy (2006) of Government of India recommends integration of conservation and wise use of wetlands into river basin management involving all relevant stakeholders, in particular local communities, in order to ensure maintenance of hydrological regimes and conservation of biodiversity. It further recommends integration of wetland conservation into sectoral development plans for poverty alleviation and livelihood improvement, and link efforts for conservation and sustainable use of wetlands with all ongoing rural infrastructure development and employment generation programmes. The Wetland Conservation and Management Rules (2010) provide an institutional mechanism to prevent any fragmentation of

[3]Resolution VIII.14 – New Guidelines for management planning for Ramsar sites and other wetlands. Also available as Ramsar Handbook 18, Fourth Edition, 2010

hydrological regimes through hydraulic structure, diversions, encroachments or impeding flow pathways.

The broad approach for management planning is characterized by the following:

- Adopting river basin approach integrating catchments and coastal processes for conservation and sustainable management of the wetland
- Integration of biodiversity into regional planning to minimize impacts of developmental activities
- Participatory approaches involving local communities, scientists, NGOs and concerned organizations to ensure sustainability of activities
- Adopting preventive measures by combating the problems at source rather than merely curative measures
- Revival of indigenous knowledge and traditional practices which are cost effective for management of biodiversity
- Application of knowledge based techniques for restoration through research and development activities
- Periodic monitoring and evaluation with focus on achieving the goals and objectives rather than merely activities

The methodology adopted for management planning follows largely the Ramsar guidelines, which recommend a diagnostic approach based on a critical evaluation of ecological, economic and socio-cultural features to identify objectives and operational limits including factors for effective restoration and management of wetland ecosystem (Fig. 1). The management planning framework addresses the following:

- establishment of preamble/policy;
- evaluation of wetland features and governing factors for describing status and trends in ecological character of wetland system and identification of threats;
- review of current institutional arrangements in terms of ability to maintain ecological character and, in particular, respond to drivers and pressures that have negative impacts;
- identification of management planning components, outcomes, performance indicators, activities and implementation strategy.

Mr. Naveen Patnaik, Chief Minister, Government of Odisha (second from right) at the opening ceremony of Stakeholder Consultation Meeting, October 2009

The management planning framework was formulated by a team of experts having specialization in catchment conservation, water resources management, biodiversity conservation, community livelihoods and institutional development. Evaluation of features formed the basis of identification of management objectives. The outcomes of various research programmes coordinated by CDA have been key inputs to defining management rationale. The targets under each management objective were defined based on field surveys and information review.

A critical part of the process was extensive stakeholder consultations at various stages of project implementation. Chilika NGO Forum organized consultations in 42 villages located in and around Chilika and representing diverse stakeholder groups. Further, a consultation workshop was also held on 23-24 October 2009, wherein the summary framework was presented as a discussion paper (full report available as WISA, 2009).

The process has also been enriched by several component specific assessments coordinated by CDA. Notable amongst these are the Fisheries Resource Management Plan (FRMP) supported by the Japan International Cooperation Agency (JICA) during 2006-2009, response strategy for invasion of *Phragmites* sp. (implemented by WISA, January

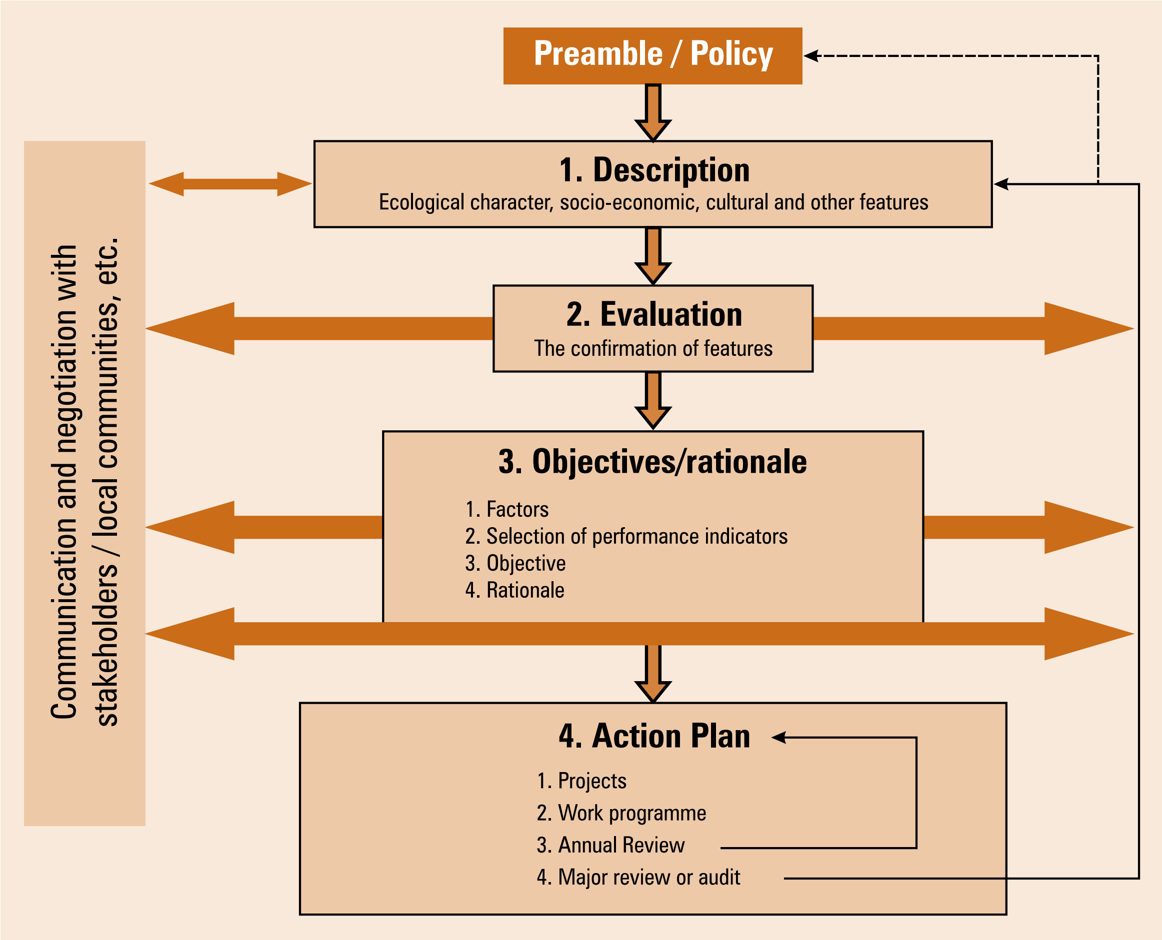


Fig. 1: Management Planning Framework for Wetlands

(Source: Ramsar Handbook 14)

2011), and perspective plan formulation for CDA focused on institutional arrangements (Xavier Institute of Management, 2011).

Wetlands are dynamic systems with complex interplay between drivers and pressures leading to changes in their ecological character. Management planning therefore needs to be flexible with ability to respond to changes in the socio-ecological system and linked institutional arrangements. Within the current framework, the intervention strategies are based on the best available information, with wetland features being continually monitored to assess effectiveness of management. Management needs to be modified if the objectives are not met. Therefore, the evaluation of wetland features as presented in this report represents the current understanding of the system, and would need to be revisited as further information from various scientific studies and outcomes of current monitoring become available. Synthesis of the existing information base is an important purpose of this document, which can support further research and evaluation of wetland features, and detect changes in ecological character.

1.4 Report Structure

The report is organized in four sections. The current section outlines the management planning background and sets the approach and the methodology. The second section focuses on the description and evaluation of wetland features in order to assess status and trends in ecological character and identification of key threats. A review of institutional arrangements follows next. The management planning framework is presented in the fourth and final section of the report.

A fisher prepares for beginning his day in Chilika

2. Description and evaluation of wetland features

2.1 Lake Chilika

Lake Chilika fluctuates in area between monsoon maximum of 1,165 km^2 and dry season minimum of 906 km^2 (Map 1). The pear shaped wetland spans between 19°28'-19°54' N and 85°6'-85°35' S with a linear axis of 64.3 km and an average width of 20.1 km. Its eastern margin is dotted by 24 islands covering an area of 18.4 km^2. Chilika is connected to the sea by a 32 km long channel opening into the Bay of Bengal opposite to Sipakuda, and in the south through the Palur Canal which links Chilika to Rushikulya estuary. The northern periphery of Chilika is fringed by large tract of marshy alluvial plains extending to around 400 km^2. The lagoon boundaries fall within eight blocks of three districts, Puri, Khurda and Ganjam.

Hydrological regimes of Chilika are influenced by three subsystems. The Mahanadi distributaries and streams of the western catchment bring in freshwater flows to the lake, whereas the Bay of Bengal contributes highly saline sea-water. Ecologically, Lake Chilika is an assemblage of shallow to very shallow marine, brackish and freshwater ecosystems. The wetland is classified into four sectors. The northern sector which receives direct discharge of freshwater from Mahanadi Delta has predominantly freshwater characteristics. The central sector with intermixing of fresh and marine flows is brackish. The southern sector is the deepest part of Chilika and has higher salinity levels as compared to central sector owing to the influence of Rushikulya estuary. Outer channel is the corridor for exchange between lake and the sea. The sector is characteristically marine but is marked by continual dynamism owing to the diurnal tidal oscillations.

The presence of unique salinity gradient enables the lake to host a wide range of biodiversity which includes 314 species of fish, 224 species of waterbirds (including 97 inter-continental migrants) and 729 species of angiosperms with several of economic value. The lake regularly hosts over one million wintering migratory birds. It is also one of the few lagoons in the world that support Irrawaddy Dolphin (*Orcaella brevirostris*). *Barkudia insularis*, a limbless skink, is endemic to Chilika.

The diverse and dynamic assemblage of fish, invertebrate and crustacean species provide the basis of rich fishery which includes 62 economically important fish, prawn and crab species with an average annual yield of 12,000 MT. Fisheries form the livelihoods of over 0.14 million fisher communities living around Chilika. High biodiversity and cultural values of the lake make it one of the important tourist destinations of the Odisha state. Chilika is visited by 0.3 million domestic and foreign tourists each year.

Chilika is also intertwined with the rich cultural heritage of the state. The temple of Kalijai is highly


A panoramic view of sunset in Chilika

Map 1: Lake Chilika

revered by the communities living in and around. Archaeological remains at Manikpatna, Palur and adjacent areas mark its rich maritime heritage.

2.2 Evaluation of wetland features

2.2.1 Geology and Geomorphology

The origin of Lake Chilika is attributed to a complex geologic process involving deposition of beach ridges and spits enclosing a body of sea water within the Bay. Chilika formed a part of the Bay of Bengal about 6,000 years ago, and served to be its gulf during Pleistocene (Map 2). The current form of Chilika is attributed to successive recession of coastline aided by marine and fluvial dynamics over 6-7,000 years (Phlegar, 1969). The process of sand bar formation was very gradual with the sea level rise being very slow during the Halocene (15-20 cm in a century). The growth of barrier is believed to be triggered by a minor tectonic elevation, subsequently aided by coastal progradation attributed to lowering of sea levels and deposition of sediments by long shore currents (Rao and Sadakata, 1996).

Chilika and its surroundings are marked by several erosional and depositional landforms. The main rock types within the region around Chilika are khondalites, unclassified granites, laterites, charnockites, anorthosites, granulites, laterites and alluvium. Some islands of Chilika comprise Eastern Ghat rocks. The overall trend of foliations of Eastern Ghat rocks is North East – South West, with local variations at several places.

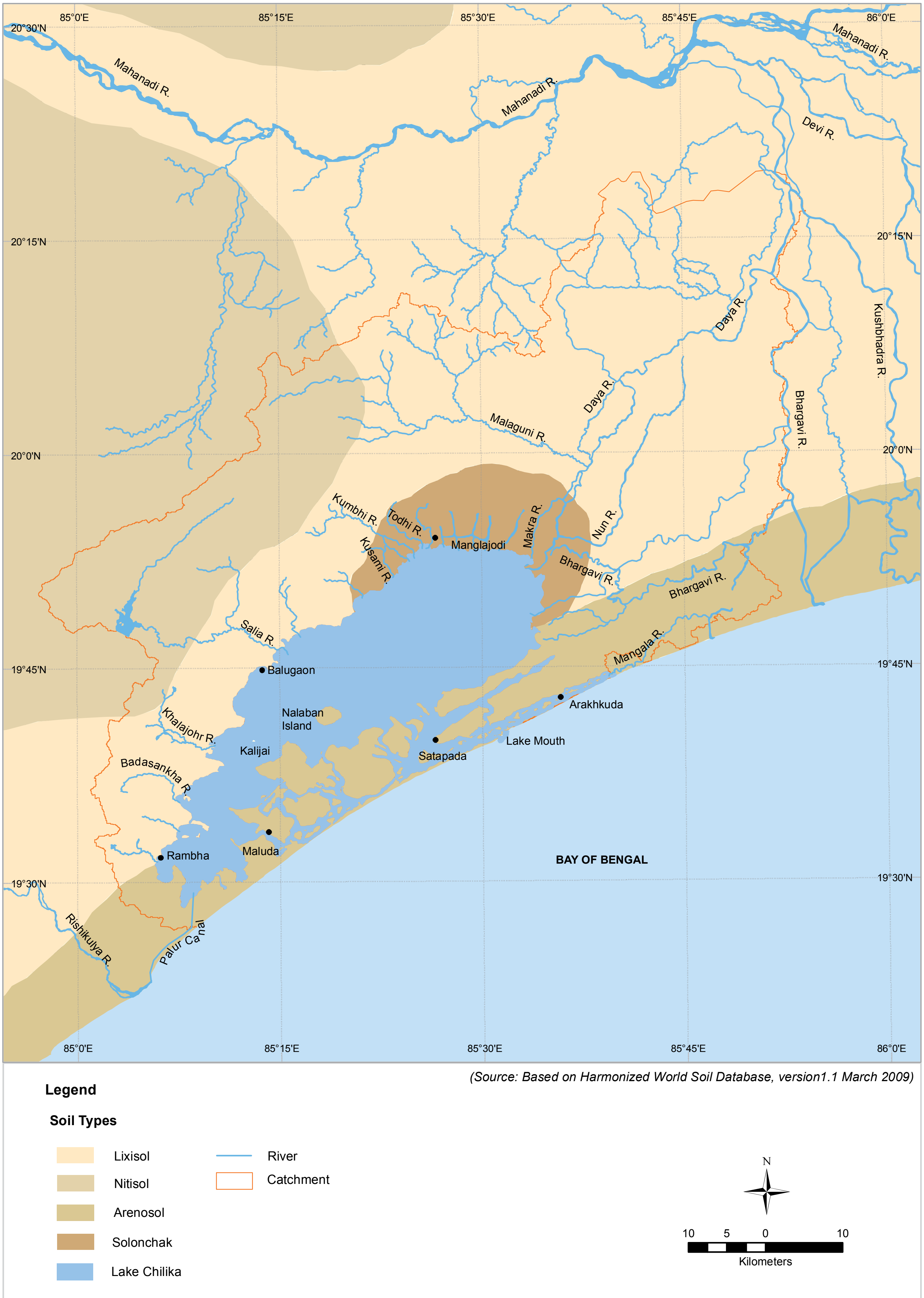
The western phalanges are marked by structural and denudational hills of khondalite, charnockite, gneisses, anorthosite and granite. The hills are followed by lateritic plains. The northern periphery of Chilika is fringed by large tract of alluvial plains extending to more than 400 km^2. This low lying tract has extremely gentle slopes and built by recent sediments. This region is drained by the Mahanadi Delta River and its distributaries Bhargavi, Luna and Makara, which have a swaggering course owing to extremely gentle elevation and sediment deposition. Two distinct shore terraces parallel to the northern shoreline mark the shoreline terraces formed due to continuous deposition and emergence of lagoon floor.

A number of sandy beach ridges are present along the eastern margin separating Chilika from open sea (Map 2). Some of these ridges rise upto 5-6 meters with characteristic swales in between which are occupied by creeks and marshes. The open coast is marked by presence of a prominent spit connected to the mainland at its southern end.

Soils within Chilika can be broadly classified into four major categories based on the Harmonized World Soil Database (Map 3). The hills on the west of Chilika are marked by Nitisols (deep and dark brown clayey soils) whereas the deltaic region has Lixisols (soils with subsurface accumulation of low activity clays and high base saturation). A patch along

Islands along the eastern margin of Chilika

Map 2: Changes in Lake Chilika shoreline



Map 3: Soil types in Lake Chilika catchment

the northern sector has Solonchaks or strongly saline soils. Arenosols or sandy soils with very weak soil development mark the coastal zone of the Chilika.

2.2.2 Mahanadi Basin and Chilika Basin

Lake Chilika forms a part of the Mahanadi River Basin drainage (Map 4). The 858 km long river originates in the Bastar Hills of Chhattisgarh and drains 141,589 km^2 area within the states of Madhya Pradesh, Chattisgarh and Odisha. The river creates a complex arcuate delta beginning at Naraj, dividing into three distributaries, namely Kuakhai, Kathjodi and Birupa. The delta itself is a formation of three sub-deltas formed by Brahmani-Baitarni in the north, Mahanadi River in the centre and Devi in the south.

Based on drainage, the lake basin has been delineated into 6 watersheds, 16 sub-watersheds, 56 mini-watersheds and 218 micro-watersheds (Map 7). Land use assessmentusing remote sensing imageries of 2011 indicates agriculture as most predominant category accounting for 36.3% of the basin area (Table 1). Dense and open deciduous forests follow next accounting for 26.1% of the land use.

The area under forests is majorly confined to the hills of Eastern Ghats located on the crown of the western catchment (Map 8). Lower elevations and alluvial plains are almost exclusively used for intensive agriculture. Rice is the main food crop whereas cashew, the main cash crop grown in Chilika catchments.

Changes in land use have important bearing for ecological character of Chilika. Analysis using remote sensing imageries indicates declining areas under dense forest cover and agriculture and increase in open forests, plantations and settlements (Map 8 and 9). Within Chilika catchment, the forest cover in 1972 was assessed to be 1,255.43 km^2, of which 567.75 km^2 was under dense and 77.55 km^2 open forests. These areas have changed to 287.99 km^2 and 403.99 km^2 respectively. A detailed discussion on land use and land cover change in the lake basin is presented in Box 1.

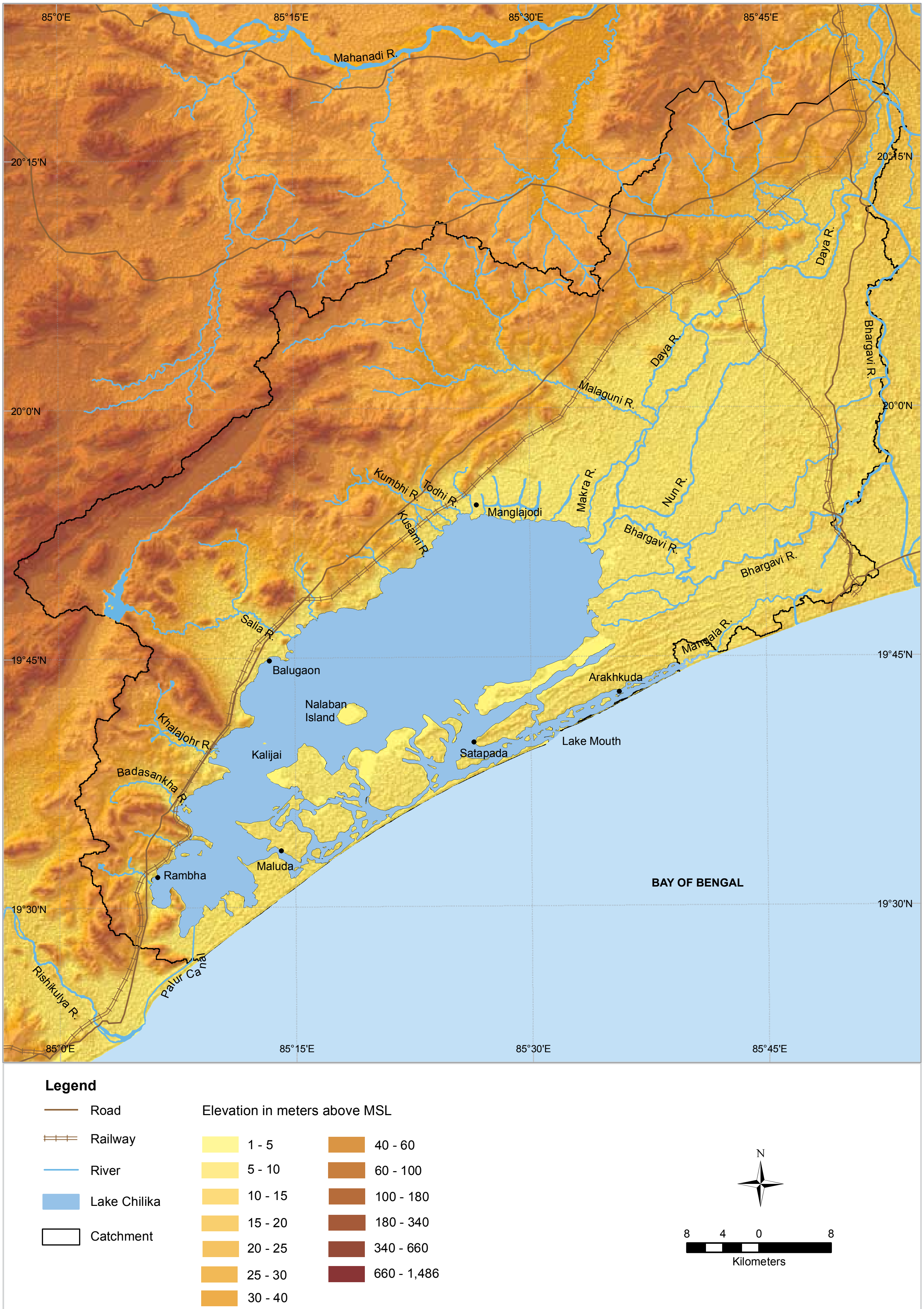
Forests in Chilika catchment

Table 1: Land use pattern within Lake Chilika basin (2011)

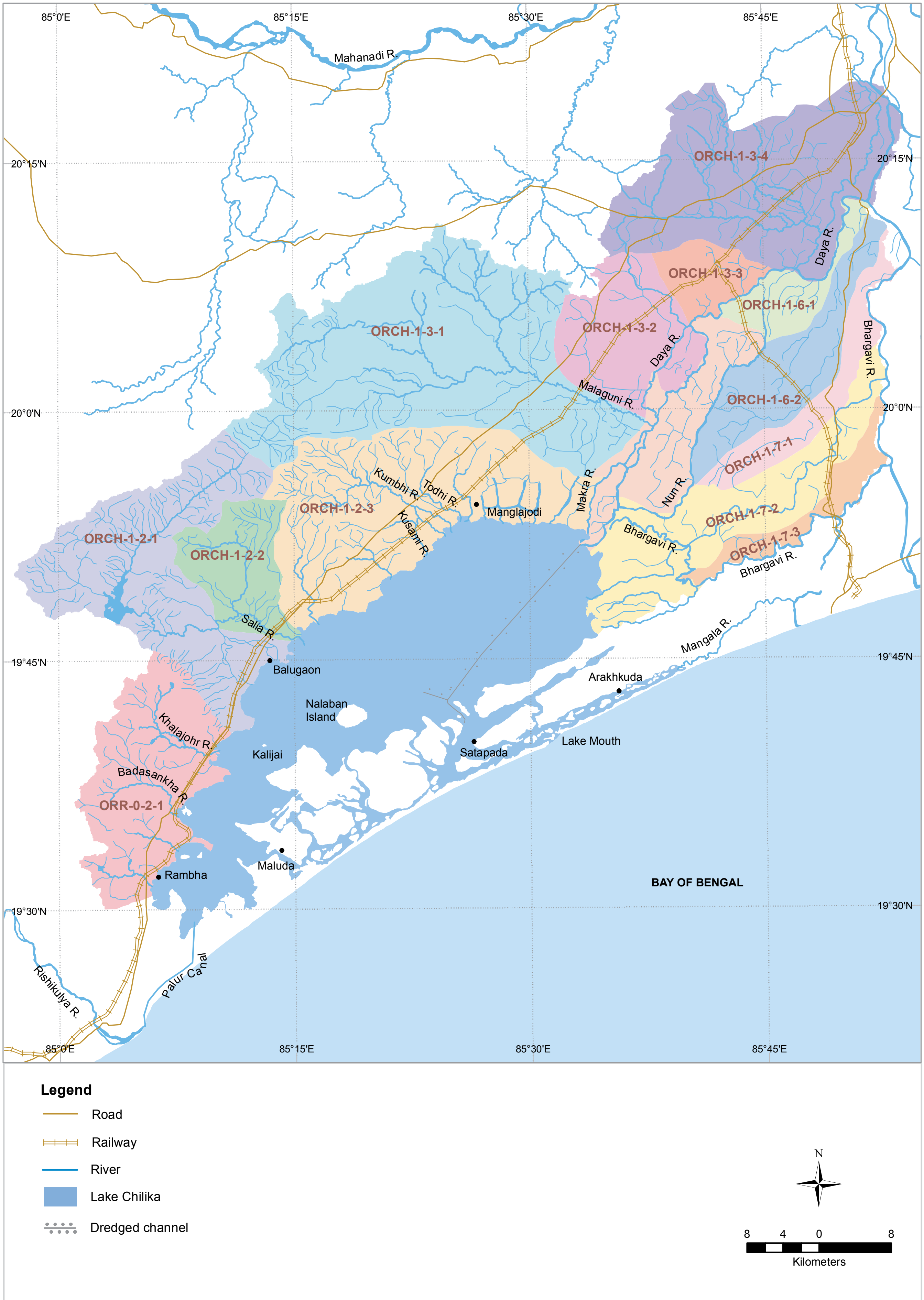
Land use/Land cover categories		Area (km²)	
Settlements			**292.63**
	Rural	179.59	
	Urban	113.04	
Agriculture			**1,761.45**
		1,761.45	
Forests			**1,267.27**
	Dense	287.99	
	Open	403.99	
	Scrub	436.72	
	Plantation	138.57	
Wetlands			**1,526.39**
Chilika			987.20
	Open water	699.08	
	Aquatic vegetation	119.43	
	Marshes	15.45	
	Aquaculture	120.02	
	Sandy areas	33.22	
Within catchments			539.19
	Marshes	97.88	
	Seasonaly flooded agriculture	381.00	
	Rivers and waterbodies	60.31	
Total			**4,847.74**

Map 4: Lake Chilika within Mahanadi River Basin

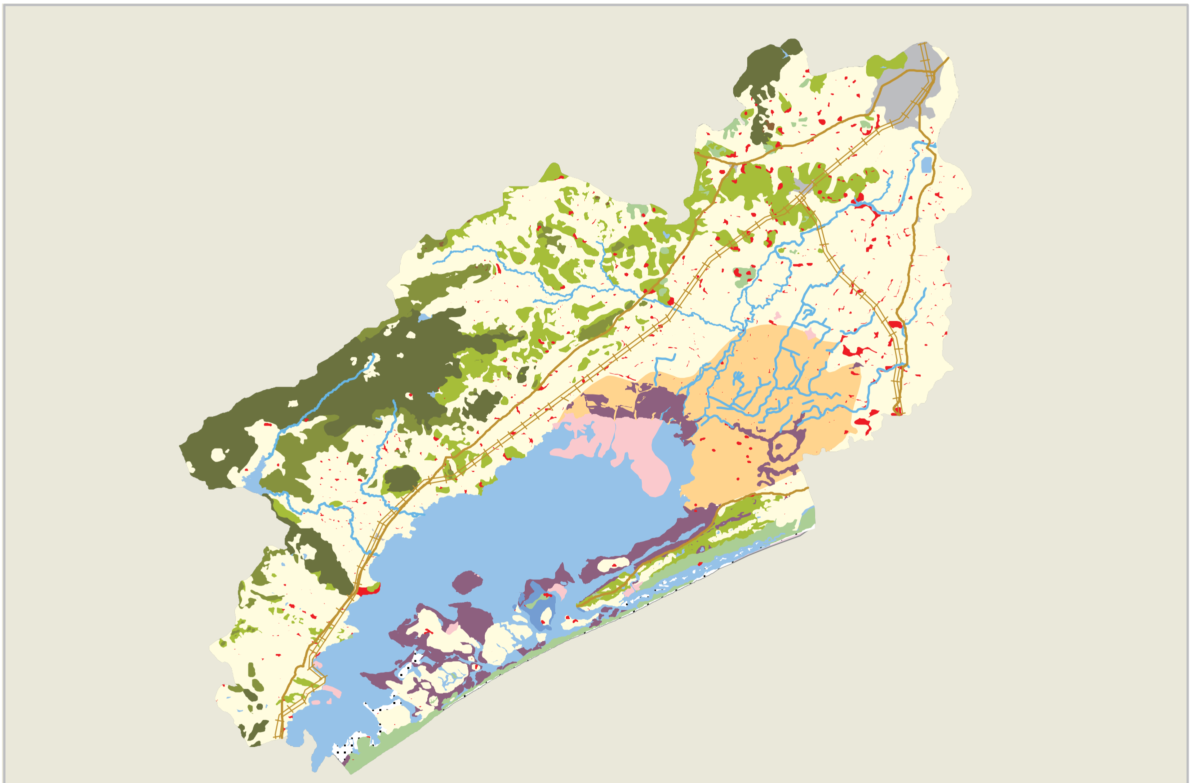
Map 5: Lake Chilika Basin



Map 6: Lake Chilika catchment elevation profile

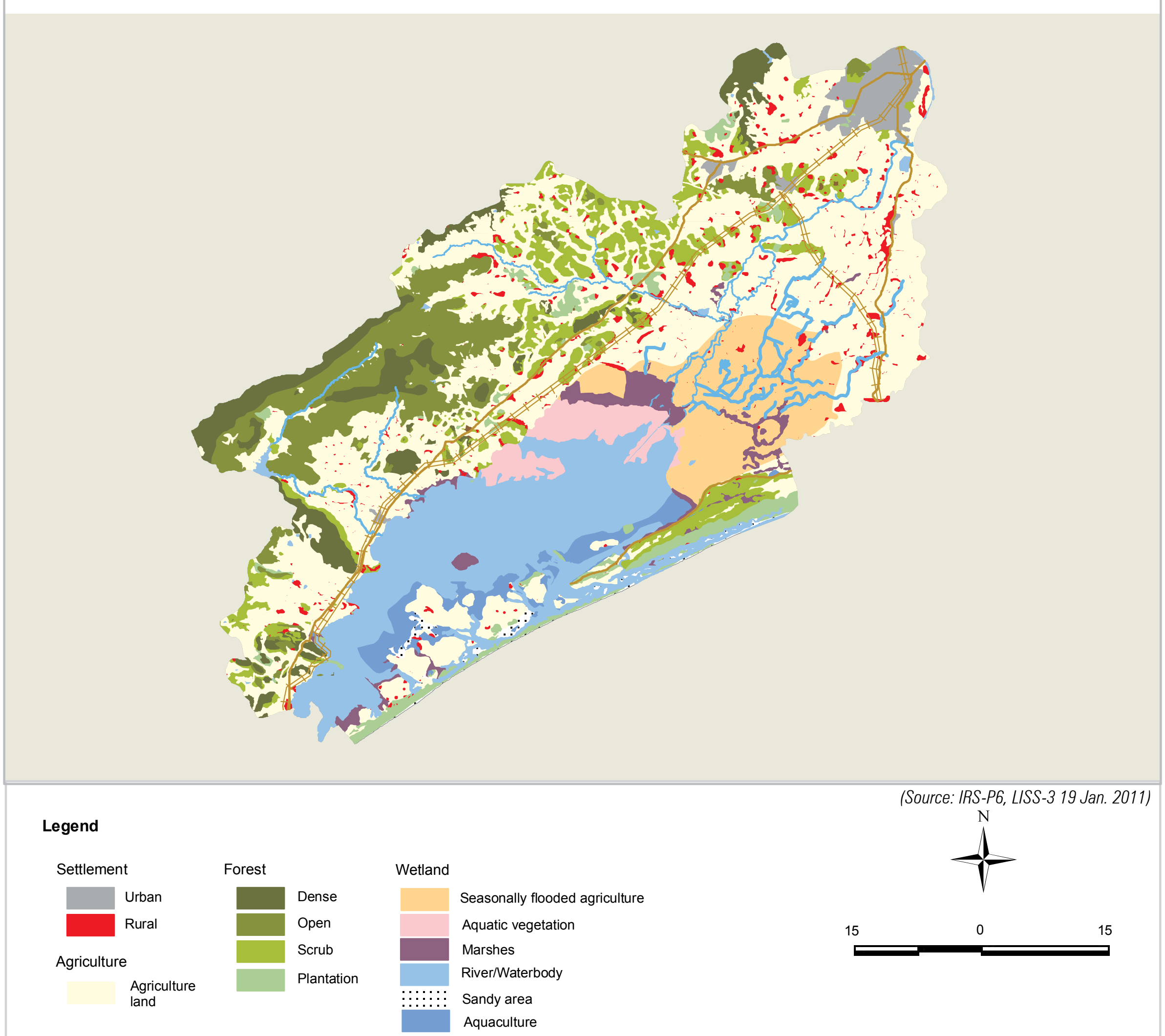


Map 7: Watersheds in Lake Chilika catchment



(Source: Landsat-5 TM 28 Nov. 1990)

Map 8: Landuse of Lake Chilika Basin (1990)



(Source: IRS-P6, LISS-3 19 Jan. 2011)

Map 9: Landuse of Lake Chilika Basin (2011)

Box 1: Land use and Land cover change in Lake Chilika Basin

Changes in land use and land cover have significant implications for maintenance of ecological character of wetlands within the landscape. For Lake Chilika Basin, this change has been assessed based on available remote sensing information. The base layers have been developed from Survey of India topographical maps. The change analysis has been done over a period of four decades. The images used for analysis pertain to 1972 (Landsat-1 MSS digital image of 7 November, 60 m spatial resolution), 1990 (Landsat-5 TM digital image of 28 November, 30 m spatial resolution) and 2011 (IRS P6 LISS-3 digital image of 19 January, 23.5 m spatial resolution). These have been digitally enhanced in ERDAS Imagine for interpretation. Along with these images, few other images from other seasons during nearby years have also been referred for validation of interpreted layers. During interpretation of 1972 image the SOI topographical maps have been referred for field level validations as they have been developed based survey during 1970-71. The digital cum visual interpretation techniques have been used in this mapping coupled with limited field verification, which ensures supervised classification as the interpreter holds the experience of field visit.

The overall trends discerned for various land use categories is presented in Table below. The land use change matrix includes only significant and logical changes that could be derived from GIS analysis.

The change matrix indicates significant changes in forests and agriculture lands. During the last four decades, dense forests areas have been majorly converted into open forests. Agricultural lands have been converted mainly for settlements (147.79 km^2) and aquaculture (13.28 km^2). Available statistics on agriculture indicate a general trend in intensification as indicated by increase in area under irrigation, chemical fertilizer use and crop productivity.The overall consumption of chemical fertilizers within the districts of Cuttack, Khurda and Puri increased from 27.16 thousand MT to 43.02 thousand MT during 2000-01 to 2005-06.There has also been a near simultaneous increase in area under irrigation (from 310,000 ha to 464,000 ha) and agricultural productivity of major food-grains[1] (from 1.19 MT/ha to 1.46 MT/ha) during the same period.

There has been a significant increase in area under settlements. As per the population statistics derived from Census of India (2001), the lake basin is inhabited by 2.58 million people, of which 37% is urban. There are presently 8 major urban centers within the lake basin. The population density of the lake basin has increased from 375 to 559 persons per km^2 during 1971-2001, as compared to 140-236 persons per km^2 for the State of Odisha.

Within Chilika Lake, there has been an increase in area under aquatic vegetation as well as aquaculture. A transformation of areas under seasonally flooded agriculture to marshes is also indicated in the analysis.

Land use/Land cover change in Lake Chilika basin

Land use/Land Cover Categories		Area (km^2)		
		Year 1972	Year 1990	Year 2011
Settlements		172.02	204.78	292.63
	Rural	135.94	131.01	179.59
	Urban	36.08	73.77	113.04
Agriculture		1,918.14	2,006.86	1,761.45
		1,918.14	2,006.86	1,761.45
Forests		1,255.43	1,099.46	1,267.27
	Dense	567.75	417.91	287.99
	Open	77.55	159.04	403.99
	Scrub	534.56	422.59	436.72
	Plantation	75.57	99.92	138.57
Wetlands		1,502.15	1,536.64	1,526.39
Chilika		912.96	918.62	987.20
	Open water	829.84	778.17	699.08
	Aquatic vegetation	27.57	77.82	119.43
	Marshes	14.72	23.59	15.45
	Aquaculture	-	11.68	120.02
	Sandy areas	40.83	27.36	33.22
Within catchments		589.19	618.02	539.19
	Marshes	116.24	121.86	97.88
	Seasonaly flooded agriculture	413.86	413.56	381.00
	Rivers and waterbodies	59.09	82.60	60.31
		4,847.74	**4,847.74**	**4,847.74**

1 Includes rice, wheat, maize, jowar, bajra, ragi, small millets and pulses.

Land use/Land cover change matrix (1972-2011)

CHANGE TO (rows) / CHANGE FROM (columns)

Land Use / Land Cover Categories	Forest				Settlement			Wetlands							
								Chilika					Catchment		
	Dense	Open	Scurb	Plantation	Urban	Rural	Agriculture	Open water	Aquatic vegetation	Marshes	Sandy area	Aquaculture	Marshes	Seasonally flooded agrculture	Rivers and waterbodies
Forest															
Dense															
Open	379.54		26.78												
Scurb	12.39	22.61					57.84								
Plantation			48.23								16.45				
Settlement															
Urban			21.44			14.09	37.89								
Rural			25.46				109.90								
Agricuture	16.02		138.02												
Wetlands															
Chilika															
Open water									22.42						
Aquatic vegetation								107.29							
Marshes														33.81	
Sandy area															
Aquaculture							13.28	43.32		58.95					
Catchment															
Marshes							21.10								
Seasonally flooded agrculture															
Rivers and waterbodies															

2.2.3 Hydrological regimes

Hydrological regimes of Chilika are influenced by river basin as well as coastal processes. These are monitored since 1999 through a network of 47 stations (Map 10) and an additional 30 water quality monitoring stations. The description of water regimes presented in this section of the report is based on analysis of data from the monitoring stations and also includes outcomes of hydrological assessments carried by various agencies.

Water inflows and outflows

Water inflows into Chilika include freshwater from the Mahanadi and western catchment system, sea-water through the mouths and Palur Canal at the southern tip of the lake.

Mahanadi River is a key source of freshwater to Lake Chilika. Mahanadi River flows undivided till the delta apex at Naraj. Subsequently it bifurcates into three major tributaries, Kuakhai, Kathjodi and Birupa, alongwith the main Mahanadi river channel. Daya and Bhargavi Rivers, which are distributaries of Kuakhai bring the Mahanadi flows to Chilika. The entry bed level of Kuakhai being higher than Kathjodi River, a flow of around 2,830 m^3/s in the undivided Mahanadi River is required before water begins to flow to Lake Chilika. In addition to the river flows, Chilika also receives runoff and irrigation drainage from the delta region (2,250 km^2).

The major bifurcations of the delta rivers and the approximate high flow distribution between the delta distributaries is shown in Fig. 2. During high flows the Daya and Bhargavi rivers together can carry

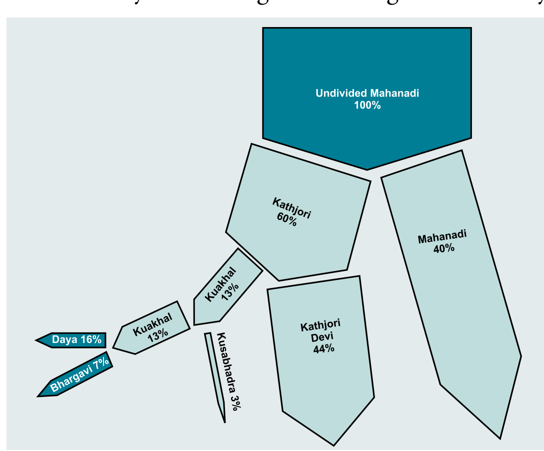
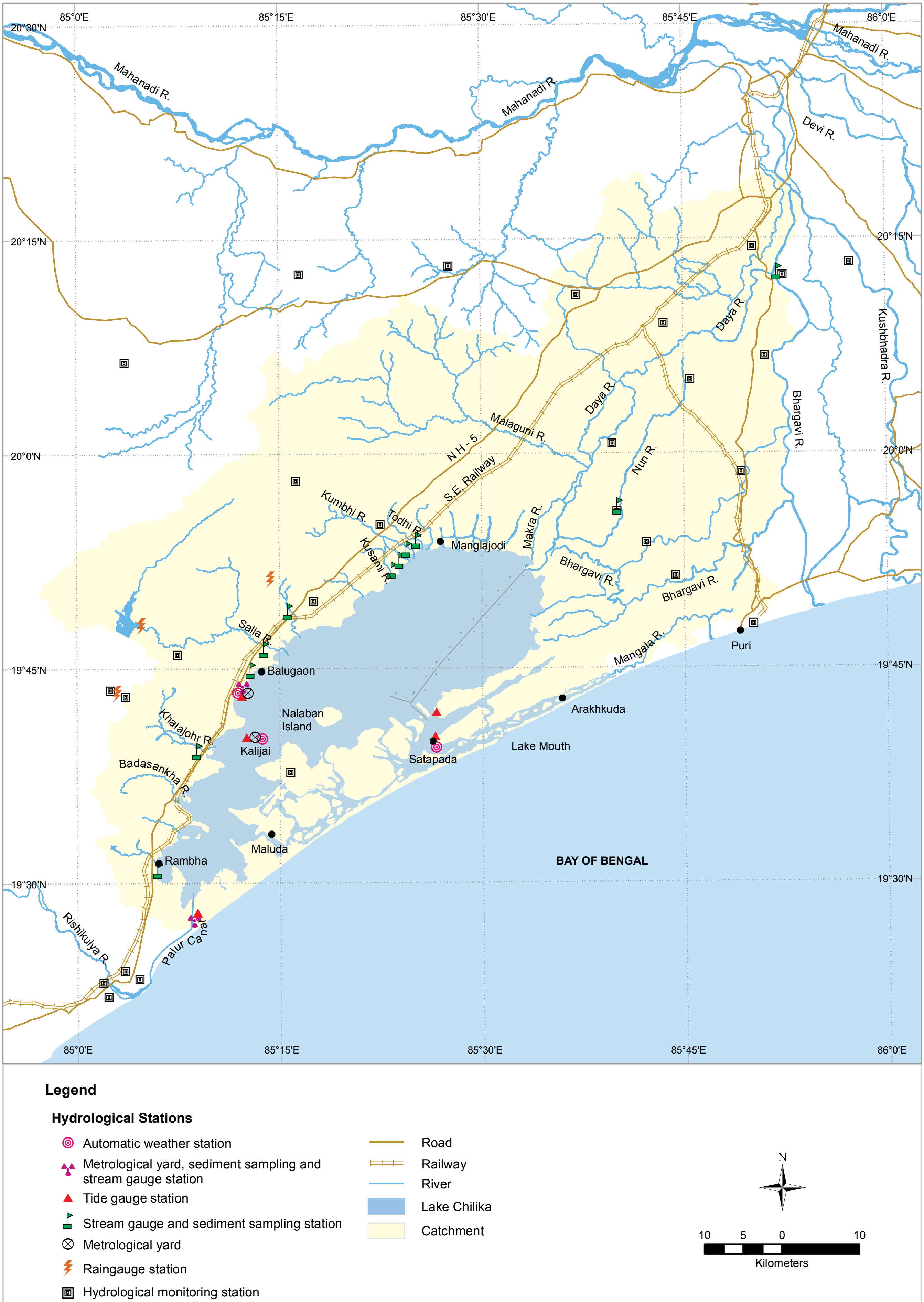


Fig. 2: Flow distribution in Mahanadi delta



Map 10: Hydrological monitoring stations within Lake Chilika catchment

about 13% of the undivided Mahanadi flow to Lake Chilika; overall however, Lake Chilika only receives less than 6% of the undivided Mahanadi flow. The distributions of flows vary with flood magnitude and are determined by bed levels and bed slopes.

Flows from western catchments are from 8 major streams, Badaghati, Badanai, Badasankha, Kansari, Kusumi, Mangalajodi, Salia and Tarimi. These streams mostly carry the monsoon runoff from a highly gullied and ravenous catchment with marginal forest cover (Fig. 3).

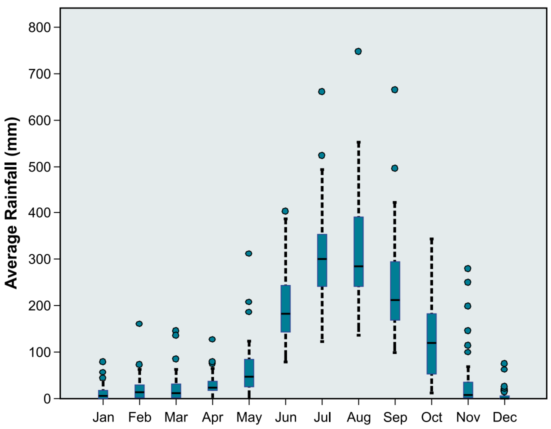


Fig. 3 : Average monthly rainfall in Lake Chilika basin (1951-2007)
(Data source : Indian Meteorological Department)

The annual freshwater flows into Lake Chilika from the river systems, based on average for 1999-2010[2], was 4,906 MCM Mahanadi Delta river system contributed 75% of the freshwater inflows and the rest by the western catchments (Fig. 4a, b, c).

The overall hydrological regimes of Chilika Basin have been highly fragmented through construction of hydraulic structures for various purposes. Hirakud Dam at Sambalpur, constructed in 1957 controls flows from 83,500 km^2 catchment area of Mahanadi River and thereby has a significant influence on the overall fluvial regimes (Map 11). Downstream at the head of the Delta, wiers and barrages have been constructed on all tributaries. The most significant of these in the context of Lake Chilika is the Naraj Barrage which has a potential to regulate the freshwater flows to the downstream reaches. The design objectives of the barrage includes ensuring continuity to irrigation in Delta Stage I irrigation area (167,000 ha) and improve flood protection in Delta Stage II irrigation area (160,000 ha).

Additionally, the delta rivers have also been embanked extensively. The Mahanadi delta command area presently has 1038.10 km capital embankment and 403.19 km of other agriculture embankments.

Sedimentation

Wetlands being depositional environment often tend to act as sediment traps which in the long run play a key role in their succession. However, enhanced rates of sedimentation would accelerate this process, and thereby risks sustenance of ecosystem processes and services.

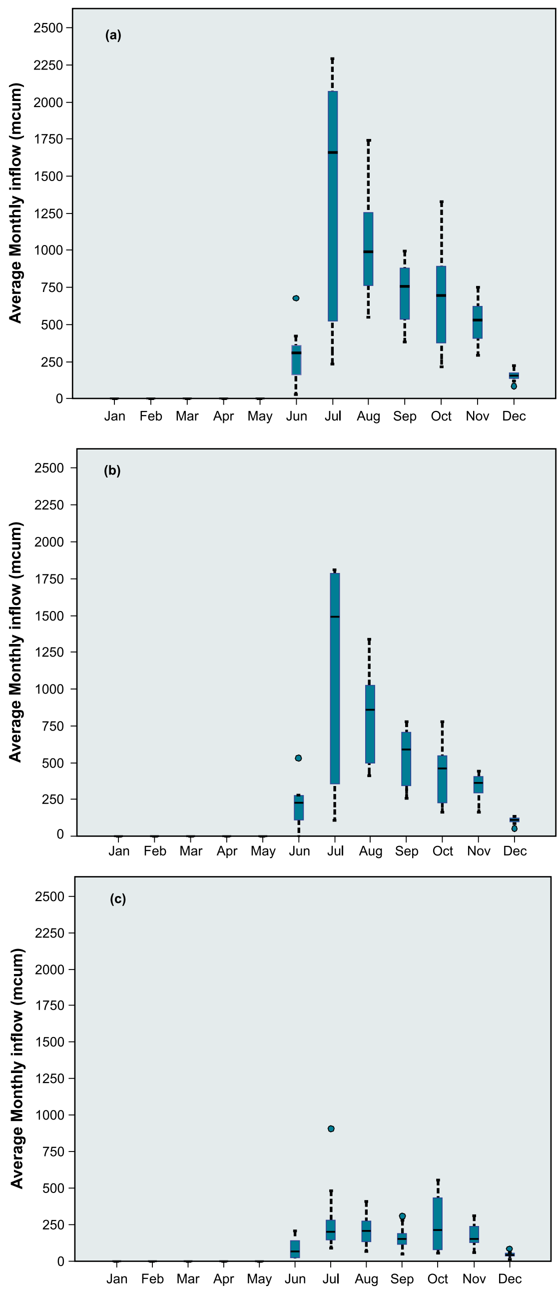
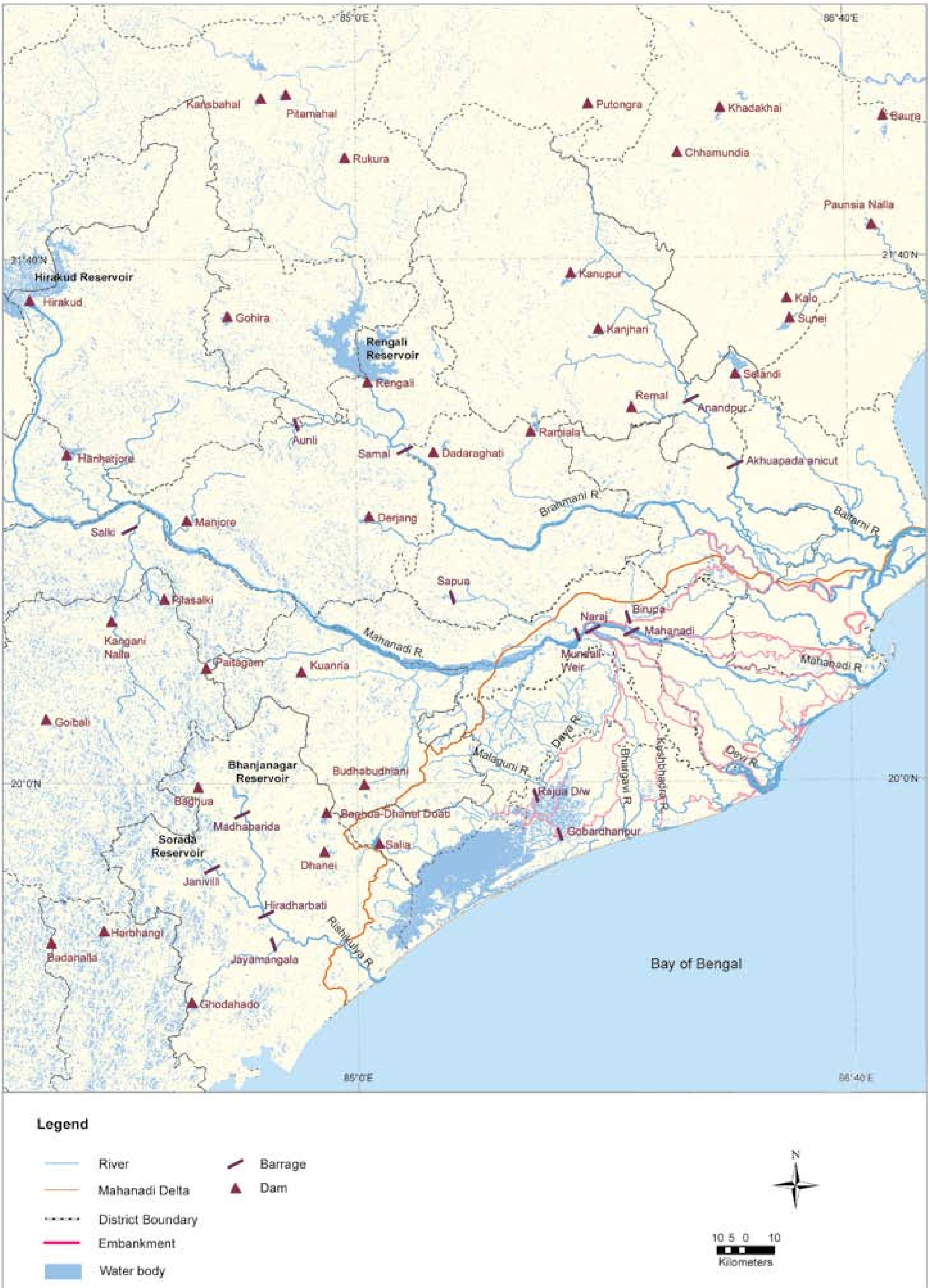


Fig. 4 : Average monthly inflow (1999-2010). (a) In Lake Chilika, (b) From Mahanadi Delta, (c) From western catchment (Data source: CDA Monitoring Records)

[2] The average has been strongly influenced by a single peak value of 7,770 MCM inflow from Mahanadi in 2001. Excluding this value, the average inflow is 4,297 MCM. The proportion contribution from the two systems however remain unchanged.



Map 11: Hydraulic structures in Mahanadi delta

Lake Chilika is subject to sedimentation from its extensive catchments as well from the sea. The extent and rates of sedimentation have been reported variously by different investigators. Pattnaik (1998), based on 1996-97 data indicate an annual sediment loading of 1.8 MT. Assessments based on modelling of 31 years flow data (carried as a part of the Environmental Flows Assessment) indicate an average annual loading of 2.35 MT of which 2.13 MT is from Mahanadi River alone (World Bank, 2004). Data for 1999-2010 indicates an average annual sediment loading of 1 million MT, of which Mahanadi system contributes 75%.

Naraj Barrage at the apex of Mahanadi delta

Sediment coring of the lake bed confirms that the lake is filling with sediment (CWRDM, 2004, 2005). The coring suggests that sedimentation is now 3-5 times as fast as 100 years ago at the margins of the northern and southern sectors, and 30% higher at the margins of the central sector. This implies that flushing of sediment from the central sector through the mouth is reasonably efficient, but that sediment transport into the central sector from the northern and southern sectors is not efficient. Young (2004) based on analysis of the coring data assess the current sedimentation rates to be 1.8 and 1.4 cm/yr at single coring locations in the northern and southern sectors respectively. Total depths of sedimentation at these locations are estimated to be 85 and 49 cm respectively, with most of this having occurred post-1950. However, these locations are very close to river exits and are likely to represent the most extreme values of sedimentation in the lake. As a comparison, the estimated sediment loads to Chilika translate to a sedimentation rate of around 0.7 cm/yr averaged across the entire lake area assuming no sediment flushing from the lake.

These rates suggest that without intervention the lake would continue to shrink in volume and area, with much of the northern and southern sectors potentially filled with sediment within 100 years. Dean and Saaltink (1991) show that by the early 1990s the area of Chilika had reduced by around 15% relative to the area surveyed in 1914.

In 2000, a channel was dredged from Mugarmukh to the mouth of the Daya River. This has already been observed to greatly enhance sediment flushing from the northern sector. Periodic dredging is done to maintain this channel.

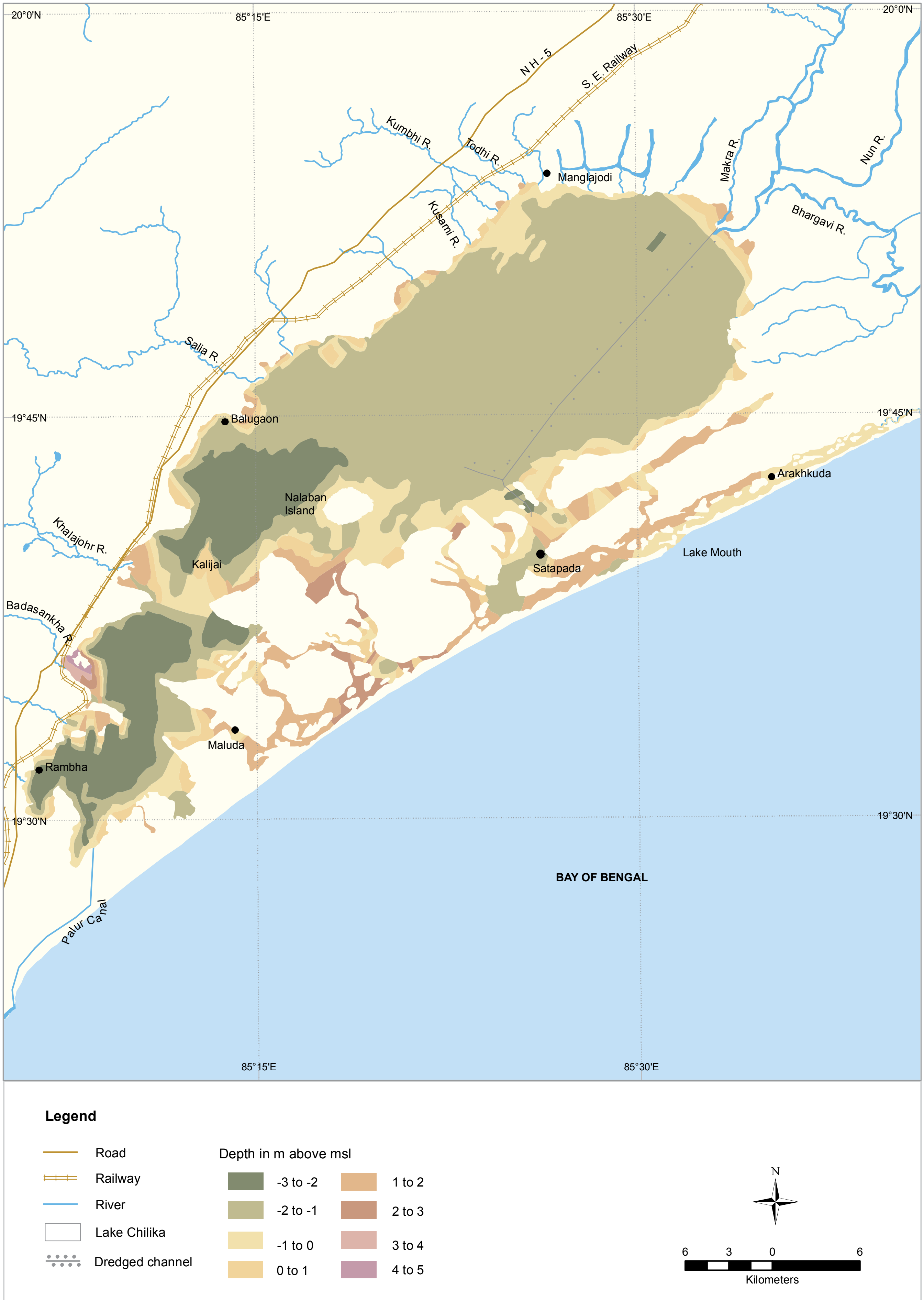
The entrainment of Delta Rivers has led to progressive aggradation of the river beds and a gradual reduction in the channel capacities. The in-channel sediment deposits in the Daya and Bhargavi rivers (and to a lesser extent the upper Kuakhai and upper Kathjori rivers) are likely to be periodically re-entrained and act as a sediment source to Lake Chilika. Without the existing distributary embankments, these sediments would of course have been deposited across the floodplain.

Understanding of the sediment exchange with the sea is further limited. For the year 2007, the total sediment discharged to the sea through the mouth was estimated as 0.13 million MT. Further assessments are required to determine the extent and pattern of sedimentation from the sea. CDA has put in place a detailed assessment of coastal processes in 2011 which is likely to address these data gaps.

Lake Bathymetry

Bathymetry is one of the key physical indicators that determine the ability of wetland system to influence hydrological processes and determine related biophysical parameters. The bathymetry of the entire lagoon was carried out in the year 2007-08 by employing echo-sounder and GIS (Map 12).

Analysis indicates that the southern sector of Chilika is significantly deeper than the northern and central sectors. The water holding capacity of the wetland, computed using Digital Elevation Model



Map 12: Lake Chilika Bathymetry

was estimated to be 1206.89 MCM at a maximum surface area of 987.796 km^2.

Analysis of the lake levels indicate that Chilika provides a huge storage capacity downstream of Mahanadi system, and thereby flood protection to upstream regions. The water levels at outer channel are usually lower than the mean sea level from January-April, with Kalijai being marginally above sea level (0.2 m amsl). With the onset of monsoon, the levels increase to nearly 0.6 m amsl (1 m amsl at Kalijai) gradually receding to the pre-monsoon levels during August-December. The levels dip below mean sea level in December (except at Kalijai) (Fig. 5).

Coastal processes

The connectivity of Chilika with sea gives it a brackish characteristics, as well as provides a medium of exchange of species, sediments and nutrients. The entire Odisha coastline has experienced complex geologic processes combined with natural factors like littoral currents, severe cyclones, storms, wave action, flood and wind since long, giving rise to various erosional as well as depositional landforms compounding shoreline changes.

Data on littoral drift indicates that the longshore sediment transport is northwards throughout the year (Chandramohan and Nayak, 1994). This is one of the factors leading to creation of a narrow channel on the north-eastern margins of the lake. High annual littoral sediment drift (1.2 MCM) causes the sea inlet to continually shift northwards leading to development of a long narrow channel running parallel to the coast. The inlet condition is rendered unstable due to reduction in tidal prism with increasing length of the channel.

There is a long history of shifting of inlet of the lake as well as changing depth, size and shape. The width of the inlet has been reported to be 1.6 km in 1780 which reduced to 60 m in 1907. The inlet was located 6 km northeast of Arkhakuda in 1914, which subsequently shifted to 8 km northeast in 1965. Tripati and Vora (2005) based on assessment of landsat imageries report that the lake had three inlets in 1975, two in 1985 and one since 1986. This northward migration of the channel has been irregularly interrupted by major monsoon outflows or cyclones that re-opened the mouth closer to the entrance channel, for example opening of a natural mouth at Gabakunda due to strong tidal action in August 2008. It is highly likely that the lake goes through periodic cycles of shifting towards a freshwater state with gradual choking of the inlet, which is subsequently restored to high salinity conditions once the mouth is opened.

The hydrological intervention of 2000 has led to marked improvement in the overall tidal regime. CDA has established tide gauging stations at Sipakuda, Satapada and Magarmukh in Chilika lagoon. The tidal variations have been recorded on an hourly basis for the whole year. Analysis of monthly tidal variation data at Satpada indicates an increase from 0.36 m in 1999-2000 to 0.56 m in 2000-01 and 0.80 m in 2006-07.

Maintaining the lake-sea connectivity poses a tremendous challenge due to high annual littoral sediment drift and the Bay being a net contributor of sediments into Chilika. An assessment of outflow velocities indicate that the lake outflows would never be sufficient enough to combat the littoral drift. Thus lake management would have to factor in solutions for maintenance of the lake-sea connectivity through a mix of approaches including management of catchments and engineering solutions for mouth stabilization and even periodic opening of new mouths. The coastal process assessment, being currently carried out on the entire sediment shelf of Mahanadi Delta coast is likely to throw better insights into these processes.

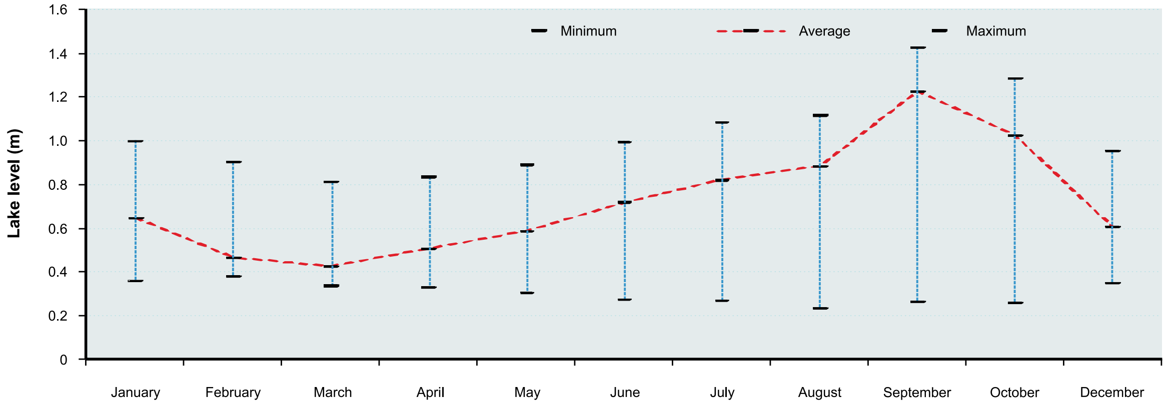


Fig. 5: Lake levels at Satpada (2011)
(Data source: CDA Monitoring Records)

Chilika mouth connects the Lake to Bay of Bengal

Water Quality

Monitoring of Lake Chilika water quality is done at 30 sampling stations representative of its four zones (Map 13). In addition, several independent research studies have also been carried out, which give a useful indication of the trends in water quality within the wetland system.

Water quality of Lake Chilika in general is warm, alkaline, well oxygenated, turbid, brackish and nutrient rich. The lake water quality is conducive for aquatic life. However, seasonal and sectoral fluctuations are observed owing to connectivity with catchments and sea, evaporation and wind action. The water quality parameters have shown marked improvements since the hydrological intervention of 2000, most noticeable being restoration of the salinity gradient.

pH

pH is one of the important characteristics known to regulate the life processes and nutrient availability in an aquatic system. It also maintains the carbonate and bicarbonate buffering system and plays a significant role in the survival and growth of aquatic plants (Sculthrope, 1967).

Lake Chilika water remains alkaline throughout the year (Map 14) which is particularly conducive for fish and several other forms of aquatic life (Swingle, 1967). Analysis of water quality sample data of 2002-2011 indicates that pH values range from 8 to 10.3, except in the outer channel and macrophyte infested areas in northern sector wherein lower values (ranging from 7.5-8) were observed (Table 2). During monsoon, the pH in the outer channel increases slightly to 8-8.5, whereas entire northern sector has lower pH values of 7.5-8. In post monsoon, central sector is highly alkaline with values ranging between 8.5-9.5.

Temperature

Lake Chilika, being a shallow aquatic system does not exhibit a high range of horizontal and spatial difference in temperature. Seasonally, surface temperatures are the lowest in winter (November-January). The average water temperature of the lake ranges from 28.1-29.2°C during 2002-2011 (Table 3).

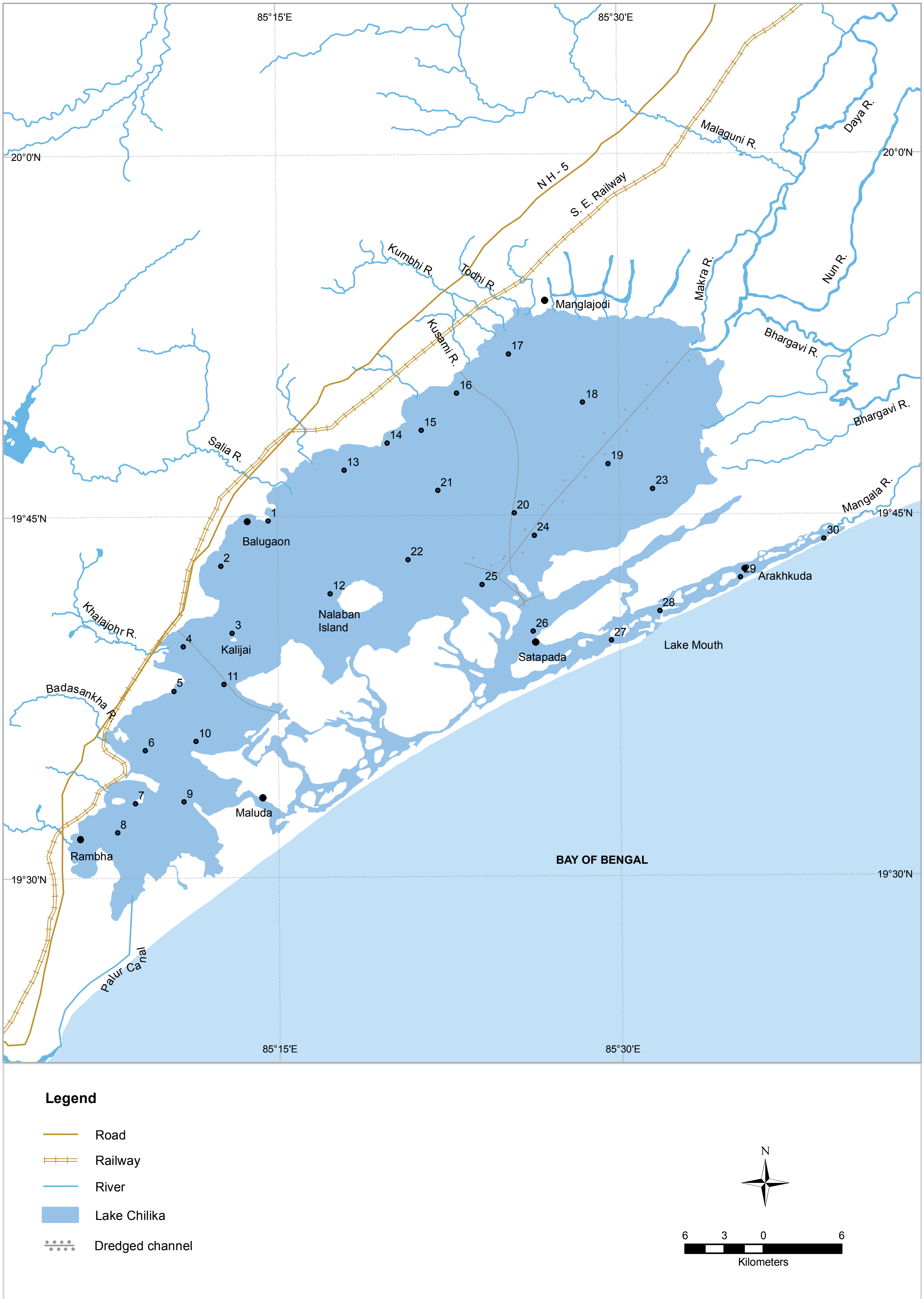
Dissolved Oxygen

Dissolve oxygen (DO) is an indicator of ecosystem health and provides conditions conducive for effective metabolism of all aerobic aquatic organisms (Banerjee *et al.,* 1998). The photosynthetic release, de-nitrification process of bacteria and wind action are known to influence the change in DO concentration. Fish do not feed or grow well when DO remains continuously below 4 or 5 ppm (Boyd, 1982). DO affects the aquatic life and the capacity of water to receive organic matters without causing adverse impacts (Wetzel, 1990).

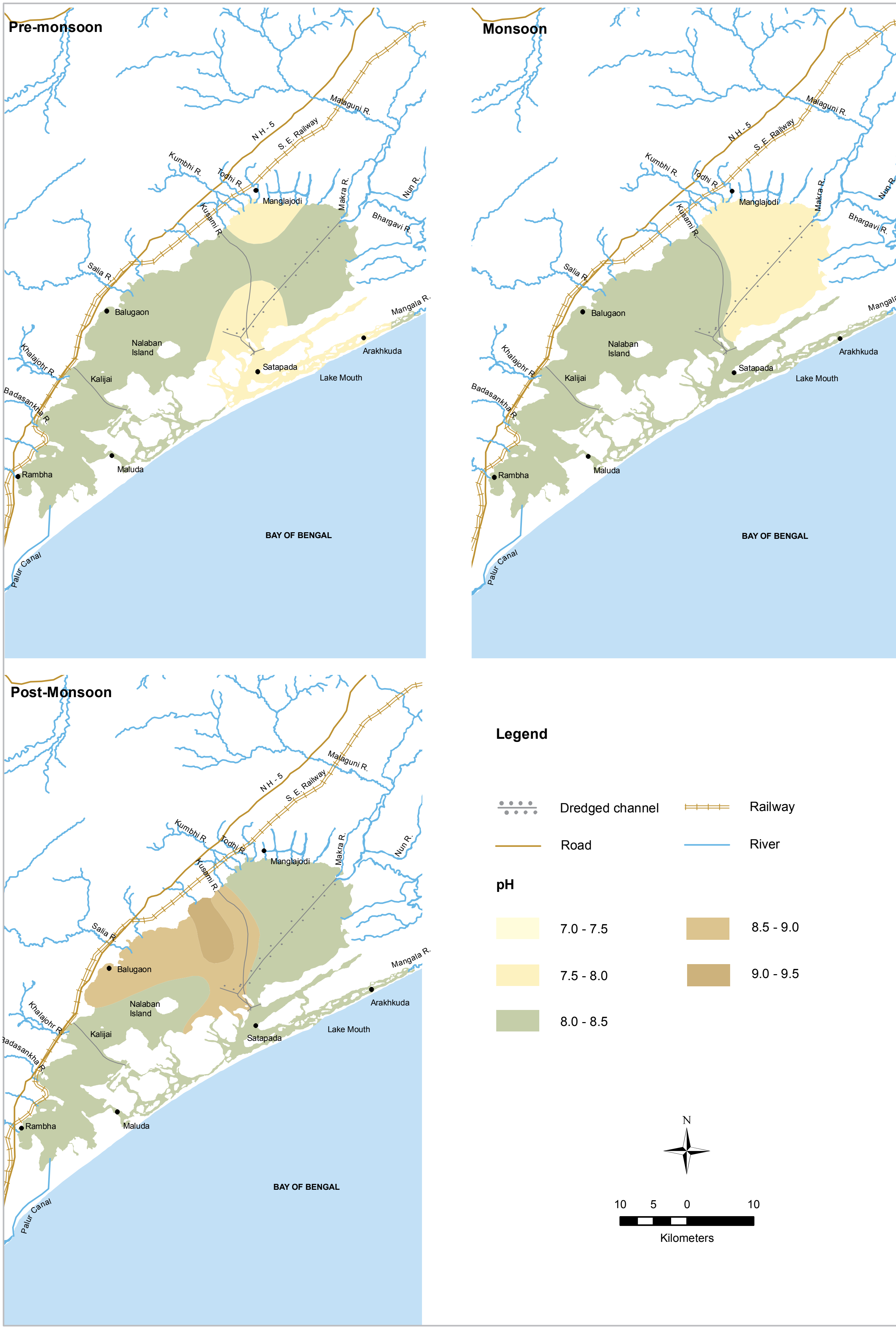
Chilika, in general, is well oxygenated throughout the year due to its large size, high photosynthetic activity and wind churning effects.

The DO content in the lake ranges between 5-9 ppm, expect for the northern sector areas under macrophyte infestation where low values of 1-3 ppm

Automatic weather station at Kalijai



Map 13: Water quality monitoring stations



Map 14: Trend in pH of Lake Chilika (2002-2011)

Table 2: Average pH of Lake Chilika (2002-2011)

Year	Range	Lake Average	Premonsoon				Monsoon				Post Monsoon			
			CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC
2002-03	6.7-10.0	8.2	8.2	8.3	8.0	8.1	8.0	8.2	7.8	8.2	8.7	8.5	8.6	8.2
2003-04	7.0-10.0	8.3	8.4	8.4	8.4	8.4	8.2	8.3	8.3	8.3	8.7	8.3	8.7	8.0
2004-05	6.7-9.9	8.3	8.2	8.2	7.8	7.8	8.3	8.2	8.3	8.2	8.8	8.4	8.7	8.3
2005-06	6.6-9.9	8.3	8.2	8.1	7.9	7.8	8.1	8.3	8.1	8.2	8.5	8.8	8.8	8.5
2006-07	7.3-10.1	8.3	8.3	8.4	8.4	8.2	8.2	8.2	8.1	8.0	8.4	8.4	8.5	8.3
2007-08	6.8-9.7	8.2	8.2	8.3	8.2	8.1	8.0	7.9	8.0	8.0	8.5	8.3	8.6	8.3
2008-09	7.2-9.2	8.2	8.4	8.2	8.2	8.0	8.3	8.1	8.1	7.9	8.5	8.2	8.6	8.2
2009-10	6.8-10.0	8.1	8.2	8.1	8.0	7.9	8.1	8.0	7.6	8.0	8.7	8.3	8.4	8.3
2010-11	7.2-10.1	8.5	8.6	8.8	8.5	8.6	8.2	8.3	8.4	8.3	8.6	8.4	8.9	8.5

Table 3: Average surface water temperature of Lake Chilika (in °C, 2002-2011)

Year	Range	Lake Average	Premonsoon				Monsoon				Post Monsoon			
			CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC
2002-03	22.8- 33.5	29.2	29.9	30.9	30.4	30.2	30.0	30.6	29.7	30.5	24.6	24.9	25.3	26.0
2003-04	21.3- 34.6	28.4	29.9	30.6	30.1	29.7	30.2	30.2	30.4	31.0	24.8	25.4	25.3	26.0
2004-05	22.0-33.8	28.6	29.6	30.2	30.2	29.5	29.8	30.0	29.8	30.1	25.5	26.2	25.6	26.6
2005-06	18.9-33.0	28.1	29.7	30.3	29.9	30.7	29.5	30.2	29.3	30.3	24.2	25.6	23.3	24.9
2006-07	22.3-34.8	28.3	29.7	29.9	30.1	30.0	29.8	30.6	29.1	29.8	24.9	25.9	24.6	25.6
2007-08	20.1-35.2	28.2	30.0	30.6	30.2	30.2	30.0	30.4	29.5	30.3	24.1	25.3	24.0	24.6
2008-09	22.1-33.2	28.5	29.7	30.1	29.9	29.9	29.5	30.6	29.3	29.5	25.7	26.6	25.5	26.7
2009-10	20.6-33.8	28.7	29.9	30.9	29.3	30.9	29.8	30.7	29.7	30.6	25.7	26.4	25.3	26.9
2010-11	20.5-35.9	28.7	29.5	30.4	29.4	29.7	30.9	31.5	31.8	31.5	23.6	24.1	23.2	24.5

CS - Central Sector • SS - Southern Sector • NS - Northern Sector • OC - Outer Channel
(Data source: CDA Monitoring Records)

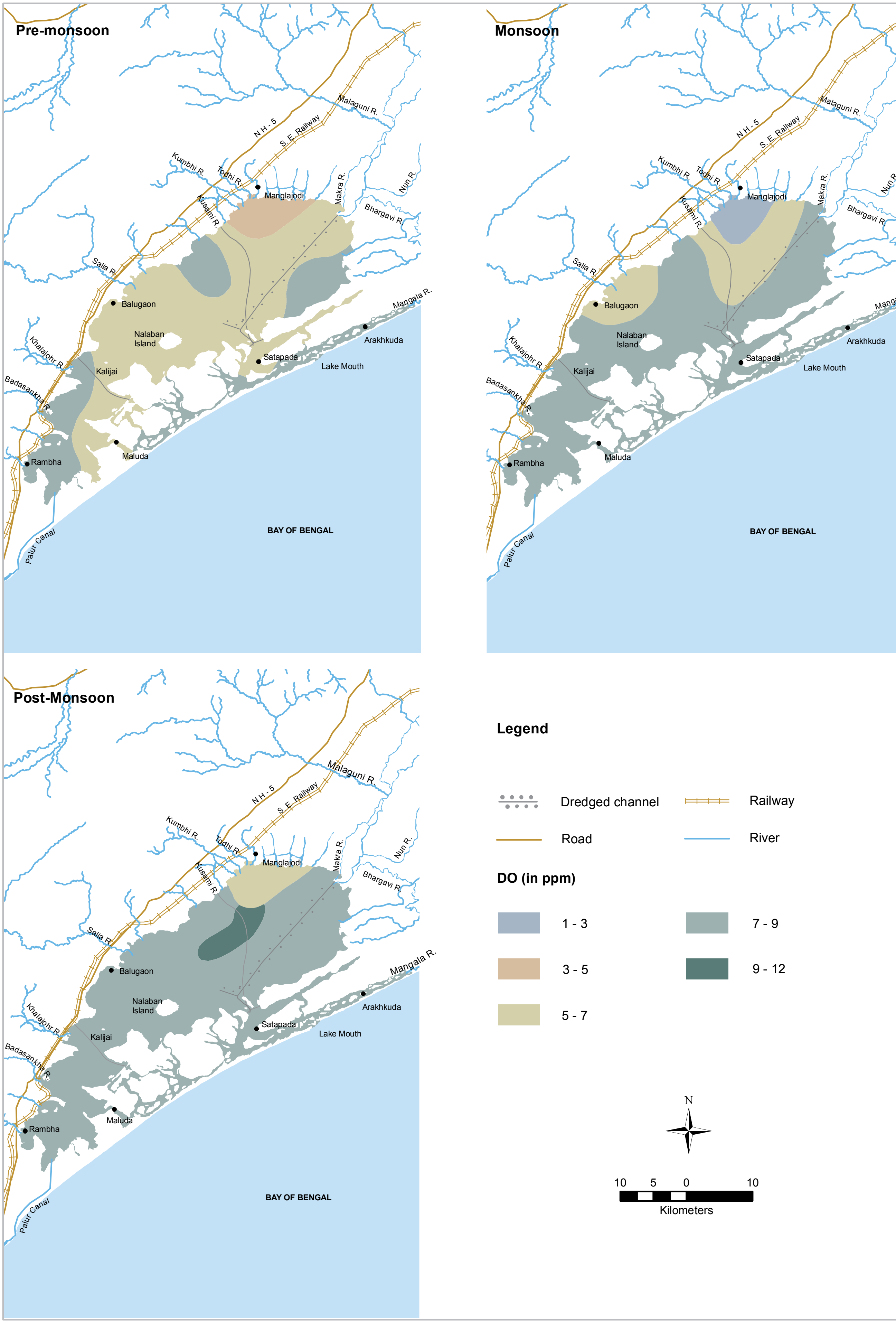
were observed (Table 4, Map 15). During summer, DO in all sectors ranged from 5-7 ppm except for the outer channel and certain isolated pockets in central northern and southern sectors. Low DO levels during summer is attributed to higher water temperature, low depth of water, and higher biological oxygen demand due to accelerated decomposition of plant detritus.

Analysis of data from previous studies indicates no discernible trend in DO levels of the lake (Banerjee and Roychoudhury, 1966; Banerjee *et al.,* 1998).

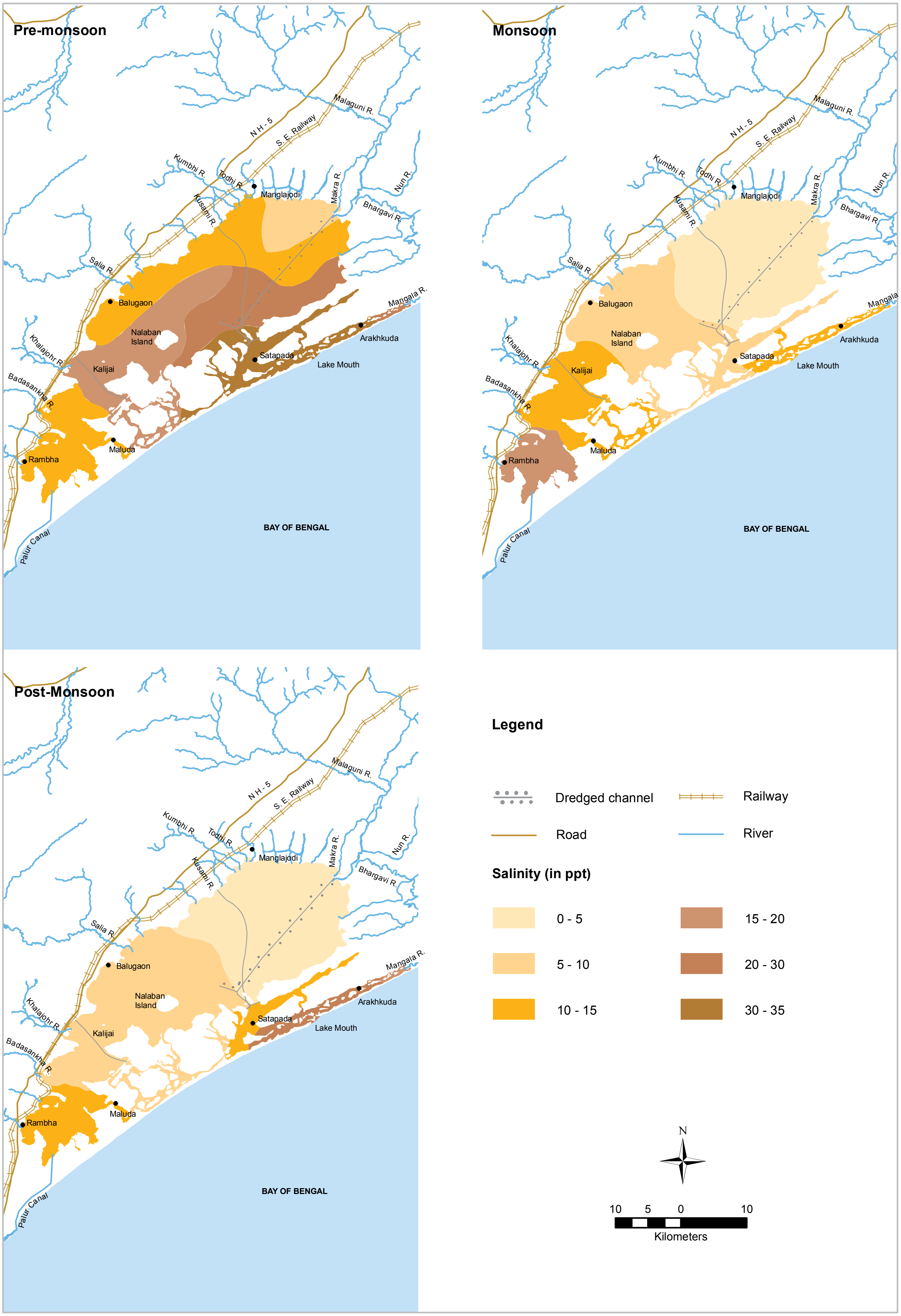
Salinity

Salinity is an important variable determining the biological productivity of Chilika. The seasonal fluctuation in salinity levels has a great impact on the migration, maturity, breeding, spawning, growth and survival of fishes and prawns. The appearance and disappearance of phytoplankton species depends upon the salinity regime of aquatic system (Singh, 1960; Nwankwo, 1996). This is true for all the aquatic organisms which maintain their body in isosmotic conditions with the environment. Even the migratory species are know to regulate the concentration of their body fluids according to the environment.

Chilika has a salinity gradient which is vital for supporting a range of biodiversity. The gradient is from the northern sector to southern sector during monsoon and post monsoon, and towards outer channel in the pre-monsoon period. Average salinity of lake ranged from 11-14 ppt during 2002-2011 (Table 5). During monsoon, low salinity values are recorded in almost all the sectors of the Lake including Magarmukh area which receives considerable amount of freshwater through the lead channel. However, southern sector remains saline (20-30 ppt) (Map 16). Southern sector experiences a fall in salinity (10-15 ppt) during winter which indicates a clear mixing of freshwater received during monsoon in all the sectors. The flow pulses till end of December are also responsible for maintaining a freshwater condition in the northern sector. But a gradual increase of salinity in the Magarmukh area during winter (30-35 ppt) is indicative of tidal influence from sea through outer channel. With decrease in freshwater input and increase in rate of evaporation, tidal influence is more pronounced during summer with increasing salinity values ranging from 10-35 ppt barring the river confluence area in northern sector where salinity remains below 5 ppt.



Map 15: Trend in Dissolved Oxygen of Lake Chilika (2002-2011)



Map 16: Trend in salinity of Lake Chilika (2002-2011)

Table 4 : Average Dissolved Oxygen of Lake Chilika (in ppm, 2002-2011)

Year	Range	Lake Average	Premonsoon				Monsoon				Post Monsoon			
			CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC
2002-03	0.8-13.0	6.9	6.0	6.5	6.6	6.8	6.6	6.9	6.1	7.3	8.2	8.0	8.6	7.8
2003-04	2.0-12.2	7.2	6.4	6.7	7.1	7.1	6.7	7.1	6.1	7.1	8.1	8.2	8.4	7.6
2004-05	1.8- 11.5	7.7	6.8	7.3	7.1	7.8	7.8	7.7	7.4	7.6	7.7	8.0	7.6	8.0
2005-06	0.3-11.0	7.2	6.4	7.3	6.4	7.6	6.5	7.0	6.0	7.1	8.0	8.1	8.0	8.4
2006-07	1.3-11.6	7.2	6.7	7.2	6.4	7.1	6.9	6.9	6.7	7.2	7.8	8.0	8.1	7.8
2007-08	1.8- 12.5	8.0	7.4	8.0	7.0	7.3	8.1	8.0	8.0	8.8	8.5	8.6	8.1	8.9
2008-09	1.6-11.7	7.61	6.6	7.3	6.7	7.4	7.7	7.8	6.9	8.3	8.6	8.3	8.3	8.1
2009-10	2.2-13.8	7.6	6.7	6.8	6.4	7.0	7.4	7.3	6.9	8.4	8.8	9.2	8.8	8.9
2010-11	1.1-11.7	6.54	5.9	6.2	5.8	6.0	6.9	7.0	7.3	7.4	NA	NA	NA	NA

Table 5 : Average salinity of Lake Chilika (in ppt, 2002-2011)

Year	Range	Lake Average	Premonsoon				Monsoon				Post Monsoon			
			CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC
2002-03	0.1-36.0	14	15.8	12.4	17.1	33.9	11.5	16.3	6.0	18.0	9.5	12.0	5.2	23.7
2003-04	0.0-37.0	13.1	20.8	16.8	19.2	32.7	9.9	14.4	4.8	10.1	5.1	6.9	1.9	15.4
2004-05	0.1-36.1	13.6	18.1	14.7	14.3	33.2	11.9	20.3	4.0	14.2	10.6	15.5	2.9	16.8
2005-06	0.1-36.5	13.4	20.7	21.6	13.4	33.1	12.9	17.6	5.3	12.6	7.6	9.9	3.6	14.1
2006-07	0.05-35.4	9.8	19.6	14.7	13.5	31.8	4.5	9.9	0.7	3.9	5.4	6.5	2.7	16.0
2007-08	0.04-35.6	11	18.4	13.7	14.5	31.2	8.6	14.3	1.7	7.3	6.8	9.3	2.0	16.6
2008-09	0.00-36.9	9.3	14.3	12.5	8.9	31.5	4.7	11.4	0.4	9.2	5.8	9.0	1.5	17.7
2009-10	0.0-33.1	11.2	16.9	12.9	16.9	26.2	7.0	11.9	2.9	6.5	5.6	9.0	2.5	22.5
2010-11	0.00-33.2	11.7	15.3	14.3	14.7	28.2	9.4	12.7	3.2	8.6	5.9	7.4	1.8	22.2

CS - Central Sector • SS - Southern Sector • NS - Northern Sector • OC - Outer Channel
(Data source: CDA Monitoring Records)

Of all lake ecological parameters, salinity has the longest trend data with earliest observations available since 1957-58 (Fig. 6). There has been a gradual decrease in the average lake salinity with near freshwater conditions during 1995-96 and 1997-98.

The hydrological intervention has helped restore the salinity gradient. The long term data however needs to be interpreted along with hydrological conditions. Salinity has been observed to be higher in years of drought.

Transparency

Transparency reflects the extent of light penetration in water, and is a key indicator of photosynthetic activity in the lake and thereby productivity. The presence of dissolved and particulate materials interfere with the penetration of light and affect productivity (Bhat, 1979).

Lake Chilika is a shallow, well-mixed water body that is generally turbid, although significant spatial and seasonal variations in water transparency have been recorded.

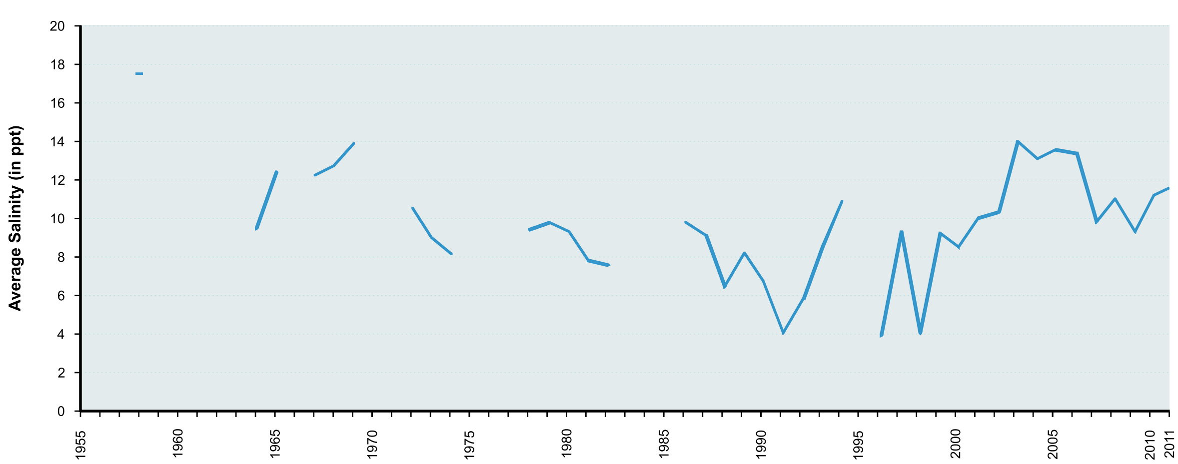


Fig. 6: Trend in salinity of Lake Chilika (Data source: Biswas, 1995; Satyanarayan, 1999; Ghosh & Pattnaik, 2005; CDA Monitoring Records)

Transparency is as high as more than 1 m in the central sector in winter, and as low as 0.3 m in the northern sector during the monsoon.

Average transparency of the lake ranged from 0.7-0.87 m during 2002-2011 (Table 6). The riverine flow during monsoon influences the northern, central and outer channel rendering the sectors turbid with values ranging from 0.2-1m, however, southern sector remaines unaffected with values ranging between 1-1.8 m (Map 17). During winter, northern sector is still turbid due to influence of slow flow pulses till Magarmukh. The transparency in Nalaban area in central sector is reduced due to lower water depth, congregation of birds and their guano droppings which lead to bloom formation. The decomposition of organic matter accumulates nutrients in the sediment. Upwelling is a common phenomenon during summer months which release these nutrients in the ambient water and lead to turbidity of lake water. Hence, low transparency was recorded during summer (0.2-1 m) barring a few places in the southern sector.

The lowest available value in transparency is that of 1996-97 linked to bloom formation by the blue-green algae (Raman and Satyanarayan, 1998). The hydrological intervention during 2000 has led to increase in transparency values of the lake (Fig. 7).

Nutrients

The role of nitrate-nitrogen and phosphate-phosphorus in biological productivity of aquatic ecosystems is well recognized. The source of both the nutrients can be allochthonous as well as autochthonous. Primary producers have the capacity to utilize these inorganic forms of phosphorus and nitrogen in their body tissues and ultimately bring them into the food chain. Nitrogen and phosphorus can both act as limiting factors influencing the growth of algal cell (Zipper *et al.,* 2004).

Data on nutrient status in Chilika is mostly available through research done by CIFRI (1995, 2003-04) or sporadic independent efforts. Chilika is a nutrient rich system. The concentration of nitrate in Chilika Lake ranged from 0.036-0.324 ppm during 2003-04 (Table 7). The nitrate levels are higher during post-monsoon in central sector (0.25 ppm) and lowest during monsoon (CIFRI, 2006). The nitrate-nitrogen levels in lake water indicate that the system is favourably productive (Jhingran, 1991).

The phosphate concentration of the lake was found to vary between 0.002 to 0.252 ppm. The values were highest during monsoon (0.10-0.252 ppm) followed by winter (0.012-0.044 ppm) and summer (0.010-0.042 ppm). Higher values during monsoon could be due to heavy rainfall and surface runoff.

Brackish water lakes have higher dominance of diatoms (Jayadesan, 1986) which utilize the available silica from the ambient water for their siliceous body walls (Panday *et al.,* 2005; Jha, 1986). The silicate in Chilika Lake was found varying between 0.5-10.2 ppm. The lowest concentration of silicate was recorded in southern sector during pre-monsoon and highest in northern sector during post-monsoon.

Lake Sediment Quality

Lake Chilika sediment mainly comprises coarse sand, fine sand, silt and clay. The percentage of coarse sand is higher towards outer channel with silt being higher in northern and southern sector (CIFRI, 2006). This may be due to the high content of organic carbon in northern and southern sector associated with the decomposition of macrophytes. Prior to opening of new mouth the sediment bed was silty loam in texture in the northern sector, silty in central sector and sandy clay in southern sector (Banerjee *et al.,*1998). The change in the texture of soil in northern

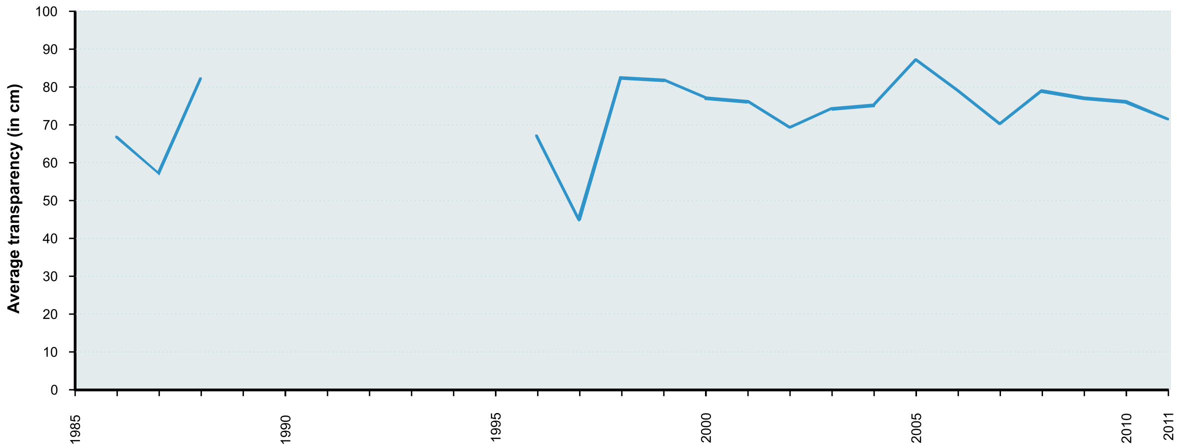


Fig. 7: Trend in transparency of Lake Chilika (Data source: Siddiqui & Rao, 1995; Banarjee *et al.,* 1998; Bhatt & Pattnaik, 1998; Satyanarayan, 1999)

Table 6 : Average Transparency of Lake Chilika (in cm, 2002-2011)

Year	Range	Lake Average	Premonsoon				Monsoon				Post Monsoon			
			CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC
2002-03	5-220	74.0	55.9	81.0	46.4	62.1	91.9	135.1	39.7	82.4	88.6	111.5	53.7	90.1
2003-04	6-289	75.0	71.9	85.8	42.6	73.7	81.3	125.7	40.1	56.6	95.1	119.3	51.3	85.8
2004-05	12-260	87.0	78.4	93.6	42.6	72.7	109.9	147.0	54.4	68.2	110.6	149.1	55.0	84.1
2005-06	8-283	79.0	77.0	97.4	39.4	69.8	84.1	153.5	41.3	64.6	75.7	137.4	50.2	75.3
2006-07	10-240	70.0	72.6	138.3	49.4	113.7	48.8	134.9	32.7	38.4	47.0	91.0	33.4	70.6
2007-08	12-340	79.0	65.2	114.3	55.5	106.1	83.5	133.8	45.0	48.0	71.5	106.2	55.5	75.7
2008-09	6-272	77.0	67.8	89.5	42.6	91.9	57.4	146.4	29.8	55.4	86.3	140.4	52.6	90.7
2009-10	7-400	76.0	56.2	103.7	35.6	124.9	81.9	126.7	27.9	85.1	73.8	102.8	46.0	108.0
2010-11	3.0-293	71.3	65.7	66.0	43.8	52.7	99.5	107.1	59.3	81.9	77.1	59.0	61.0	109.7

(Data source: CDA Monitoring Records)

Table 7 : Nutrients in ambient water of Lake Chilika (in ppm, 2003-2004)

Season	Pre-monsoon				Monsoon				Post-Monsoon				Avg
Sector	CS	SS	NS	OC	CS	SS	NS	OC	CS	SS	NS	OC	
Nitrate	0.14	0.19	0.12	0.15	0.10	0.09	0.10	0.11	0.18	0.25	0.22	0.21	0.15
Phosphate	0.03	0.03	0.03	0.03	0.05	0.04	0.02	0.06	0.03	0.05	0.02	0.02	0.03
Silicate	6.04	2.75	1.40	2.52	6.73	4.41	2.84	4.27	7.08	3.50	3.50	4.20	4.10

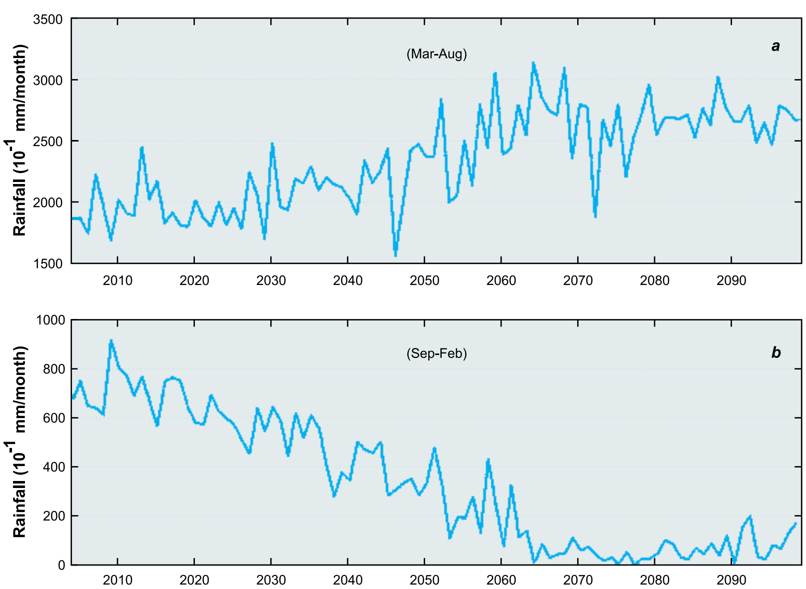
CS - Central Sector • SS - Southern Sector • NS - Northern Sector • OC - Outer Channel
(Data source: CIFRI, 2006)

sector and southern sector could be attributed to the flushing of silt load brought in by the rivers. Sediment of lake soil remains neutral to moderately alkaline throughout the year (pH 7.0-9.28). The available nitrogen in sediment varies between 2.28-56 mg/100 g. The available phosphorus content of sediment varies from 0.64-4.04 mg/100 g which may be attributed to alkaline soil reaction or continuous up take by macrophytes and algal weeds (CIFRI, 2006).

The nitrate and available phosphorus are considered as the limiting factors being the primary nutrient for an ecosystem (Carney *et. al.,* 1993; Brown, 1981). Bio-manipulation of shallow lakes showed that the aquatic macrophytes act as a link for both nitrate and phosphate during their growing phase withdrawing upto 60% of nitrate and phosphate from the sediment and after their decomposition the nitrate and phosphate is released back to sediment as well as water (Donk *et al.,* 1993).

However, the data on soil chemistry remains fragmented; soil water interactions and release of nutrients to the system and absorption/utilization of the same by the aquatic plants are to be studied in Chilika.

Fig. 8 : Projected rainfall for Odisha for wet (a) and dry (b) periods (Source: Ghosh and Majumdar, 2006)



Climate change and impacts on hydrological regimes

Climate change is expected to have implications for several of wetland features. Changes to India's annual monsoon patterns have been predicted in several assessments. There is a high likelihood of a decline in winter rainfall by 5 to 25% leading to droughts during the dry summer months. At the same time, only 10 to 15% increase is predicted in the monsoon rainfall. More intense rainfall spells are also projected in a warmer atmosphere, increasing the probability of extreme rainfall events (Lal *et al.,* 2001). State level assessments based on downscaling of general circulation models also confirm the trend (Fig. 8). A decline in rainfall during the dry period (September-February) is projected along with an increase in summer and monsoon rainfall coupled with an increase in maximum/peak rainfall.

Map 17: Trends in transparency of Lake Chilika (2002-2011)

An increased incidence of hydrological extremes is projected (Ghosh and Majumdar, 2006).

Basin level assessments of impacts of climate change on hydrology also indicate an increasing variability of flows within Mahanadi River. The basin is predicted to receive comparatively higher level of precipitation in future and a corresponding increase in evapo-transpiration and water yield. Flow duration curves indicate a marginal increase in dependable flows (Gosain *et al.,* 2006) (Fig. 9). Given the fact that much of the river flows are concentrated during the months of monsoon, enhanced flows would exacerbate flood conditions as well as pose a serious risk to the current flood regulation infrastructure. While changes in groundwater have not yet been assessed, increased frequency and severity of floods may affect groundwater quality in alluvial aquifers.

Changes are also predicted in the coastal processes. The Bay of Bengal has recorded the maximum annual sea level rise of 2.42-4.87 mm within the Indian coast (Unnikrishnan and Shankar, 2007). An increase in sea level by 1 meter is projected to inundate 1700 km^2 of agricultural land in Odisha (www.envfor.nic.in). The Puri District has been identified to be the most vulnerable to a one meter sea level rise (TERI, 1996). Sea level rise has implications for salinity as well as livelihoods of coastal communities in Chilika.

One of the key implications of the existing hydrological assessments is the impact on overall salinity regimes which holds the key to high ecological productivity of the wetland ecosystem. Changes in water temperatures can also trigger

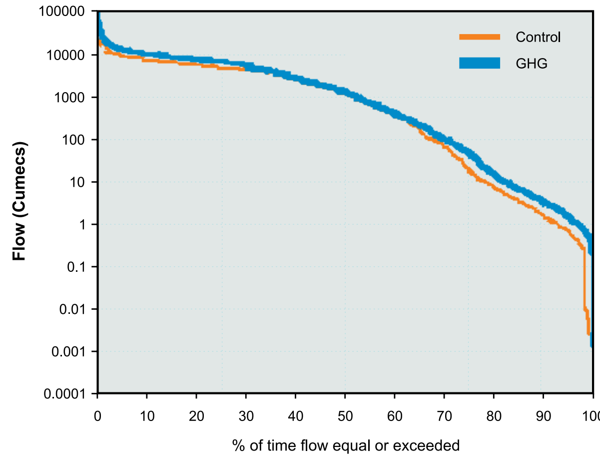
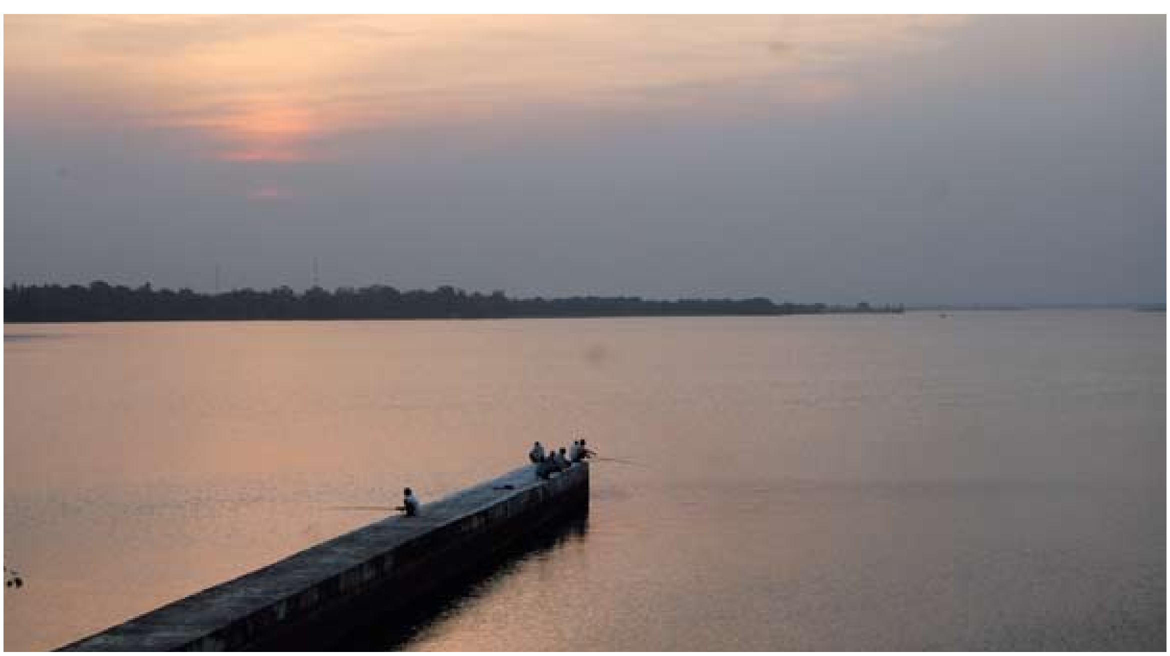


Fig. 9: Flow duration curve for Mahanadi River for control and GHG scenarios (Source: Gosain *et al.,* 2006)

implications for aquatic biodiversity, for example migration pattern within fish species. Changes in resource base could have impacts on community livelihoods and coping mechanism. An assessment of impacts of climate change on fisheries livelihoods and Chilika concludes that the impacts cover not just occupational activities but also multifaceted aspects of rural livelihoods that determine the extent of their capacity to adapt (Iwasaki *et al.,* 2009). The vulnerability contexts are also likely to be different for different regions. A vulnerability assessment in the context of climate change has been initiated in 2011, which will provide better insights on the impacts of climate change on Chilika, and the need to revise response strategies.



Mahanadi River at the apex of Delta at Naraj

2.2.4 Biodiversity

Aquatic ecosystems harbour a variety of communities which are responsible for the functioning of the ecosystem and provision of ecosystem services. Chilika, its fringe areas and the islands are a habitat for 399 phytoplankton, 14 algae, 729 plants, 37 zooplankton, 61 protozoa, 6 porifera, 7 coelentrata, 29 platyhelminthes, 36 nematoda, 31 annelids, 136 mollusca, 62 crustacea, 5 echinoderms, 1 protochordata, 314 fish, 7 amphibia, 30 reptilia, 224 birds and 19 mammals. The lake is also a habitat to some rare and endangered species (numbers indicated in Table 8).

The physico-chemical features of water and sediment are the intrinsic factors governing the reproductive cycles, growth and survivability of the organisms living there in. The change in biodiversity of the lake with changing ecological parameters is elaborated in the following discussion.

Floral Diversity

Phytoplankton

Most recent assessment of phytoplankton diversity in Chilika is of 2003-2004 undertaken by CIFRI (Jha, 2009). As per the assessment, 399 species are present in Chilika which include 181 bacillariophyceae, 79 euglenophyceae, 50 dinophyceae, 44 cyanophyceae, 29 chlorophyceae, 11 xanthophyceae and 5 species of chrysophyceae *(ibid)*. Three peaks in phytoplankton abundance were observed during winter, summer and monsoon dominated by bacillariophyceae, dinophyceae and chlorophyceae respectively (Patnaik, 2010).

Earliest records of phytoplankton within Chilika is of Devasundaram and Roy (1954) who reported 43 species of phytoplankton, including 2 chlorophyceae, 30 bacillariophyceae, 7 dinophyceae, 1 rhodophyceae and 3 myxophyceae. *Asterionella japonica* was recorded to be the most dominant contributing to 49.92% of total abundance. Along with these many other species like *Anabaena* sp. *Coscinodiscus* sp., *Rhizosolenia* sp. *Spirogyra* sp. were also found in large numbers. Further assessment in 1987 and 1996-97 revealed 42 species (Raman and Satyanarayan, 1998).

Changes in hydrological regimes of Chilika had a marked impact on the phytoplankton diversity and abundance patterns. Post restoration, there has been an increase in diversity (from 42 species in 1996-97 to 399 in 2003-04) but decline in abundance

Table 8: Conservation status of flora and fauna in Lake Chilika (2011)

Biodiversity Group		No. of species	Record data	Status						
				CR	EN	VN	NT	DD	LC	NE
Flora	Phytoplankton	399	2003-04	Not evaluated						
	Algae	14	2003							
	Plants	729	2008							
Fauna	Zooplankton	37	2003-04							
	Protozoa	61	1985-87							
	Porifera	6	1985-87							
	Coelenterates	7	1985-87							
	Platyhelminthes	29	1985-87							
	Nematodes	36	1985-87							
	Annelids	31	1985-87							
	Mollusca	136	1985-87							
	Crustacea	31	1985-87							
	Decapoda	31	1985-87							
	Echinodermata	5	1985-87							
	Protochordata	1	1985-87							
	Fish	314	20011	2	2	4	17	15	61	213
	Amphibian	7	1985-87	0	0	0	0	0	7	0
	Reptile	30	1985-87					1	8	21
	Birds	224	2009	1	0	5	12	0	206	0
	Mammals	19	1985-87	0	1	1	1	0	16	0

CR - Critically Endangered • EN - Endangered • VN - Vulnerable • NT - Near Threatened • DD - Data Deficient • LC - Least Concern • NE - Not Evaluated
(Source: IUCN Red List of Threatened Species accessed in July 2011)

(18315 no./l recorded in 1996-97 to 9375 no./l in 2003-04). Several bacillariophycean species like *Bacteriastrum* sp., *Biddulphia* sp., *Ditylum* sp., *Lauderia* sp., *Triceratium* sp., *Thalassiothrix* sp. found in 1987 assessment were no longer observed in the outer channel in 1996-97 assessment, but reappeared in 2003-04. The higher abundance during 1996-97 was attributed to freshwater algal bloom (mostly *Oscillatoria* sp.) triggered by lowering of salinity and a near two fold increase in nitrogen and phosphate levels (Raman and Satyanarayan, 1998). Restoration of hydrological regimes has led to reappearance of true marine and brackish water forms like *Biddulphia* sp., *Chaetoceros* sp. and *Bacteriastrum* sp. (Patnaik, 2010). A total of 35 algal species reappeared after hydrological intervention (Panigrahi, 2006).

Algae

The most recent assessment of algal diversity was undertaken in 2003, indicating presence of 14 species including 8 chlorophyceae and 6 rhodophyceae species with two new records *Enteromorpha flexuosa* and *Ulva fasciata* (Sahoo *et al.,* 2003) (Annex I). Of these, *Ceramium diaphanum* was observed to be confined to certain areas of the southern and central sector. *Grateloupia filicina* was found confined to the central sector and *Chara* sp. attached to the sandy and muddy bottom in northern sector. *Gracilaria verrucosa, Enteromorpha intestinalis* and *Chaetomorpha linum* were found abundantly in the lake (Rath and Adhikary, 2005).

Previous assessments on algae have focused only on benthic forms. Biswas (1932) reported 11 benthic algal species including 5 green algae and 6 red algae belonging to Chlorophyceae, Ceramiales and Carrageenophytes families. Chlorophyceae was represented by *Enteromorpha compressa, Enteromorpha intestinalis, Chaetomorpha linum, Cladophora glomerata* and *Pithophora oedogonium;* Ceramiales represented by *Ceramium elegans, Polysiphonia sertularioides* and *Polysiphonia subtilissima* and Carrageenophytes by *Grateloupia filicina* (Biswas, 1932). These species not found in 1998 assessment are currently present in the lake along with two new chlorophyceae members *Enteromorpha flexuosa* subsp. *flexuosa* and *Ulva fasciata* (Sahoo *et al.,* 2003).

Vegetation

The most recent floristic account of Chilika has been made by Pattnaik (2003), recording 729 angiosperms (708 reported by Pattnaik, 2003 and 21 species by earlier researchers) from 454 genera and 120 families (Annex II). These includes some rare, vulnerable and endangered plant species as *Cassipourea ceylanica, Colubrina asiatica, Capparis roxburghii, Maerua oblongifolia, Macrotyloma ciliatum and Indigofera aspalathoides.* A brief profile of aquatic and terrestrial vegetation follows.

Aquatic Vegetation

The aquatic flora in Chilika comprises emergent, submerged and floating forms. The northern sector is inhabited by *Nymphaea nouchali, Vallisneria spiralis, Eichhornia crassipes, Ipomoea aquatica, Nymphoides indica, Najas graminea var. minor, Najas, faveolata, Hydrilla verticillata, Ceratophyllum demersum, Jussiaea repens, Scirpus articulatus, Typha angusta, Polygonum glabrum, Paspalidium geminatum, Panicum repens, Porteresia coarctata, Halophila ovalis, Sphenoclea zeylanica, Cyperus exaltatus* and *Eragrostis interrupta* (CIFRI, 2006). Northern sector is dominated by emergent and submerged type most notably *Phragmites karka, Hydrilla verticillata, Vallisneria spiralis, Eichhornia crassipes* which was dominant in the freshwater zone of northern sector is now confined to the river confluence areas. *Najas minor, Nymphoides indica* and *Halophila ovalis* were recorded only from the isolated pockets of central and southern sector due to ability to tolerate high salinity concentration *(ibid).* The vegetation of central and southern sectors is


Algal mass on the rocks of Kalijai

mostly submerged brackish water type represented by the dominant genus of *Najas, Potamogeton* and *Halophila.* The outer channel area having marine influence has very less vegetation in comparison to other sectors and is represented by submerged stands of *Potamogeton pectinatus*.

Six species of sea grass, *Halophila ovalis, H. ovata, H. beccarii, Halodule uninervis, H. pinifolia* and *Ruppia maritima* were also recorded from the lake during post-intervention period (Map 18 and 19) which included two new records of *Halodule uninervis* and *H. pinifolia* (Bhatta, 2003). The area under sea grass has also increased since 2000 (Map 18 and 19).

During 1990, reduced salinity and increased nutrient load from catchment greatly favoured the luxuriant growth of large variety of macrophytes in lake. As a result of reduction in salinity and depth in northern sector, *Paspalidium geminatum, Ceratophyllum demersum* and *Panicum repens* have restricted their distribution to areas with higher depth and salinity in the southern sector (Mohapatra, 1998). Many submergent macrophytes as *Potamogeton pectinatus, Najas flaveolata, Najas graminea, Hydrilla* sp. and *Vallisneria* sp. have restricted their distribution only in western half of the northern sector upto 6 km inside the shore. The species *Potamogeton pectinatus* and *Najas flaveolata* dominate 80% of water tracts (*Ibid*). The free-floating macrophytes *Pistia stratiotes* and *Azolla pinnata* which were absent in the lake previously have colonized rapidly (Panigrahy, 1998). Along with this, many emergent macrophytes like

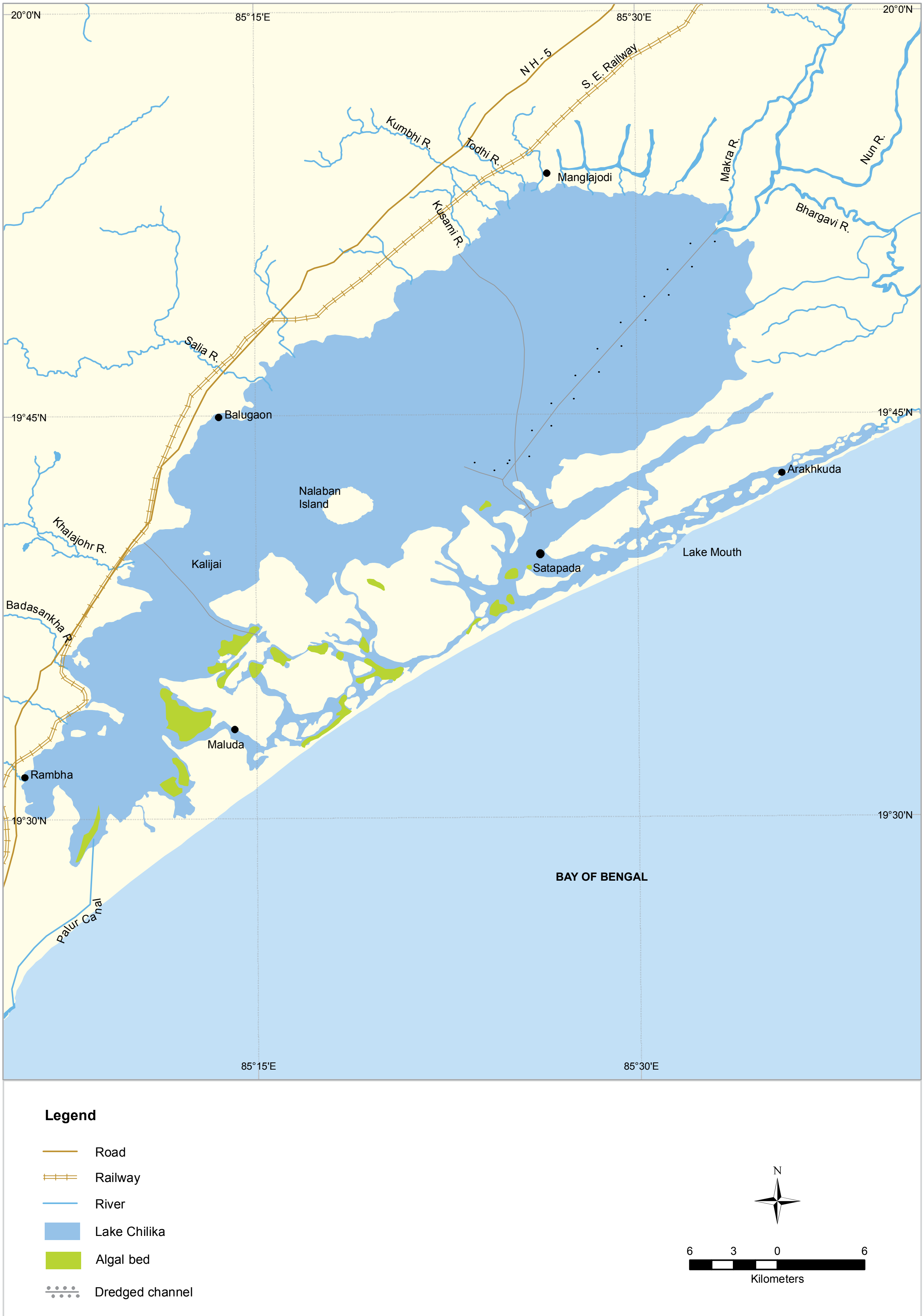
Seagrass beds in Chilika

Scirpus littoralis, *Cyperus* sp. *Eleocharis plantaginea* too expanded their range of distribution. The rate of infestation was found to increase from 20 km^2 in 1973 to 440 km^2 by 1988 (*ibid*). Similarly, the northern sector was highly infested with *Eichhornia crassipes*. With increase salinity, the area under *Eichhornia crassipes* rapidly declined. However, there has been a rapid increase in area under *Phragmites* which is known to tolerate salinity upto 18 ppt, (Meyerson *et al.*, 2009). The area under emergent vegetation increased from 76.4 km^2 in 2000 to 105.1 km^2 in 2010 (Map 20 and 21; Box 2).

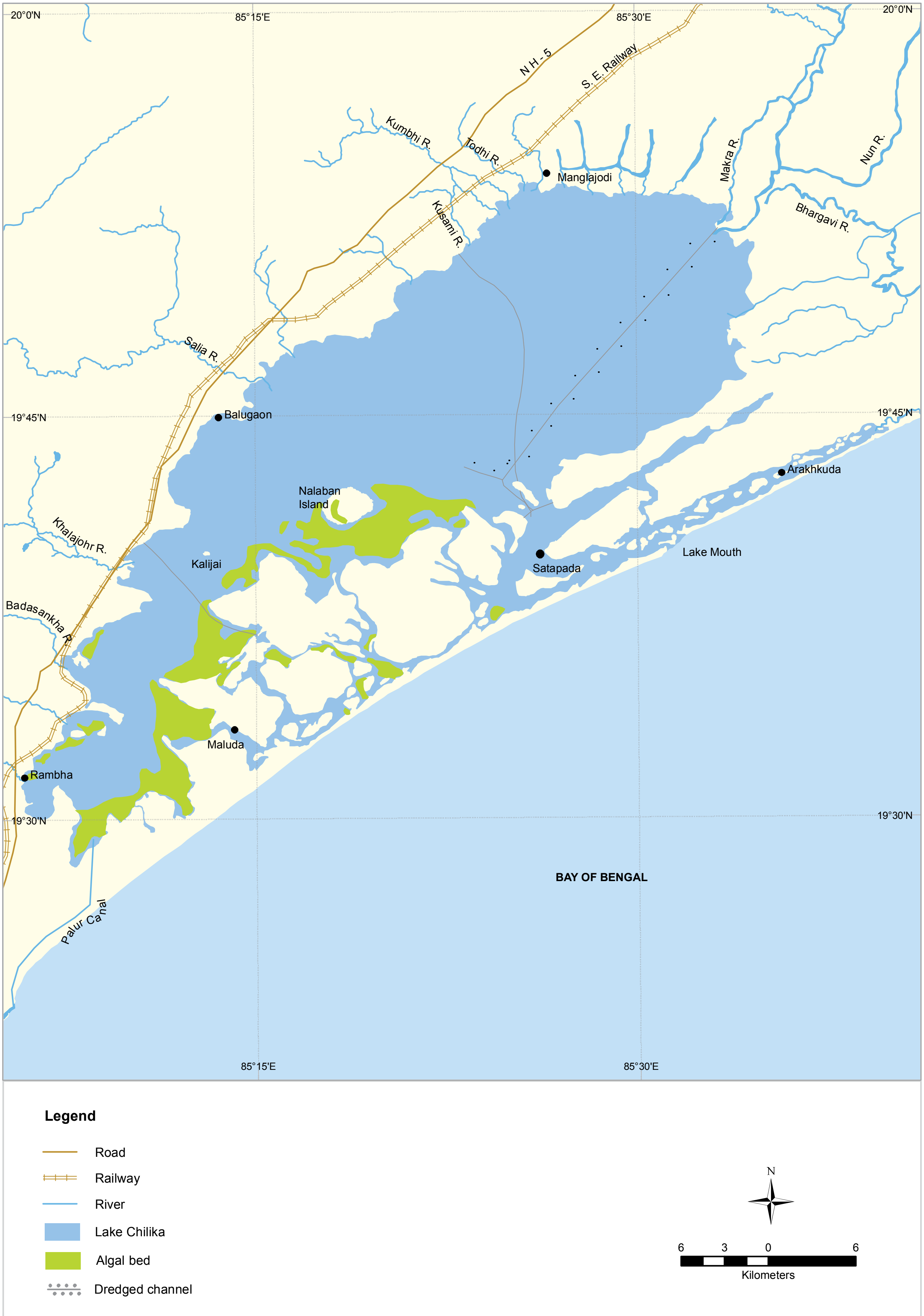
Terrestrial Vegetation

Knowledge on terrestrial vegetation in Chilika primarily pertains to islands. A few mangrove associates such as *Aegiceras corniculatum, Excoecaria agallocha, Salvadora persica, Pongamia pinnata and Cassipourea ceylanica* have been recorded from the

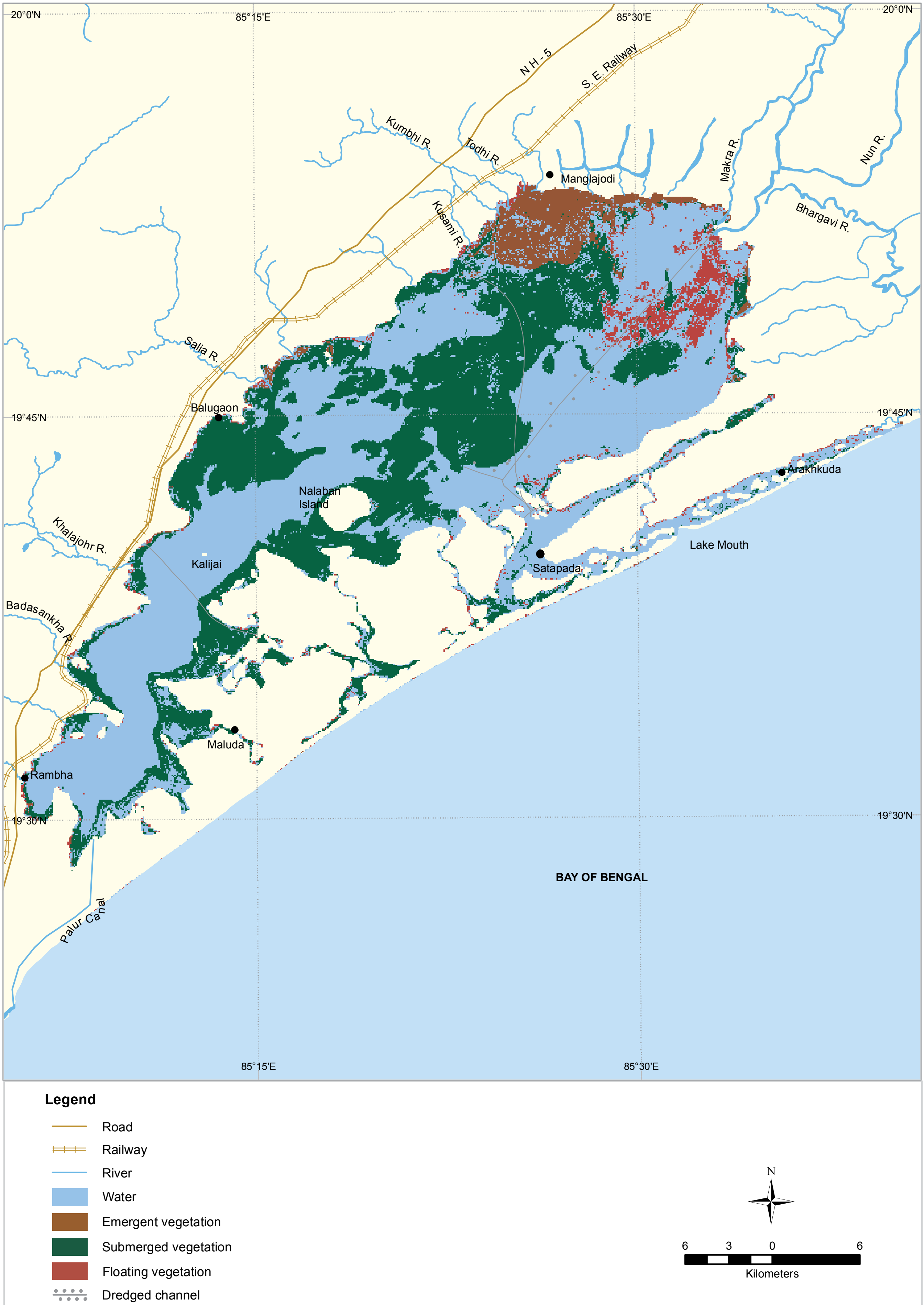
Mangroves have been recently planted in the outer channel by communities considering their role in supporting nursery grounds for fish, prawns and crabs and ability to buffer storms



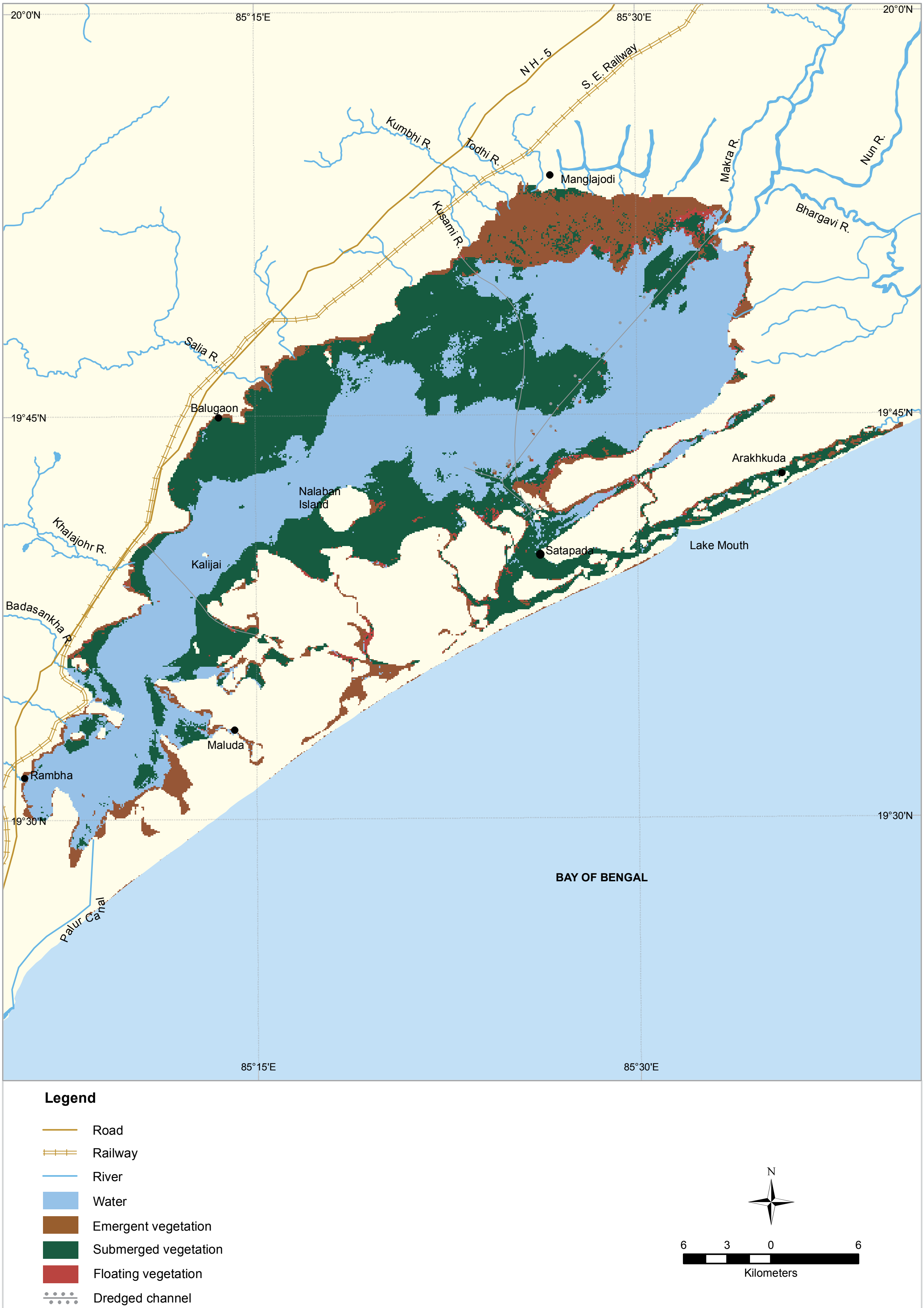
Map 18: Algal bed extent in Lake Chilika (April 1999)



Map 19: Algal bed extent in Lake Chilika (Novermber 2011)



Map 20: Lake Chilika vegetation (2000)



Map 21: Lake Chilika vegetation (2010)

Box 2: Invasion of *Phragmites karka* in Chilika

One of emerging stresses on ecological character of Chilika is changes in composition of macrophytes, particularly after the hydrological intervention of 2000. While the opening of new mouth and subsequent changes in salinity regimes have led to drastic decline in area under water hyacinth *(Eichhornia crassipes), Phragmites karka* (locally called Nala dala) has rapidly invaded north and north-western segments of lake. Its area in Chilika has significantly increased from 76.4 km^2 in 2000 (the survey for assessing current spread was still in progress at the time of writing this report).

Phragmites invasion in Chilika has several implications hydrological, ecological and social implications. The presence of *Phragmites karka* in the northern zone is likely to have an impact on the flushing of sediments thereby leading to sediment accumulation and retention. From an ecological perspective, the northern sector serves as breeding ground for several economically important fish species, which would be affected through stressed environments for juveniles as well as blocked migratory pathways. *Phragmites* has also tended to colonize areas previously under submerged vegetation (primarily *Hydrilla, Vallisneria* and *Potamogeton*). It has also gradually shifted towards the fringe areas, and as per imageries of 2010, borders the entire lake margin. The northern sector is also important from the perspective of waterbirds. Several species of ducks have been observed to avoid dense stands (Balachandran *et al.,* 2005). The delta communities are primarily agrarian, with agricultural productivity dependant on the flood and sediment enrichment cycles. *Phragmites* is seen to be a causative factor, particularly within the fringe communities for extended periods of waterlogging in agricultural fields. This is also impacting movement within the lake. Dense strands of *Phragmites* are also triggering mosquito breeding and thereby a health hazard. Highly silted up areas create conducive conditions for encroachment of land.

An experimental attempt to address *Phargmites* invasion using chemical methods was undertaken in 2007-08 in partnership with Odisha University of Agriculture and Technology. Herbicide Glyphosate at a dose of 15 ml per litre of water was applied to foliage over 13.5 acres. This however was of limited success, and raised several questions related to the short and long term implications of the chemicals on the ecology of the wetland as well as the biota living therein.

WISA and CDA convened a consultation workshop in January 2011 to develop a response strategy for the managing *Phragmites* invasion. The workshop concluded that the response strategy for managing *Phragmites* invasion in Chilika needs to be integrated building broadly on two sets of actions: a) controlling the current invasion, and b) enhancing preparedness to manage risks of future invasions within the wetland ecosystem. The strategy should be nested with the management planning processes and include preparedness as part of solutions. Key considerations for evaluating intervention options should include: ecological implications, for example impact on species replacement; cost effectiveness (preferably achieving higher degree of control for every unit of resources spent); social impacts; and institutional priorities (including ability to sustain interventions over long term if required).

The following control options were identified, to be implemented following pilot experimentation: a) Mechanical removal (cutting and removing stands); b) Chemical control (use of different products, as imazapyr and concentrations); c) Habitat management (cutting and submergence for 4-6 months, breaking monospecific stands and managing salinity in northern sector); d) Economic use by creating linkages with paper industry and scoping other options with business models. It was also recommended to nest in-situ management options with long term sediment and nutrient management interventions in the Northern Sector. Finally, it was agreed to revisit current monitoring systems and indicators to assess their ability to capture changes in ecological character, and to put in place a risk management system within the current institutional arrangements for enhancing preparedness for future threats.

Phragmites stands in Northern sector

margins. In addition to this several climbers like *Cissus quadrangularis* and *Tylophora indica* and shrub *Lantana camara* are commonly present in the islands. *Ipomoea pes-caprae, Macrotyloma cilium, Hydrophylax maritima, Spinifex littoralis, Bulbostylis barbata* and *Casuarina equisetifolia* are commonly found on the sandbars and shoreline areas.

Faunal Diversity

A comprehensive survey of faunal diversity of Lake Chilika undertaken during 1985-87 led to enumeration of 61 species of protozoa; 6 species of porifera; 7 species of coelentrata; 29 species of platyhelminthes; 36 species of nematoda; 31 species of annelid; 62 species of crustacea; 136 species of mollusca; 5 species of echinodermata; 216 species of pisces; 7 species of amphibian; 30 species of reptilia; 168 species of birds; and, 19 species of mammals (ZSI, 1995). One of key conclusions of the assessment was relative predominance of freshwater species, which formed the basis for hydrological intervention. Post hydrological intervention, assessment of faunal diversity has focused on few major groups as fish, birds and charismatic species Irrawady Dolphin within mammals. Few isolated and discontinuous studies have been conducted on the lower faunal groups. The rare and endemic limbless lizard *(Barkudia insularis)* recorded by Annandale and Kemp (1915) was again recorded in the year 2003 in Barakuda island by CDA. In addition to this the lake provides habitat to several threatened species which include 8 fish, 6 birds and 2 mammalian species. CDA has recently commissioned comprehensive faunal assessments which would indicate the status of species diversity and impact of various management interventions.

Zooplankton

Zooplankton plays an important role in energy flow process in lake. From fishery point of view, zooplankton is a vital link in the pelagic food chain. Many micro-zooplanktons constitute the major food item of the larvae of crustaceans, molluscs and fishes.

The most recent assessment of zooplankton in Chilika was carried in 2003-04 leading to listing of 37 species belonging to 18 genera (CIFRI, 2006). Copepods were the most dominant groups followed by protozoa, rotifers, cladocera, mysids and crustacean larvae. The maximum abundance was observed in summer (1075 no./l) and minimum in monsoon (330 no./l). Abundance was the highest in southern sector and minimum in northern sector *(ibid).* High zooplankton population during dry season could be related to the stable hydrological condition while low density during monsoon is attributed to turbulence created by floods and high inflow of freshwater (Patnaik, 1986; Patnaik and Sarma, 1997; Santhanam *et al.,* 1975; Shanmugam *et al.,* 1986; Kumar, 1993; Rajasegar, 1998).The abundance of zooplankton was observed to be correlated to changes in salinity (Fig.10).

Limbless skink (*Barkudia insularis*)

During pre-intervention period, 170 species of zooplankton were recorded in the lake (Panigrahy, 1998). Copepod was the dominant group comprising *Pseudodiaptomus annandalei, Pseudodiaptomus binghami, Pseudodiaptomus hickmani, Acartia chilkaensis, A. major, A. minor, A. centra, Paracalanus crassistris, Oithona nana, O. brevicornis, Labidocera pavo, Parategastes sphaericus var. similis,* and *Diaptomus* sp. Marine forms were largely observed in the outer channel area, brackish water forms in the central and southern sectors, whereas freshwater species (like *Diaptomus* sp., *Cyclops* and *Mesocyclops* sp.) were dominant in the northern sector (Sarma *et al.,* 1988). However, most of these assessments are based on limited sampling data for short and discontinuous periods. Systematic assessments are required for monitoring the status and trends in the zooplanktons.

Macrobenthos

Latest status of benthos diversity in Chilika is of 2007-08, wherein 6 groups-Polychaeta, Crustacea, Bivalves, Gastropods, Mysids and Isopods have been recorded (Mahapatro *et al.,* 2009). The wetland harbours 7 species of polychaeta, 5 species of crustacea *(ibid),* 15 species of bivalves and 22 species of gastropods (Patnaik *et al.,* 2009). Gastropod is the most dominant group whereas polychaeta, oligochaeta and amphipoda are restricted to isolated pockets.

The growth and distribution of macrobenthic fauna are influenced by water temperature and salinity which acts as regulators of their reproductive cycle (Ingole and Parulekar, 1998). The macro-benthic abundance (66,019 no./m^2) recorded during year 2003-04, was found to be higher as compared with 1995-1996 (2,757 no./m^2) which could be due to improved food supply (Ingole, 2002) and enhanced salinity (Das, 2004). During 2003-04, maximum abundance was observed in central sector (29,433 no./m^2) followed by northern (22,656 no./m^2), southern (8,916 no/m^2) and outer channel (5,014 no./m^2) (Fig.11).

Assessments in 1988 indicated the presence of 117 species of macro-benthos in Chilika, prominent groups being foraminifers, nematodes, polychaetes, ostracods, isopods, amphipods, gastropods and pelecypods (Sarma *et al.,* 1988).

Post hydrological intervention, 44 species of macrobenthos were recorded in 2003-05 (Patnaik *et al.,* 2009). Abundance was observed to be highest during summer and the lowest during monsoon indicating peak reproductive period (Harkantra and Parulekar, 1985). The important variables controlling the distribution and abundance of benthic organisms in tropical environments are salinity (Parulekar and Dwivedi, 1974) and sediment stability (Alongi, 1990; Wildish and Kristmanson, 1979; Warwick and Uncles, 1980). This holds true for the northern sector during monsoon which records lowest abundance during this season (Patnaik *et al.,* 2009).

The reduction in number of macrobenthic species, from 117 to 44 needs to be interpreted with caution, as the studies were of limited duration and sampling frame. As holds good for several other groups, consistent monitoring systems are required for better understanding of the diversity pattern.

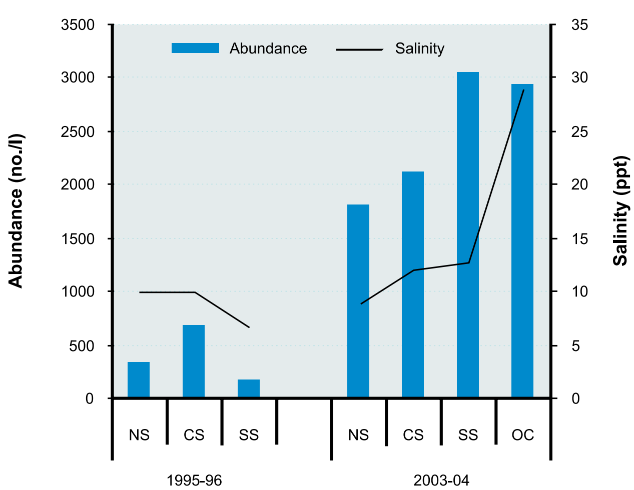


Fig.10: Salinity and zooplankton abundance in Lake Chilika
(Data source: CIFRI, 2006; CDA Monitoring Records)

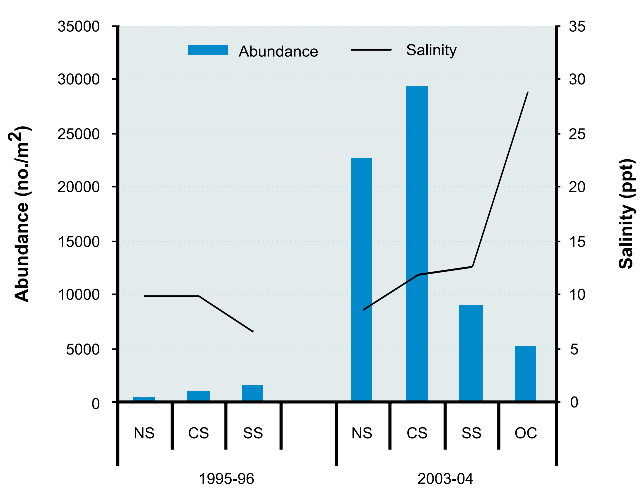


Fig.11: Salinity and macrobenthos abundance in Lake Chilika
(Data source: CIFRI, 2006; CDA Monitoring Records)

Fish

Chilika fisheries form a key basis for supporting local livelihoods, and thereby is an important component of food-security infrastructure of Odisha State. Fisheries biodiversity and productivity is primarily monitored through an intensive catch sampling in place since the hydrological intervention of 2000. Additionally, CDA has also commissioned research on maximum sustainable yield and migration patterns through the Central Inland Fisheries Research Institute (CIFRI). The current section is built on the analysis of catch data for 2000-11, specific assessments by CIFRI and historical studies on various aspects available since 1915. The overall fisheries monitoring framework is summarised as Annex III.

Diversity

Lake Chilika provides suitable habitat for a range of catadromous, anadromous and endemic finfish and shellfish species. As per assessments by CDA, Chilika harbours 314 fish species belonging to 86 families. In addition to this 29 species of prawn and 35 species of crab are found in the lake (Annex IV). Of this, 64 are true freshwater, 94 marine and 156 brackish water species (Annex V). Overall, 62 species contribute to the commercial landing (species contributing more than 1% to the total landing) (Annex VI).

Historical records of fish diversity of Chilika are available since the pioneering studies undertaken by Zoological Survey of India in 1914. Annandale and Kemp (1915) recorded 115 fish species in the lake. Jones and Sujansinghani (1954) further increased the number of species to 138, with 25 new records. Fish diversity, prior to the opening of new mouth stood at 225 species of fish (149 genera, 72 families and 16 orders) 24 species of prawn (13 genera, 9 families, 16 orders) and 28 species of crab (22 genera, 9 families and 1 sub-order) (Mohapatra *et al.,* 2007). This included 38 commercially important species. The economically important species i.e. *Megalops cyprinoides, Elops machnata, Rhinomugil corsula, Chanos chanos, Tenualosa hilsa, Acanthopagrus berda* have reappeared after the hydrological intervention.

Migration patterns

More than 70-75% of fishes and 70% of marine prawns and crabs which contribute to the Chilika fishery are migratory (Banerjee *et al.,* 1998 and Mohanty, 2002). Migration pattern of catadromous and anadromous species is triggered by salinity changes. As on date, tagging experiments are being carried out to assess migration behaviour of six commercially important species, i.e. *M. cephalus, L. troschelli, E. tetradactylum, L. calcarifer, S. sarba and D. albida*. Further assessments are still required to understand migration from riverine and marine systems.

Lake Chilika serves as an ideal habitat for 207 species undertaking river-lake-sea migration and vice-versa. Of this 15 species are catadromous, 13

Mud crab contributes significantly to commercial landing since 2000 anadromous, 110 amphidromous, 36 potamodromous and 33 oceanodromous (Annex VII). The river confluence area serves as breeding ground for 18 freshwater species (Pattnaik *et al.,* 2004). The outer channel serves as an important spawning ground for several commercially important fish (*E. tetradactylum, L. calcarifer, M. cephalus*), prawn (*P. monodon, P. indicus*), and crab (*S. serrata* and *S. tranquebarica*). The northern sector is potential zone for breeding and spawning of euryhaline species of which *T. ilisha* is most important. The central sector of the lake provides an ideal environment for breeding and spawning of resident species and serves as the nursing ground of *M. cephalus, E. suratensis, L. calcarifer, E. tetradactylum, T. ilisha, D. albida, P. monodon, P. indicus* and *S. serrata*. Southern sector serves as the spawning and nursing ground of *P. indicus* and nursing ground for *E. suratensis, E. tetradactylum, M. cephalus, L. calcarifer, D. albida* and *P. monodon* (JICA, 2009a). The breeding and feeding grounds of some commercially important species are indicated in Map 22 and 23.

The tidal influence being accessible throughout the year aids in recruitment of stocks subjected to the breeding cycles of the various species. The sectoral affinity of larvae is supported by the richness of planktons sustained by the sector (Kowtal, 1967). Auto-recruitment also continues in the lake by resident species (eg. *E. suratensis*), since most of these are perennial breeders. Details of brood and juvenile recruitment of commercially important species are presented at Annex VIII.

Temporal changes in breeding and nursing grounds can be discerned through an analysis of assessments made in 1950s and 60s (Table 9). The most noticeable shift is in the breeding ground of Hilsa from middle and upper reaches of Daya and deltaic branches of Mahanadi to the areas near mouth of Makara. This can be attributed to reduction in monsoon flood discharge through Daya and the main discharge taking place through Makara. In general, a shift in breeding and nursing grounds towards Magarmukh is observed for the species previously using Northern Sector. *M. cephalus* which used to breed only near lake mouth is reported to use the entire outer channel habitat. However, these assessments are based on few species and further studies are required for a fuller understanding of breeding and migration behaviour.

Table 9 : Comparative account of breeding and nursing grounds during 1960 and 2006

Breeding Ground	Jhingran and Natarajan, 1966	JICA, 2009a
M. cephalus	Breeding near lake mouth	Breeding near new lake mouth and Magarmukh
T. ilisha	Upper and middle stretches of Daya and deltaic branches of Mahanadi	Northern Sector near mouth of river Makara
D. albida	Tuanali close to river Daya	Near Magarmukh
E. tetradactylum	Northern sector near river Daya	Near Magarmukh
L. calcarifer	Near lake mouth	Near new lake mouth
E. suratensis	Western shore areas of northern, central and southern sector and Palur canal	Restricted to small patches in central and southern sectors
P. monodon	Lake mouth	Not studied
P. indicus	Lake mouth	Not studied
Nursing Ground		
M. cephalus	Outer Channel	Outer Channel
T. ilisha	Lower stretches of Daya and river confluence area in northern sector	Lower stretches of lead channel area in northern sector
D. albida	Shoreline and river confluence areas of northern sector	Tuanali near Magarmukh
E. tetradactylum	Throughout northern sector	Eastern areas in central sector in between Nalban and bordering islands
L. calcarifer	Outer channel	Outer channel, Magarmukh and western shoreline areas of southern sector
E. suratensis	Throughout the lake	Small pockets in Central sector
P. monodon	Eastern shores and outer channel	Outer channel, southern sector and central sector
P. indicus	Eastern shores and outer channel	Outer channel, southern sector and central sector

Box 3: Hydrological regimes and fish migration

Dynamic hydrological regimes of Lake Chilika play an important role in influencing salinity regimes and thereby migration. With the onset of monsoon and increase in freshwater flow, there is a sudden fall in lake salinity which triggers the gravid *P. monodon, P. indicus and M. monoceros* to undertake migration to high saline areas near the lake mouth for breeding (Fig. 12). Fall in salinity with low flows from July till end of August acts as a stimulus for *T. ilisha* to ascend the river Daya and Makara for breeding. The seaward migration of *M. cephalus* also starts during this period and extends upto December. Increase in flow pulses during September and October flushes the juveniles of *T. ilisha, E. tertadactylum, E. suratensis, P. canius* along with the seeds of a number of minor and major carps, catfishes and featherbacks from river into the lake.

The stable flows during winter months with rise in salinity aid in lakeward migration of marine brood stocks of *N. nasus* and *A. arius* and seaward movement of *S. sarba, C. crenidens, P. monodon and M. dobsoni*. The tidal influx during the dry period brings along with it the juveniles of *P. monodon, P. indicus and M. dobsonii* which require a salinity lower than that of the sea during their post-larval stages. Juveniles of *E. tetradactylum, C. chanos, Thryssa* sp., *E. saurus, S. sarba* and *M. cyprinoides* are encountered in the outer channel area during the summer months which mainly enter the lake for feeding purpose.

The freshwater flow from northern sector and the intermediate floods are highly essential for addition and distribution of fish stocks in different sectors. The inflow of freshwater during monsoon aids in flushing out the anoxic conditions by inundating the areas rich in nutrients and providing a conducive environment for growth of fish food organisms which in turn influence the recruitment of juveniles.

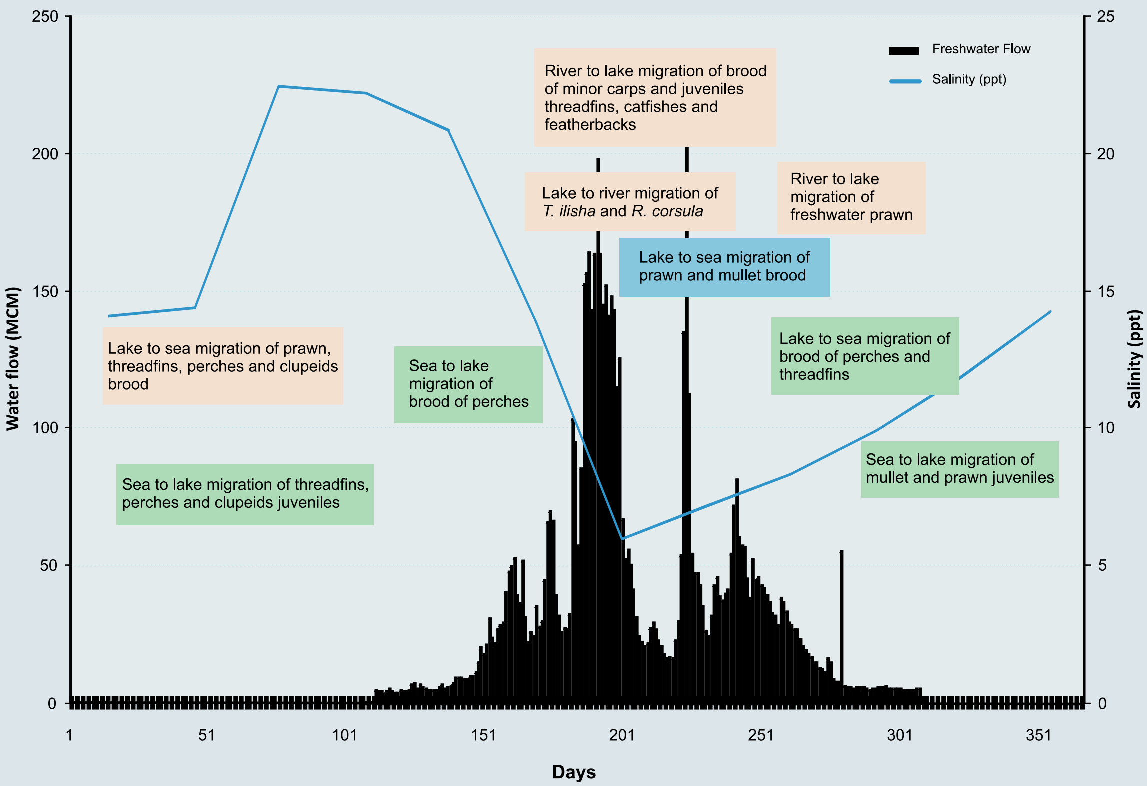
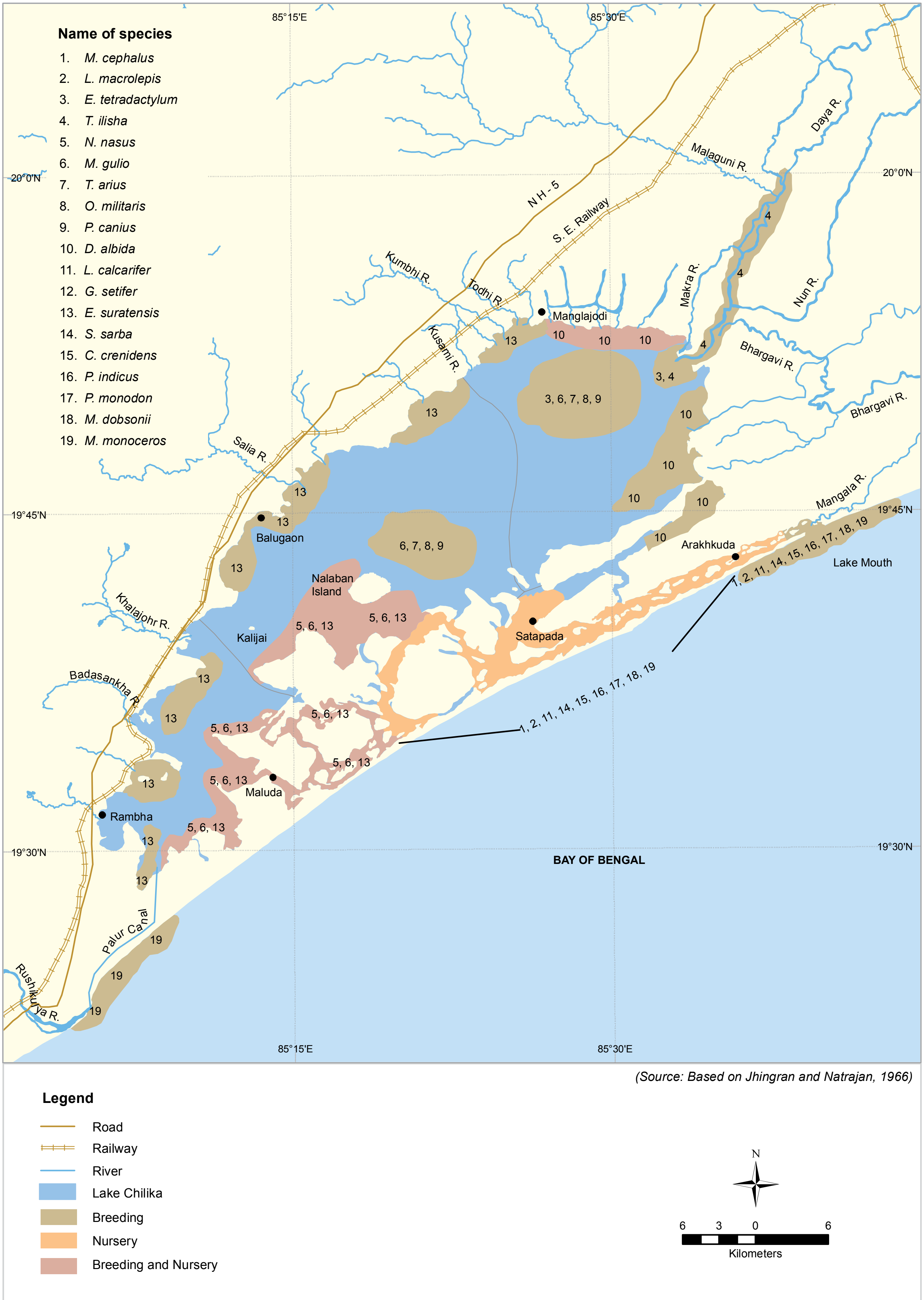
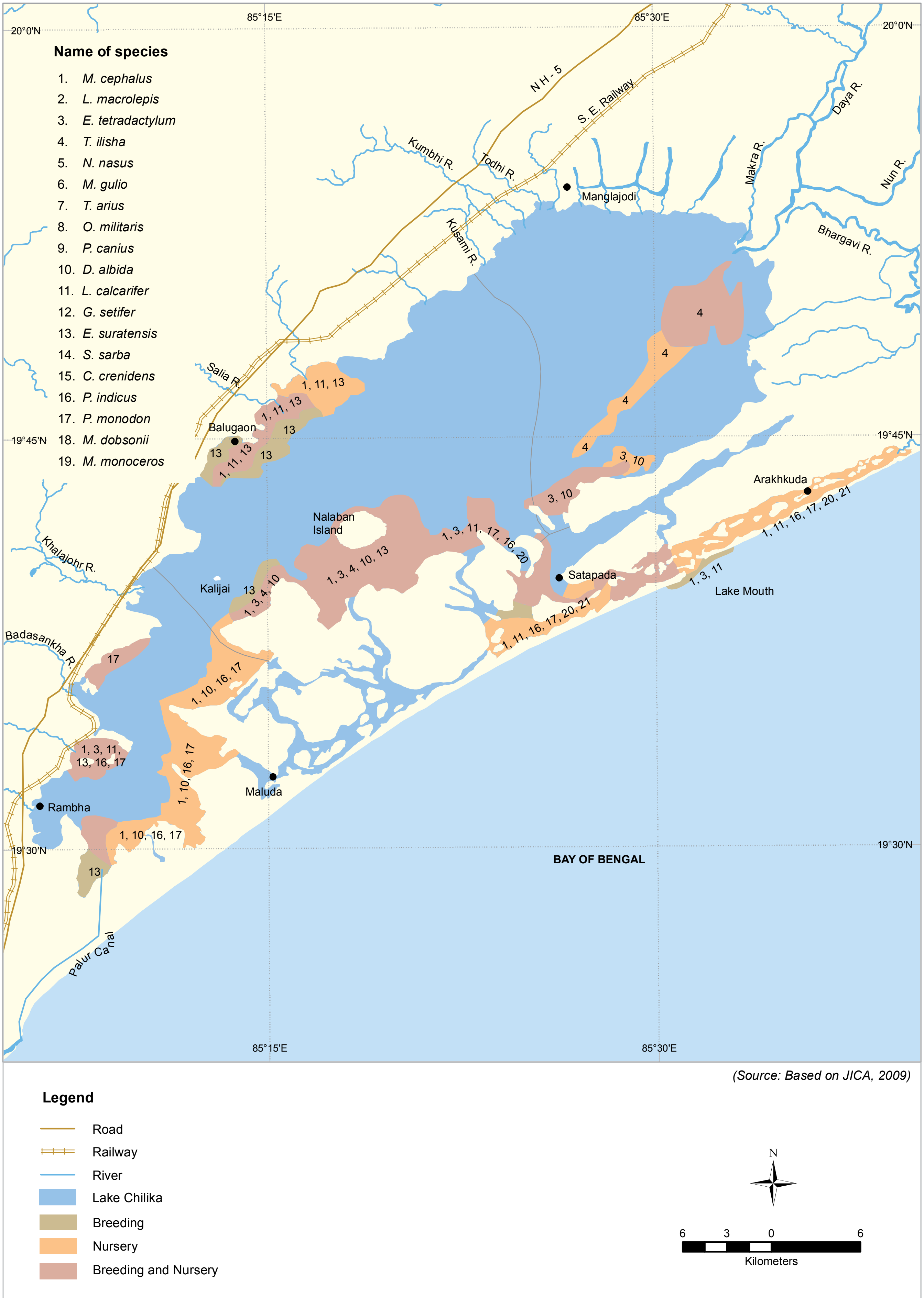


Fig. 12 : Hydrological regime influencing salinity and recruitment



Map 22: Fish breeding and nursery grounds in Lake Chilika (1960)



Map 23: Fish breeding and nursery grounds in Lake Chilika (2006)

Fish Yield

The average annual fish yield of Lake Chilika during 2001-11 was 11,961.37 MT. There was sharp decline during 1986-1999 (from an annual total landing of 8,861 MT to 1,734.9 MT) linked to declining salinity regimes amongst other factors. The hydrological intervention has played a distinct positive role in restoring the yield (Fig 13 a and b).

The potential annual fish yield of Lake Chilika was assessed in 2003-04 to be 27,153 MT provided all the environment parameters function at an optimum level including the unhindered recruitment of fish, prawn and crab, both from riverine and marine sources. The maximum sustainable yield (MSY) calculated from the catch and effort data indicated that the system could sustain a catch of 1,053 MT/month to 1,158 MT/month i.e. 12,636 MT/year to 13,896 MT/year (CIFRI, 2006). The current yield[3] levels almost match up the potential yields.

The major groups contributing to catch during 2011-12 were clupeids (11.66%) and catfishes (8.51%). Mullet catch which had declined to 4.96% during 2001-02 was found to gradually increase to 7.77% during 2011-12. The share of brackish water species in catch has significantly increased since 2000 (Fig. 14).

Perches, polynemids, cichlids, tricanthus, murrels and featherbacks registered a decline in the catch contribution. *Chanos chanos* and Elopiformes which were absent in the commercial landings before opening of new mouth registered a phenomenal annual growth rate of 71.87% and 143.61% respectively during 2003-04 (Mohapatra *et al.,* 2007).

On an overall, the relative proportion of landing has shifted in favour of prawn and crab species (Fig. 15). *M. monoceros* is the most dominant shrimp contributing 31.32% of the total prawn landing, followed by *M. dobsonii* (28.7%). The relative catches of *P. monodon* and *P. indicus* increased during the post-intervention phase (Mohapatra *et al.,* 2007).

Post hydrological intervention, there has been an exceptional increase in the crab landings. Data of 2000-11 indicates a steady rise of their contributiong to total commercial landing from 0.34% in 1995 (4.5 MT) to 2.61% in 2011 (372.17 MT). Two species, *Scylla serrata* and *S. tranquebarica* formed the major portion of mud crab fishery during post-intervention period. Their utilization of the southern sector habitat is a post hydrological intervention phenomenon, and has not been reported in earlier studies. *Portunus pelagicus* also contributes to the commercial landing during the high salinity (post-winter and pre-monsoon) months in the post intervention period.

The hydrological intervention of 2000 has improved the CPUE as compared to 1996-2000. Mohapatra *et al.* (2007)

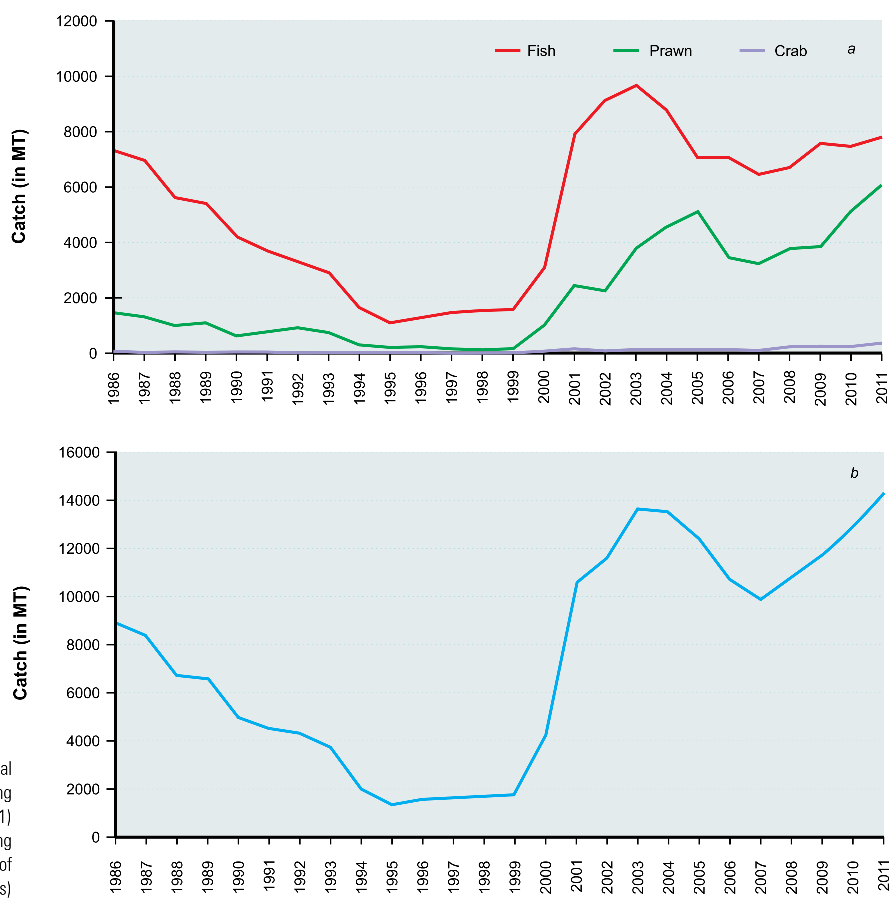


Fig. 13 a and b: Trend in annual fish, prawn and crab landing (1986-2011)
(Data source: CDA Monitoring Records; Department of Fisheries)

[3] It should be noted however that the yield data excludes production from illegal prawn gheries. Further, the catch estimate represents the yield of only commercially important species with no information on the by-catch.

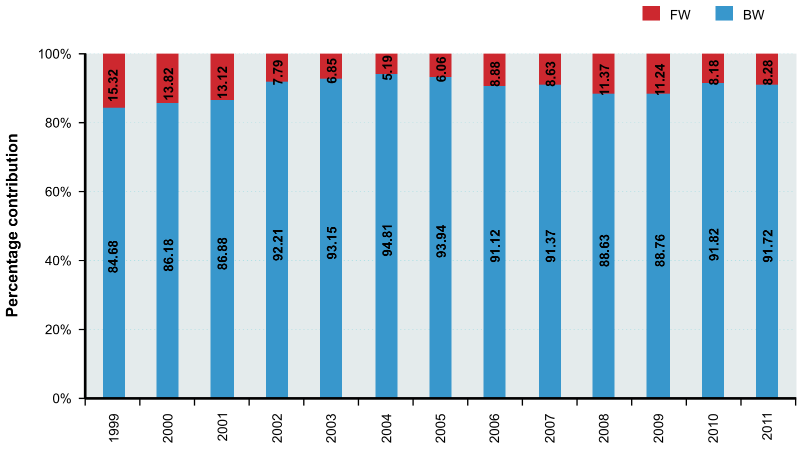


Fig.14: Percentage composition of freshwater and brackish water species in commercial fish catch
(Data source: CDA Monitoring Records; Department of Fisheries)

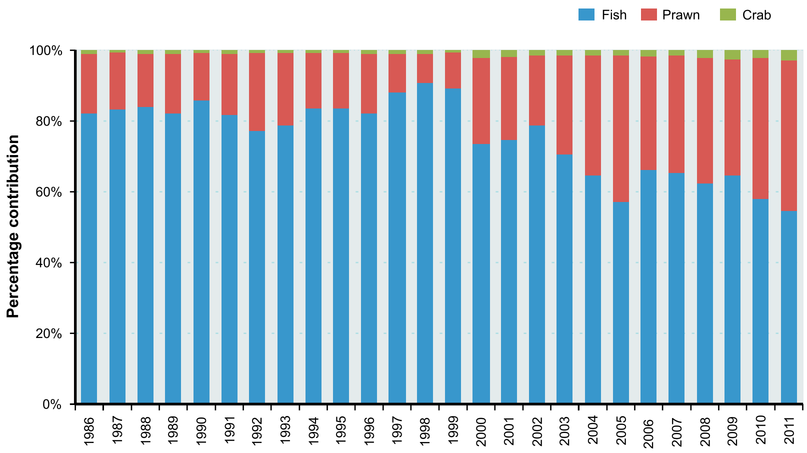


Fig. 15 : Percentage contribution of fish, prawn and crab to total landing
(Data source: CDA Monitoring Records; Department of Fisheries)

reported increase in CPUE from 1.1 to 6.2 kg boat^{-1} day^{-1} during 1996-2004. However, trend analysis of the catch, boat and active fisher data (from various availale sources) indicate a stagnation in catch per boat and catch per active fisher (Fig. 16).

Crafts and gears

Fishing in Chilika is done using a range of crafts and gears. However, the catch is dominated by *khonda*[4] and gills nets. An assessment carried during October 2007-September 2008 indicated that 48% of commercial landings were through use of khonda followed by 32% using gill nets. The rest is harvested using drag nets, sieve nets, long lines, scoop nets and cast nets.

The use of gears has undergone a massive shift over a period of time. Jones and Sujansinghani (1954) reported use of over 15 types of gears under 54 different names, each suited for a distinct species and operated by a fisher caste (Jones and Sujansingani, 1954; Sekhar, 2004). The use was also related to depth profile of the lake (Map 24). Net fishing areas, called *bahani*[5], were largely confined to areas with higher depth and *janos*[6] in shallow areas. Net fishing was practised in approximately 29% of the fishing areas and mostly concentrated in shoreline areas of northern, central and southern sectors towards the western side and in some portions of the central sector close to Magarmukh. *Jano* grounds were also used for *bahani* and prawn fishing in southern and central sectors which was 16% of the total fishing area. The prawn grounds were found mostly in the northern sector above the Tuanali near the river confluence area and in some isolated pockets in central and southern sector. The prawn grounds were approximately 13% of the total fishing area where capture prawn fishery was practised.

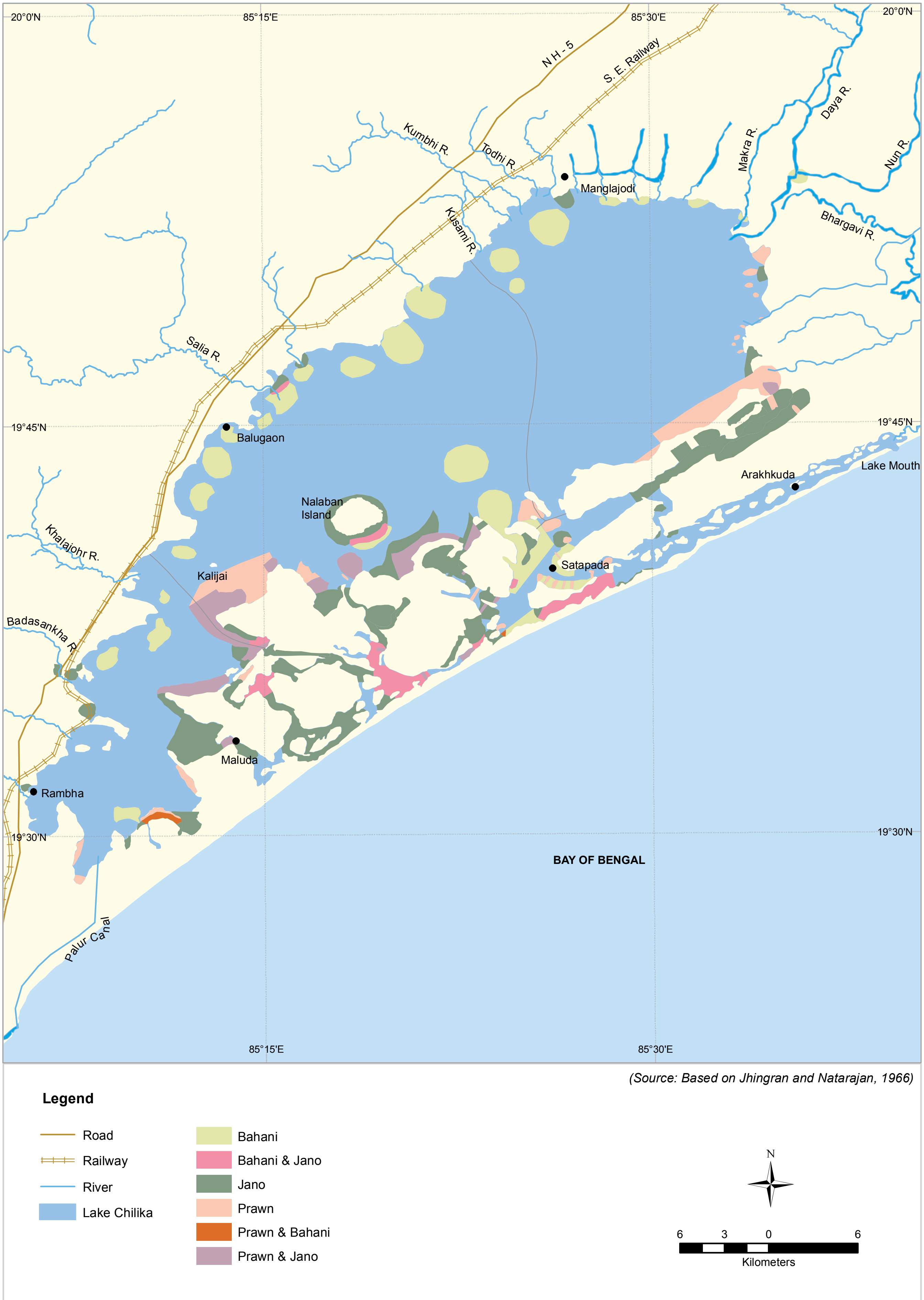
With the onset of prawn culture in Chilika during early 1990s, the *jano* and *bahani* areas in the shallow zones were occupied by prawn *gheries*[7] (Map 25). A total of 33 leased *bahani* grounds operational in the lake during 1960 reduced in area due to *ghery* operation. Similarly 112 units of *jano* which were operational in the lake during 1965 became non-existent after 1995. A total of 67 units of prawn khatis or traps operational in the lake were non-existent and a few were replaced by the *ghery* and *khonda* fishing grounds.

[4] Fixed nylon nets having a wing of 20-60 cm length net of 20-25 mm mesh that meets a 10m semicircular net area with 0mm mesh and two box trap or 'puda' (2mx1.5mx1.5m) with net of 10-15m mesh.

[5] Net impoundments erected with split bamboos used during the period October-February for prawn and fin-fishes

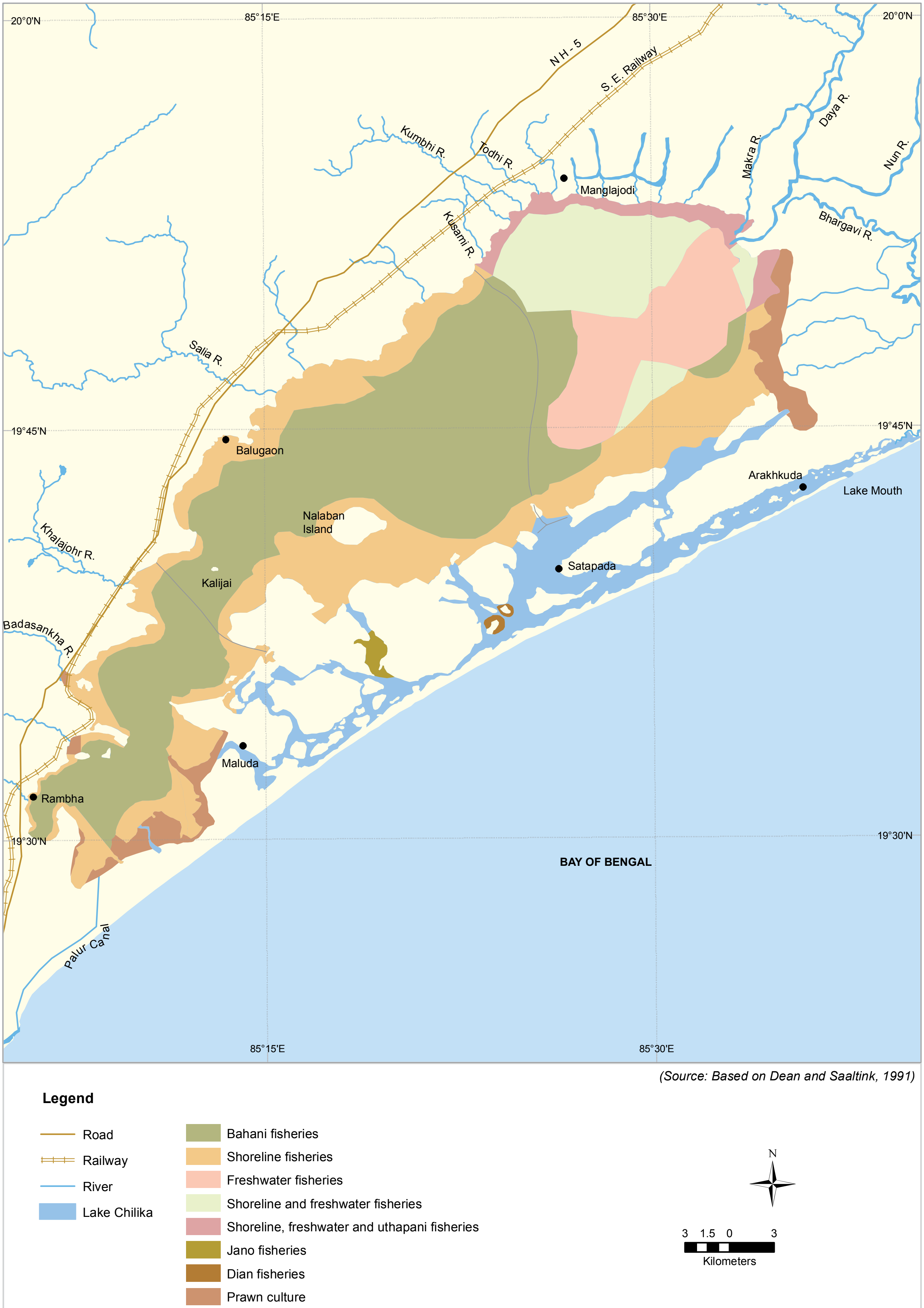
[6] Net fishing

[7] Enclosed water bodies by earthen bundhs or bamboos and nets



(Source: Based on Jhingran and Natarajan, 1966)

Map 24: Fishing grounds in Lake Chilika (1960)



Map 25: Fishing grounds and fishing practice in Lake Chilika (1990)

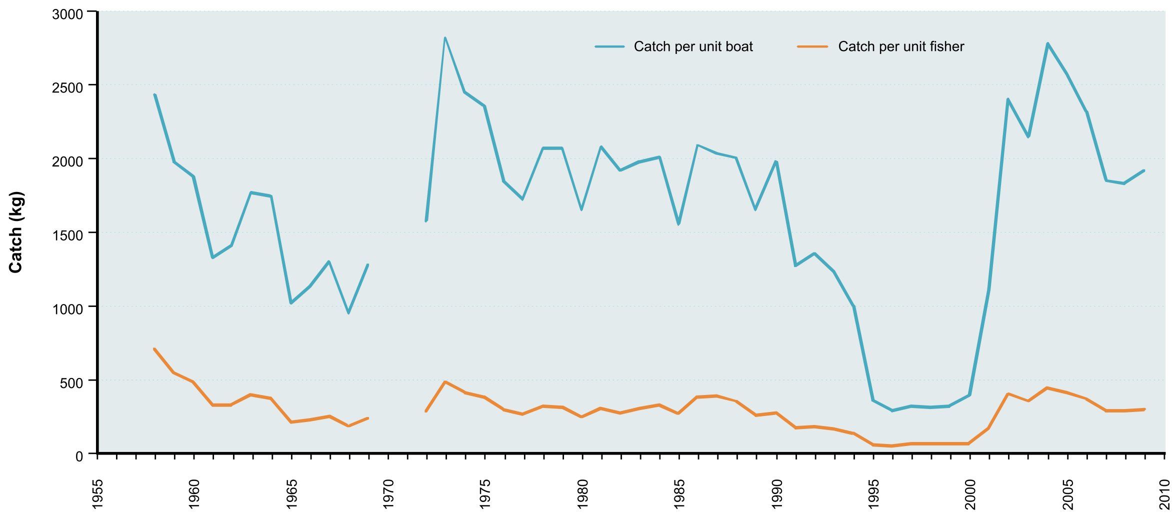


Fig. 16 : Trend in catch per unit boat and catch per unit fisher (Data source: Mitra & Mahapatra, 1957; Rao, 1982; Biswas, 1995; Samal & Meher, 1999, JICA, 2009b, CDA Monitoring Records)

The 111 units of *Dian*[8] fishery were occupied by illegal *gheries* and the *Uttapani*[9] grounds became non-existent. In recent years, approximately 30% of the lake area has been encroached by *gheries* and *khondas* (Map 26). A detailed analysis of changes in fishing crafts and gears, along with institutions is presented in Social capital subsection of Livelihoods section.

Trends representing breeding and nursing grounds (Map 21 and Map 22) and change of gears (Map 24 and Map 26) are indicative of their exploitation for commercial fisheries. The *jano* areas of 1960s coincided with the major nursing areas of *M. cephalus* (Map 27). Jhingran (1963) ascribed around 60% of mullet catches to these areas. The decline in mullet fisheries coincides with occupation of *jano* areas by gheries for prawn culture. Further discussion on caste dynamics and power relationships is done in the livelihoods section of the report.

There has also been a change in the type of fishing boats. Traditionally, fishing boats in Chilika were wooden planked flat bottom known as *'Naha'*. Each fishing trip lasted nearly 4 to 5 days (Jones and Sujansinghani, 1954). With introduction of motorized boats, the number of non-motorized boats almost stagnated. Based on survey in 2007, the number of fishing boats in Chilika was estimated to be 5,600, 40% of which is mechanized. The fishing trip duration has also reduced to 1 day.

[8] Entrapping fishes by mud walls and nets when they move from *Jano* areas towards upland shallow waters

[9] Fishing in shallow areas adjacent to shore land

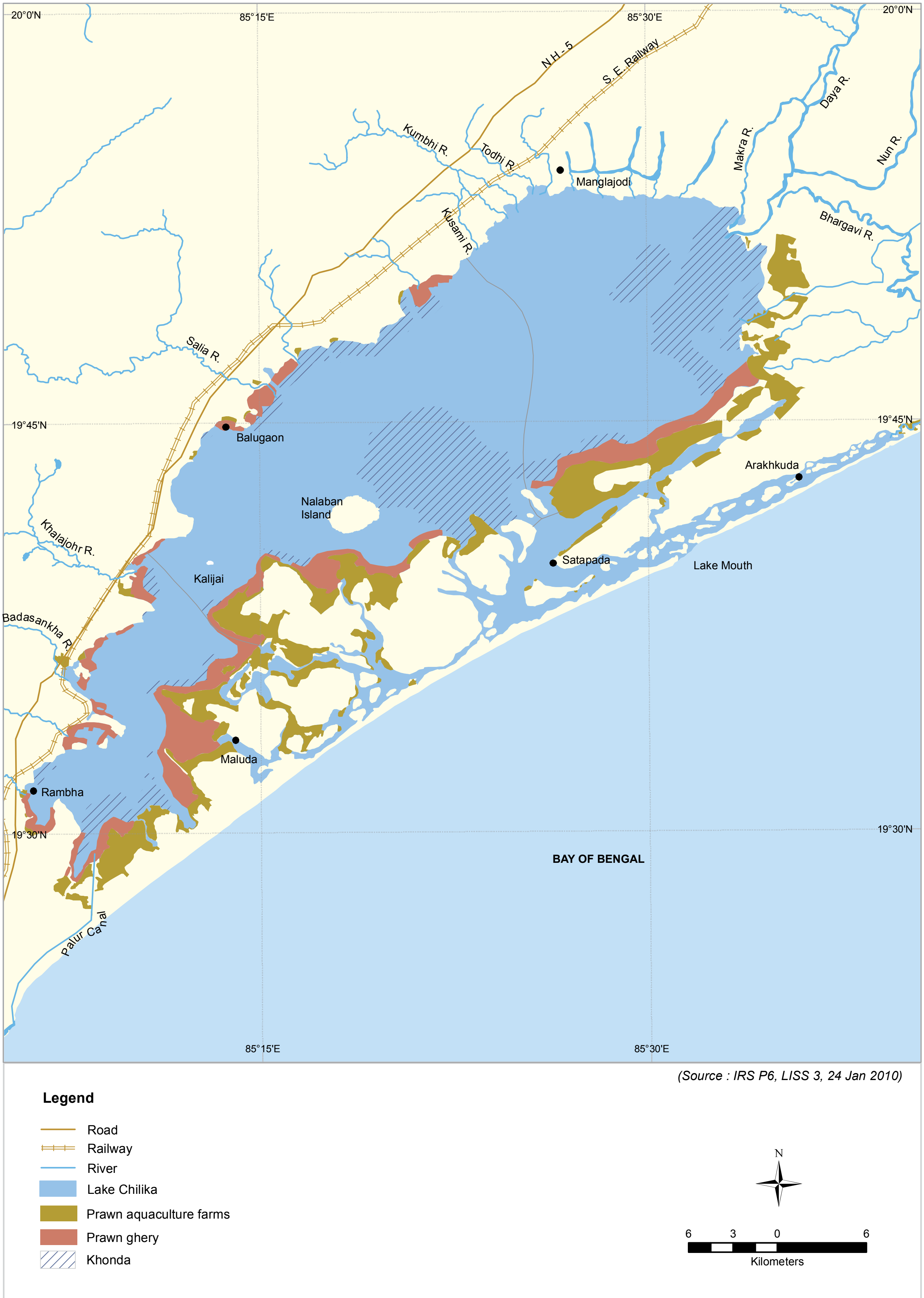
Infrastructure

The infrastructure supporting fishing activities in the lake include landing centres, jetties, ice factories and transport facilities (Map 28).

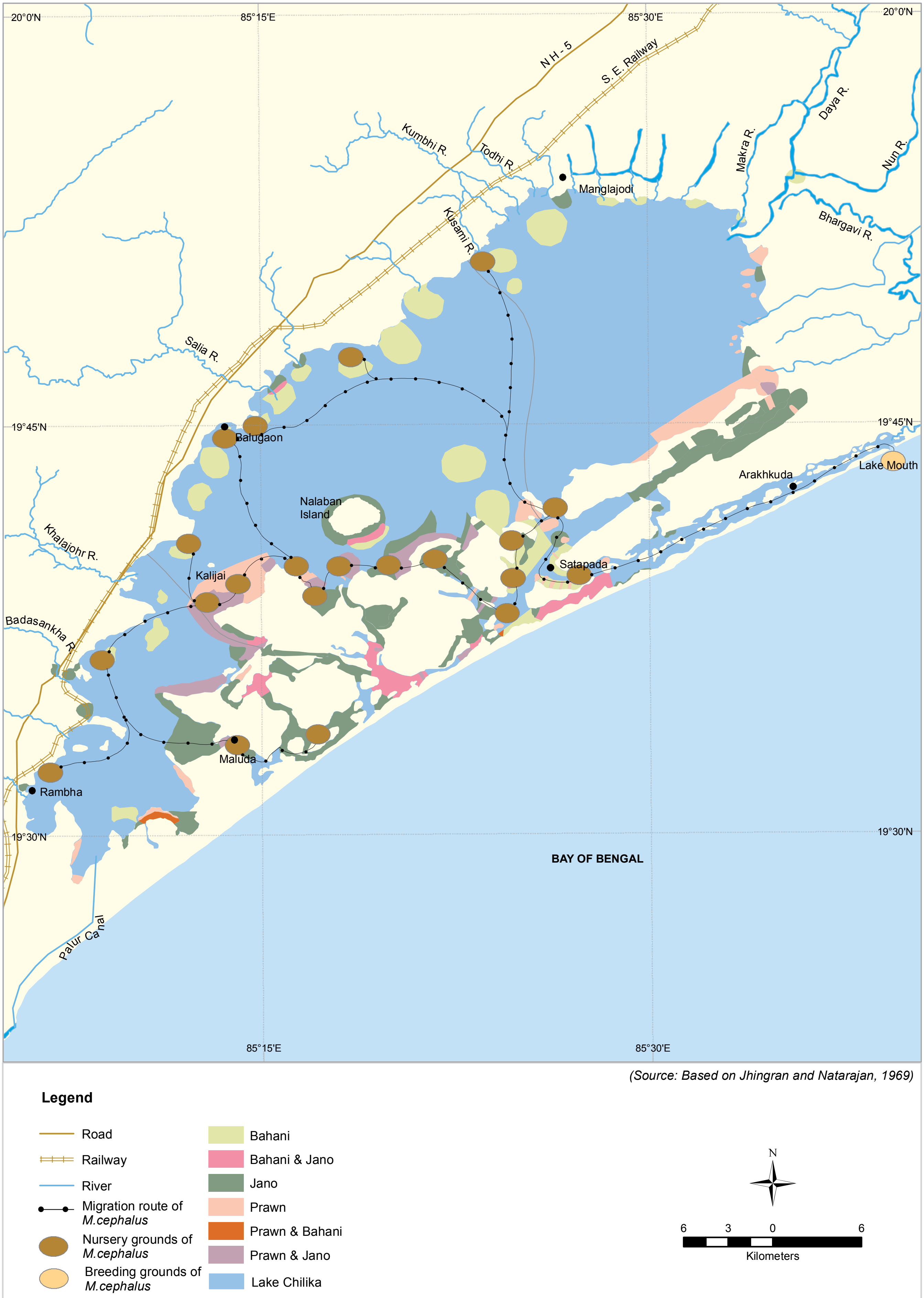
A total of 18 fish landing centres are operational around Chilika. Majority of landing centres (15) are present in the south-western shore of the Lake. Sorana, Balugaon, Kalupadaghat and Bhusandapur handle around 80% of the total annual landing. Two village fish markets in Maluda and Jadupur directly receive catch from fishers on daily basis. Additionally 14 private prawn collection centres are present on the eastern parts of the lake which collect the capture prawns directly from the fishers for supplying to the processing plants. A few centres also collect the prawns from gheries which do not come to the fish landing centres and contribute to the total landing. Instead they are directly procured from the culture gheries by the processing companies through agents.

There are 10 jetties in Lake Chilika, 8 in the western shoreline and 2 in the eastern part. The 8 jetties in western shoreline 6 are used for landing the fish catch. The jetties are well connected with roads.

Crushed ice is used for preservation of fish during transport from the fishing grounds to the landing centres and export to the consuming centres. A total of 21 ice factories are present in and around the major landing centres of Chilika. The total quantity of ice produced from these factories during 2001-02 was 214 MT which is 56 times less than the fish produced during the year. Approximately 88% of the fish produced are transported to markets in different districts and state and even exported to other countries. During summer equal weight of



Map 26: Destructive fishing practice in Lake Chilika



Map 27: Migratory route of *M. cephalus* in Lake Chilika during 1960s

Map 28: Fisheries infrastructure around Lake Chilika

Fish catch being preserved with ice for transport to markets

ice is required for transporting a specific weight of fish and during winter the requirement of ice reduces to two-fourth of the weight of fish. Considering the requirement for transporting the catch from fishing grounds to landing centres the need increases many folds.

The fish catch from Chilika is transported to local markets, nearby districts, states and international markets in the form of fresh, live, dry fish and frozen fish. The catch is dispatched by railway or road transport. Seven railway stations bordering the western shoreline of Chilika dispatch the catch to different states of the country which include West Bengal, Jharkhand, New Delhi, Madhya Pradesh, Tamil Nadu, Gujarat, Kerala and Andhra Pradesh. For transportation by road, the catch is packed at private merchant godowns at landing centers on daily basis and brought to 'Bent Dhaba' at Chandpur and transported by lorries and trucks to West Bengal.

Destructive fishing practices

Lake Chilika is also subject to several detrimental fishing practices which threaten the overall sustainability of the operations (Map 26).

Ghery Aquaculture

Aquaculture was introduced in the peripheral area of Chilika under the "Economic Rehalitation of Rural Poor" scheme with an objective of poverty alleviation (Mohanty *et al.,* 2004). In 1983-84, culture of *P. monodon* was introduced in 1500 ponds of 0.2 ha area each. Culture period of 9-10 months for a single crop yielded 300-600 kg/ha and an additional average income of Rs 40,000-60,000/ ha per family per year (CDA, 2004). The demand of *P. monodon* in international market led to illegal

Collection of post larvae of *P. monodon* is highly detrimental to lake biodiversity

encroachment of the traditional fishing grounds *janos* by local people and *mafias*. The shallow fringe areas were enclosed with earthen embankments and nets to form large enclosed water bodies covering thousands of hectares. This has also contributed towards the sedimentation process and developed anoxic conditions. The earthen embankments even reduced the flood cushioning areas. The traditional fishers have lost their fishing grounds which has led to social conflicts.

Intensive culture of *P. monodon* requires supplementary feeding of 2,352 kg. Excess feed, faecal matter and metabolites exert tremendous influence on the water quality of the shrimp ponds. (Pushparajan and Soundarapandian, 2010).

Spread of aquaculture has also led to increase in collection of *P. monodon* seed from wild. Local people engaged in collection of post-larvae throw away seeds of other species (CIFRI, 2006). This poses a threat to the overall diversity of fin and shell fish population by destroying their juveniles.

Use of nets of smaller mesh size

The *Khonda* with small meshed net boxes (*Pudas*) are operated intensively throughout the lake where juveniles of *P. monodon* are more concentrated during December-March. *Khonda* sieves out the larvae, post-larvae and juveniles available in ambient water which has lead to heavy loss of seeds and juvenile. *Khonda* fishing is mostly concentrated in the recruitment routes such as Outer Channel, Palur canal and dredged channel (Map 26). These nets are arranged in rows, to capture the mature spawners (JICA, 2009a). More than 98% of the pre-mature spawners of *M. cephalus* are caught by *Khondas* during their breeding migration to sea (JICA, 2009a).

Khonda nets placed in the outer channel

Nylon nets with different types of synthetic floats were introduced during 1970s. Subsequently nylon nets with smaller mesh size have been operational in the lake (popular brands being 'zero', 'mantle', 'boby', 'super' and 'disco' nets) mainly in Magarmukh, Nalaban, dredged lead channel and western part of Tua-gambhari island. This leads to considerable economic loss in the form of lost potential cath (Table 10).

In addition to this, the fishers also catch brood fishes by cast nets in outer channel area. The absolute fecundity of *M. cephalus* being 1,403, 808 eggs (Sikoki *et al.,* 2001), economic loss to fishery is aggravated when the fishers remove the ovary for drying and selling in market. One mullet brood if allowed to breed in coastal water can produce 10,000 juvenile (considering only 0.5% survival) which can yield about 5 MT of fish valued Rs 3 lakh. This value is completely lost when the brood mullet is captured and killed.

Fishers using seine nets in Lake Chilika

Table 10: Economic loss due to catch of juveniles (2001-2002)

Species	Estimated Juvenile catch (MT)	Av. size at capture (g)	Av. harvestable size (g) and av. survival	Estimated yield loss (MT)	Estimated revenue loss as per base price during 2001-02 (Rs in lakhs)
P. monodon	32.64	7.5	40g, 60%	71.86	412.79
E. tetradactylum	36.17	30	600g, 55%	434.04	276.71
D. albida					
D. russelli	49.19	25	400g, 65%	249.55	69.87
E. suratensis	32.32	18	225g, 65%	230.28	75.55
Total	151.04			985.73	834.92

(Source: Annual Report 2001-02, CDA)

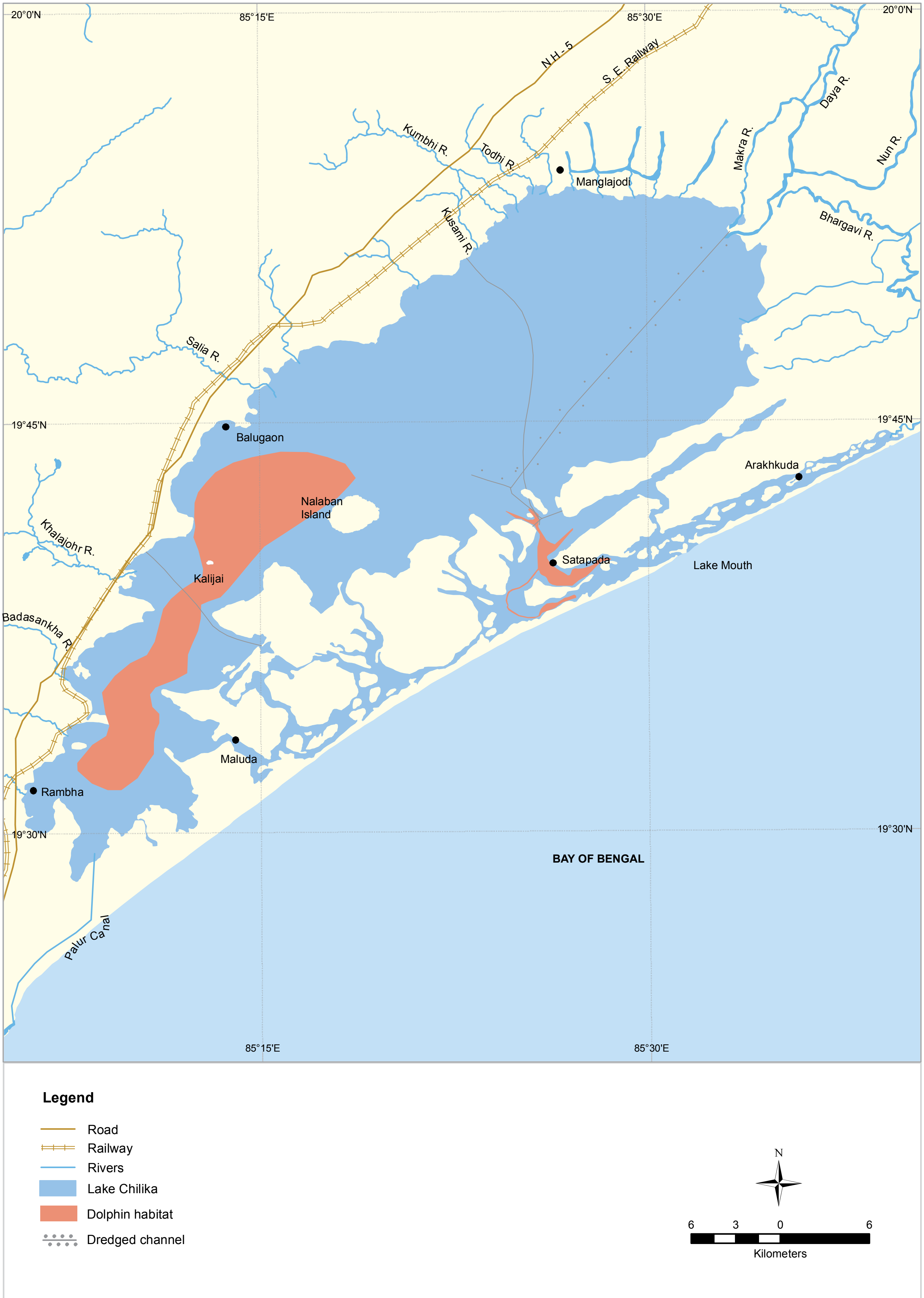
Dolphins

Orcaella brevirostris (Irrawaddy dolphin) is the flagship cetacean inhabiting Lake Chilika. Chilika is one of only two known lagoons in the world that support Irrawaddy Dolphin populations, the other being Lake Songkhla in Thailand. The species is found confined within Asia, between Chilika and Indonesia. Irrawaddy dolphins are globally threatened, but have an increasing population in Chilika (Map 29). In 2011, the total population was 156, including 131 adults, 21 sub-adults and 4 calves (CDA, 2011). Genetic studies on the species indicated close proximity to haplotypes of Thailand (Jayasankar *et al.,* 2011).

Irrawaddy dolphins were first recorded in Chilika lake in 1915 (Annandale and Kemp, 1915) but information regarding their numbers, movements between coastal and lake water remained fragmented. During 1985-1987 dolphins restricted themselves in the outer channel in winter and summer (Sinha *et al.,* 2000) which could be due to higher concentration and density of the fisheries resources and complexity in the benthic profile in outer channel. A total of 60-70 dolphins were reported by Dean and Saaltink (1991) which reduced to 20 in 1992 (Mohanty and Otta, 2008) (Fig. 17). The degradation of lake created a discouraging environment for the Irrawaddy dolphins (Stacey and Leatherwood, 1997).

CDA has accorded conservation of dolphins a key priority. Intensive programmes have been undertaken for making the community aware of the biological behaviour of the mammal. The habitat has also been improved by dredging the outer channel, and improving the lake-sea connectivity. Systematic assessments of habitat use indicate an increase in

An Irrawaddy Dolphin in Lake Chilika (photo by Muntaz Khan)



Map 29: Dolphin habitat in Lake Chilika (2011)

Nalaban supports the highest congregation of birds in Lake Chilika

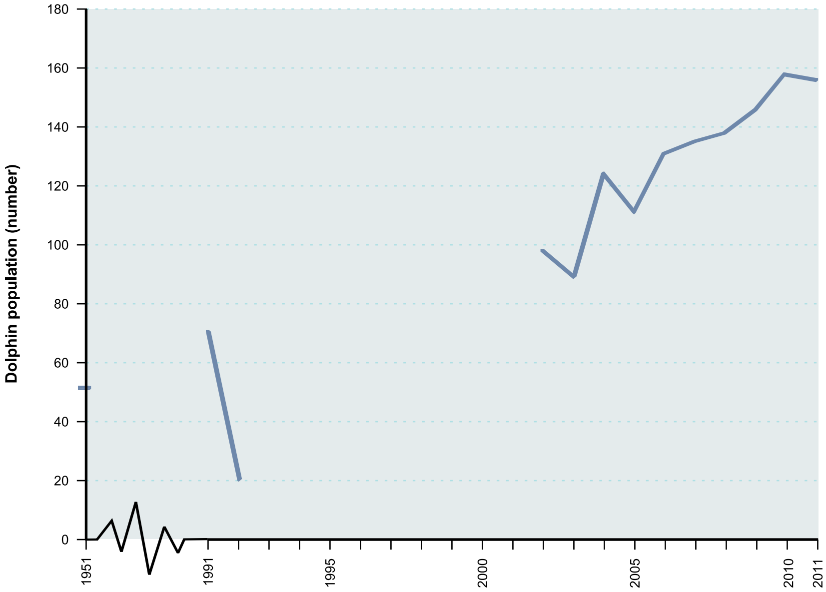


Fig.17 : Trend in dolphin population
(Data source:Dean & Saaltink, 1991; CDA Monitoring Records)

area, with their presence also recorded in southern and central sectors, which was only limited to outer channel in the past. Number of causalities due to fishing and tourist boat operations has also come down drastically, with no such instances in last three years.

Birds

Chilika is known for harbouring a wide range of bird species, which apart from being a key component of its biodiversity are also a tourist delight. Assessment of diversity and number of birds in Chilika has been systematically carried out by Bombay Natural History Society (BNHS) since 2000. BNHS has also been conducting bird migration studies in Chilika since 1960s. A bird atlas compiling information from 2001-09 assessments has also been published (Balachandran *et al.,* 2009).

Lake Chilika provides habitat to 224 bird species belonging to 50 families (*ibid*) which include 129 waterbird species belonging to 19 families (Annex IX). A total of 97 of intercontinental migrants come from Arctic Russia, West Asia, Europe, North East Siberia and Mongolia. Northern Pintail (*Anas acuta*) and Gadwall (*Anas strepera*) are the most common species amongst the ducks and geese found in the lake. The lake also provides habitat to nine threatened birds species namely Dalmitian pelican (*Pelecanus crispus*), Pallas Fish eagle (*Haliaeetus leucoryphus*), Indian skimmer (*Rynchops albicollis*), Spoonbill sandpiper (*Calidris pygmeus*), Lesser white fronted Goose (*Anser erythropus*) and Great knot (*Calidris tenuirostris*) (Source: IUCN Red Data List).

The BNHS assessment also highlighted the ornithological importance of Lake Chilika. Under Ramsar Criteria 5, a wetland is considered internationally important if it regularly supports 20,000 or more waterbirds. The assessments indicate that the wetland regularly supports 0.7-0.95 million waterbirds annually. It acts as a staging, moulting, wintering and summering sites for the migrant waterbird species and the breeding ground for several resident species. Further, the assessments also indicated presence of 45 species whose population at


Flamingos are one of the most eagerly awaited visitors of Lake Chilika

Chilika exceeded the 1% threshold population. In five species, over 30% of the threshold population was recorded, establishing the significance of the wetland as a key wintering site for waterbird population in the Central Asian Flyway.

Though almost entire shallow regions of the wetland are used as habitat by the birds, Nalaban Island and Mangalajodi stand out in terms of congregation sizes. The Nalaban island (15.52 km^2) is located in the central sector of the lake and provides ideal staging and wintering ground for the wintering birds. The island is completely submerged during monsoon and emerges during winter until late summer. Hydrological changes affect the growth, survival and reproduction of invertebrates and submerged weeds which serve as food for the visiting birds. With decrease in the water level and exposure of mud-flats in Nalaban, waders, Northern Pintail and Gadwall start congregating in shallow areas having maximum abundance of gastropods (Balachandran *et al.,* 2005). Along with this the major food plant for the migratory waterfowl, *Potamogeton pectinatus, Najas* sp. and *Halophila* sp. are abundantly available during this period. Birds remain confined mainly to the island till October end and started disbursing to other sectors from early November onwards (Map 30). During eighties, BNHS recorded 150 species of birds in Chilika of which 90 species were found confined to Nalaban Bird Sanctuary alone (Mohapatra and Hussain, 1988).

Recently, the north western area of Chilika close to Mangalajodi has developed as the most recognised site after Nalaban for holding sizeable number of bird population. The marshy area of Mangalajodi also harbours high density of molluscs and fish fingerlings and is gradually becoming potential feeding and roosting ground of migratory water birds especially dabbling ducks such as Northern Pintail (*Anas acuta*), Northern Shoveller (*Anas clypeata*), Garganey (*Anas querquedula*) and Brahminy Shelduck (*Tadorna ferruginea*). In addition, Managalajodi marsh is frequented by Purple Moorhen (*Porphyrio porphyrio*), Asian Openbill Stork (*Anastomus oscitans*), Common Moorhen (*Gallinula chloropus*). Adjoining to the northern sector, the area also has a variety of micro-habitats with *Phragmites* zone, wet meadows, openwater patches with *Nymphaea* sp. and water hyacinth. Mangalajodi used to be a poachers' village but with concerted efforts by CDA and constitution of Bird Protection Groups which included the local community, the number of birds visiting the region has recorded a gradual increase.

Congregation of birds helps in recycling the nutrients back into the system through guano deposits. Ducks and geese add 33.8 t of nitrogen and 10.5 t of phosphorous (in the form of guano) to the lake which helps in high biomass production of macrophytes and lucrative fisheries in Chilika. Foraging by waterbirds helps in thinning the lake vegetation and enables free movement of fish.

The freshwater conditions which prevailed in the lake prior to hydrological intervention supported the resident freshwater species. However, the population of moorhens, jacanas and cotton teal declined due to reduction in freshwater condition (Balachandran *et al.,* 2005). Besides, prolonged flooding which regulates the invertebrate community also influenced the bird population in 2002-03. Preference for shallow clear water with submerged weeds by 67% of bird population was also one of the key factors (Balachandran *et al.,* 2005).

BNHS recorded nesting colonies of Gull-billed Tern in Nalaban, establishing its southern breeding range extension. The uncommon/rare migrants to India namely Great knots (*Calidris tenuirostris*), Red knots (*Calidris canuta*), Rufous-necked stint (*Calidris ruficollis*) and Common shelduck (*Tadorna tadorna*) not recorded before hydrological intervention made their presence during 2001-09 (Balachandran *et al.,* 2009).

Trends in waterbirds in Chilika based on annual waterbird census is presented in Fig. 18. There is a pressing need to conserve Chilika as a waterbird habitat considering the fact that in Asia, 62% of waterbirds with known trends are decreasing (Li *et al.,* 2009).

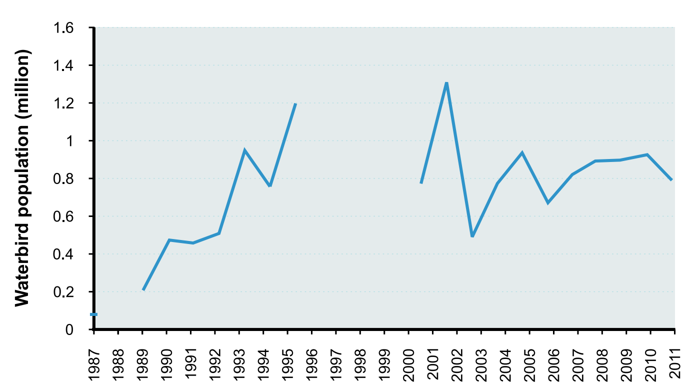
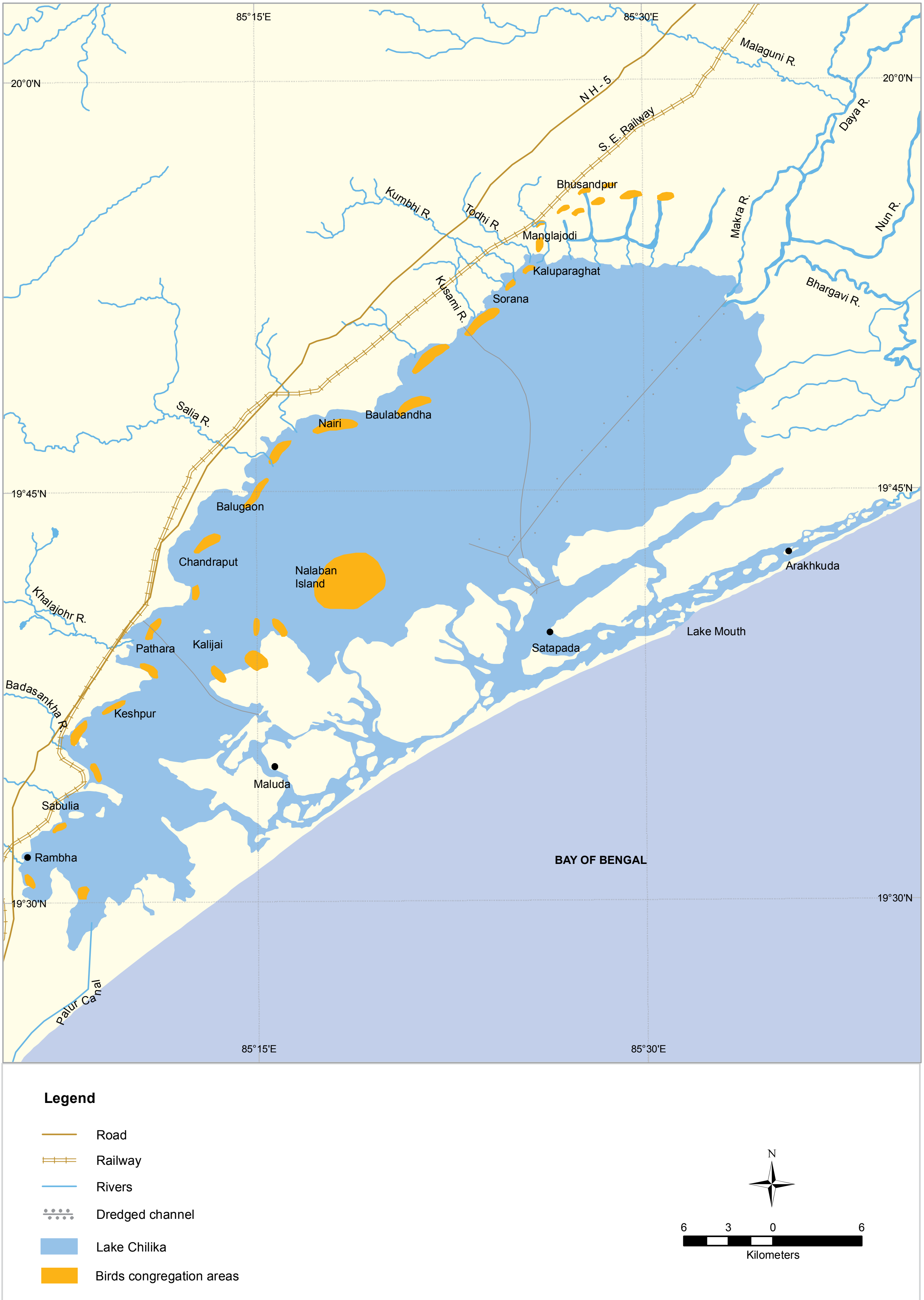


Fig 18: Trend in waterbird population
(Data source:Asian Waterbird Census; BNHS; CDA Monitoring Records)



Map 30: Waterbird congregation areas in Lake Chilika (2011)

A fisher laying nets on the shoreline

2.2.5 Livelihood systems

Ecosystem services of Lake Chilika directly and indirectly form a key component of livelihood strategies of a large population living around the wetland. The current section focuses on the interlinkages of Chilika's ecological character with the livelihood systems of the dependent communities. The analysis is based on household survey and participatory rural appraisals carried in 42 villages involving 4,074 households in 2009. Status and trends of livelihood capitals (natural social, financial, human and physical) have been analyzed to identify vulnerability contexts. Analysis of trends is based on existing literature and monitoring records.

Chilika as a setting for wetland-livelihoods interactions

The shorelines of Chilika are densely populated, especially on the southern, central and northern sector margins. There are 424 villages within 2 kilometres of the wetland boundary (including all island villages on the seaward side) falling within eight blocks of three districts (namely, Puri, Khurda and Ganjam) (Map 31).

Livelihood systems prevailing in and around Lake Chilika are mainly related to fisheries, agriculture, petty business or employment in service sectors. Fisheries based livelihoods include fishers[10], small time fish traders (who procure fish from the fishers/ local markets and sell in areas adjoining Chilika) and middlemen and commission agents (who procure fish from fishers and primarily indulge in export to markets outside Chilika). Fishing and fish trade are the predominant activities supporting livelihood of 64% of the working population (Table 11). Agriculture follows next as the primary occupation for 27% population. The rest draw sustenance through employment in the private/government sector and undertaking petty business. The northern and central sectors, fed by Mahanadi Delta Rivers and western catchment tributaries have relatively higher proportion of population dependant on agriculture (40% and 56% respectively) as compared to fisheries (48% and 33% respectively). The southern sector and outer channel have the highest proportion of fish traders and middlemen. The data also indicates that 0.10% of the population living in the villages engage in shrimp culture, which is an illegal activity within and on the wetland periphery.

Fisher settlements are dispersed over 152 revenue villages[11] (Annex X). Their overall population in 2009 was 403,356, of which the fisher households formed 36% (146,031 within 23,115 households- Table 12). The highest concentration of fisheries household was observed to be in northern sector (accounting for 41% of the population), followed by 28% in the southern sector. Projecting from the data on workforce participation, the number of active fishers was estimated to be 34,700, and the number of middlemen and traders in the range of 2,900[12].

Natural Capital

Ecosystem services of Chilika form a part of the natural capital of the fishers, who harvest fish as well as aquatic vegetation for various purposes. A small section of fishers also engage in tourism. Inland transport based on Chilika also forms an important means of communication for island villages. Further description of these is provided in ecosystem services section (Section 2.2.6).

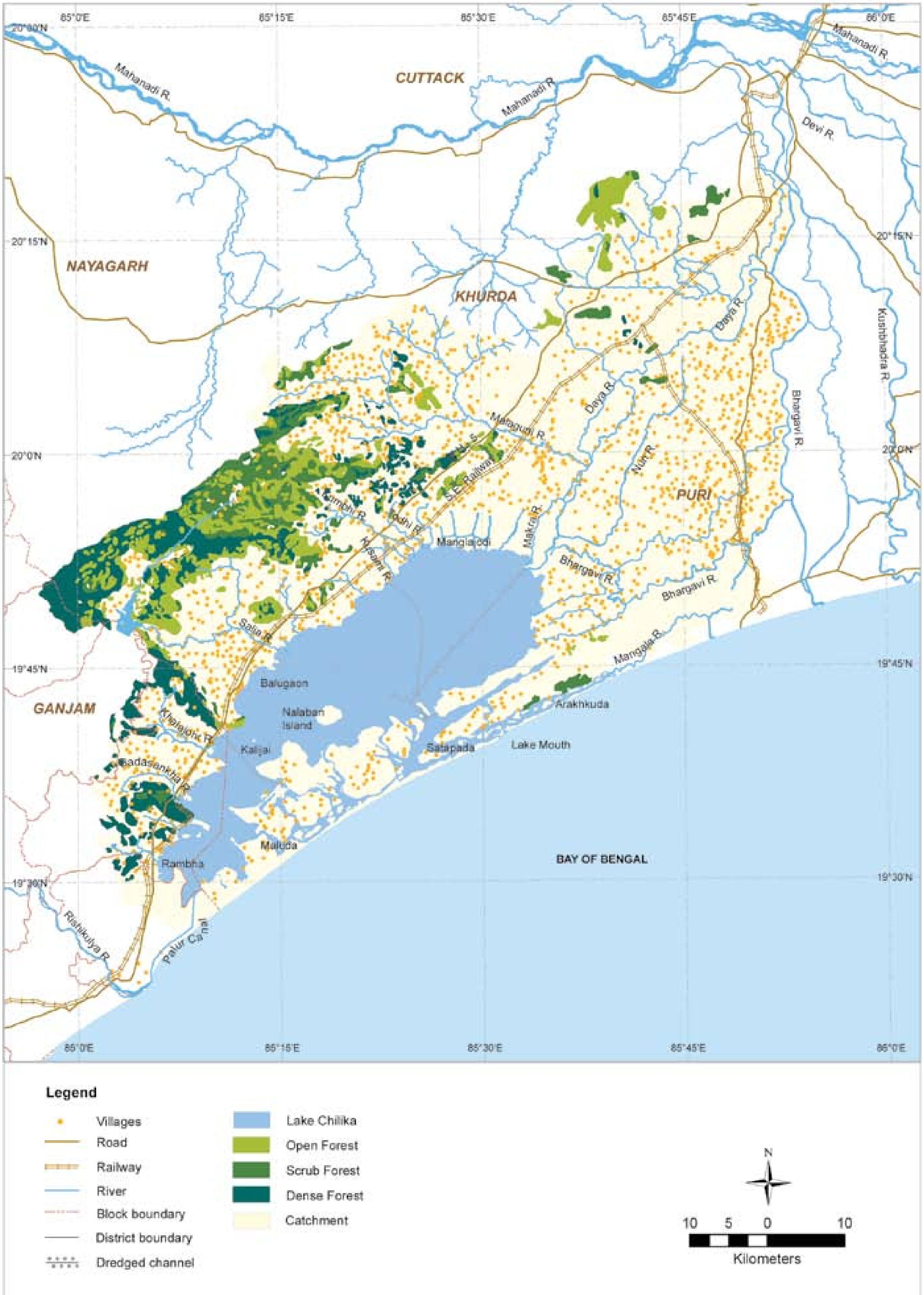
Social Capital

Social capital is an all-encompassing term for the norms and the social networks that facilitate cooperation among individuals and between groups of individuals. Social capital is described within the sustainable livelihoods framework as social resources upon which people draw in pursuit of livelihood objectives, and are developed through networks and

[10] Fishing in Chilika was traditionally carried out by caste fishers (also thereby referred to as traditional fishers). However, presently non-case fishers also fish in the lake.

[11] The number of fisher villages has been reported variously by different investigators. Mitra and Mahapatra (1957) reported 114 fisher villages. Ferguson *et al.,* (1992) report 273 villages in and around the wetland system of which only 122 were fisher villages. Samal and Meher (1999) while conducting the baseline socioeconomic assessment of Chilika communities developed a list of 137 fisher villages, adding 23 new villages to the list of 114 provided in Mitra and Mahapatra (1957). More recently, JICA (2009b) entrusted with the task of creating a baseline socio-economic survey of fishers concluded that fisher settlements were existent only in 103 revenue villages due to reclassification of village boundaries and changes in names.

[12] The proportion of population forming the workforce has been estimated to be 23.7% (marginally higher in northern sector, i.e 26% and 23% in other sectors). Number of middlemen is estimated as 403,356 × 0.62% × 23.75% = 593, rounded off to nearest hundred to 600. Similarly, number of fish traders is 403,356 × 2.40% × 23.75% = 2,299, rounded off to nearest hundred to 2,300.



Map 31: Villages in Lake Chilika basin

Table 11: Occupational profile of communities living around Lake Chilika

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Average
Fishing	47%	33%	76%	78%	59%
Fish trading	1%	3%	6%	8%	5%
Middleman	~1%	~1%	~1%	<0.5%	~1%
Shrimp farmer	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Agriculture farming	40%	56%	4%	6%	27%
Petty Business	4%	2%	3%	4%	3%
Govt./Private service	<0.5%	~1%	~1%	~1%	~1%
Others	4%	4%	10%	3%	6%

Table 12: Population structure of fisher villages

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Total
Revenue Village (Nos.)	54	31	43	24	152
No. of households	19,287	15,315	11,575	15,038	61,215
Population	138,600	94,279	69,002	101,475	403,356
Fishers					
No. of households	8,288	4,027	7,024	3,776	23,115
Population	60,571	22,866	40,163	22,431	1,46,031

connectedness (increasing people's trust and ability to work together and expand access to wider institutions); membership of more formalized groups (entailing adherence to mutually agreed or commonly accepted rules, norms and sanctions); and relationship of trust (facilitating co-operation and often providing the basis of safety nets amongst the poor). Social capital can function on three levels, as an asset that can be used for "linking" (Woolcock, 2001), "bonding," or "bridging" (Woolcock and Narayan, 2000).

The role of social capital within Chilika livelihoods is most evident in fisheries management and more recently management of tourism sector. Fisheries in Chilika evolved based on community managed system which however was challenged by emergence of profit and rent seeking market structures. Collective management of tourism sector is a development since the 90s and is still in consolidation phase (Kumar *et al.,* 2011).

Community managed fisheries in Chilika

Organized fishing in Chilika dates back to 17th century wherein it is believed that Srihari Sevak Mansingh settled in the hostile but secure island environs and gradually settled villages in and around the wetland which earned livelihood through agriculture, fisheries, and manufacturing salt. Fisheries in Chilika were taken up as an occupation by the lowest strata of the society, primarily belonging to seven major sub-castes eg. Keuta, Kartia, Kandara, Gokha, Nolia, and Tiara.[13]

The fishers established a unique system of community governance evolving around caste, with an aim of securing livelihoods based on rich understanding of the ecological functions of the wetland system. Over generations, Chilika fishers was managed based on a complex system of resource partitioning; whereby access by each fisher group was based on the species caught (Sekhar, 2007). The norms included setting spatial limits (what places to fish), temporal limits (seasonality), gear restrictions (what harvesting gear may be used), and physical

[13] A survey in 1957 undertaken by the State Fisheries Department revealed that out of total population of 31,550 living in and around the lagoon, 67.1% were Keuta, considered to be belonging to the higher strata amongst case fishers. These fishers primarily used nets to catch fish. Kandara followed next in terms of population (14.3%), distributed mostly in the south-west and south-east shores, and used jano as the main fishing gear. Tiaras followed next constituting 7% of the fishers, distributed along the north-eastern and north-western shores and fish with bozas and thattas. Nolia were Telgu fishers fishing mainly in the sea and partly near the south and south-eastern portions of the lagoon with drag nets and constitute 6.8% of the population. Kartia, Nairi and Gokha constituted 2.7%, 1.9% and 0.2% of the population respectively, and fish using traps and nets.

limits (what sizes may be fished). These were traditionally set and were even exchanged during periods of scarcity and calamities (*ibid*). Each fisher village had an organization called 'desh' responsible for settling disputes, administering common property resources and organizing collective fishing for communal purposes (Samal and Meher, 2003). A description of the relationship between castes, fishing methods, fishing grounds, species and seasonality is presented in Table 13.

Prawn trap used by traditional fishers

The rulers and administrators perpetuated communal fisheries by supporting the rights of caste fishers, and preventing entry of non-caste fishers, or non-fishers. Records dated 1880 indicate that Chilika was divided by its owners into 333 sources (or fishing grounds) with the rights exclusively with fishers. The sources were leased out to fishers on payment of revenue, which in certain circumstances was re-invested into welfare of fishers. Chilika fisheries were under the control of Zamindars (land revenue administrators) till the abolition of the estates and princely rules in 1953. Since 1953, when the government of Odisha took control of the Lake Chilika, the fishery sources were leased out through open auction by erstwhile Anchala Adhikary (later re-designated as Tahasildar).

Emergence of Bengal as an important trade centre in the early 19th century ushered in the role of traders in fisheries leasing. This prompted the government to ensure systems for organizing collective fisheries,

Table 13: Traditional relationship between caste, fishing ground and fishing methods

Fishing Group	Fisher population	Fishing Methods	Main species they fish	Area of fishing	Season
Keuta (also known as Kaibarta or Khatia)	68%	Nets, Jano, Dian	*M. cephalus, E. suratensis, N. nasus, M. gulio, T. arius, O. militaris, P. canius, D. albida, T. ilisha*	Shallow shoreline areas, narrow channels and deep waters in central part of the lake	Jano: May- September Nets: October- June Dian: May - September
Kandara	14.2%	Daudi, Thatta and Jano	Prawns, crabs, *N. nasus, G. setifer, E. suratensis*	Southwest and southeast shores	Daudi and Thatta: Throughout the year Jano: May- September
Tiara	6.3%	Bozas, Daudi, Menjhas, Thattas	Prawn and crab	North-western and north-eastern parts of lake	Throughout the year
Nolia	6.7%	Cast nets and drag nets	*M. cephalus, L. macrolepis, L. calcarifer, C. crenidens, S. sarba, P. indicus, P. monodon, M. dobsonii, M. monoceros*	Open sea near Lake mouth	–
Karitai	2.5%	Bamboo screen traps and nets	Prawns, crabs, *N. nasus, G. setifer, E. suratensis*	North-western and north-eastern parts of lake	–
Niari	2%	Nets	*M. cephalus, L. macrolepis, L. calcarifer, C. crenidens, S. sarba, P. indicus, P. monodon, M. dobsonii, M. monoceros*	Open sea near Lake mouth	–
Gokha	0.3%	Cast nets and drag nets	Marine fish	Open sea	–
Fisher and non-fisher caste	-	Uthapani	Prawn and fish	Inundated areas during monsoon	July- September

primarily with an objective for protecting the rights of traditional fisheries. In 1922, the erstwhile Bihar-Odisha Government established the first fishery cooperative store at Balugaon for supply of fishery requisites and other daily necessities at fair prices to the Chilika fishers. The cooperative store continued to function till later part of the 1950s.

Late Dr. Gajendranath Mitra, the first fishery officer of Odisha State and the founder Director of the Odisha Fisheries Department is credited with establishing of the first fishery cooperative society in 1942 as a part of the rehabilitation measures for a cyclone devastated village in southern shores of Chilika. The key objectives for setting up the cooperative were to empower the fisher communities and to enhance their livelihoods by addressing exploitation in the hands of middlemen. By 1959, 25 Primary Fishers Cooperative Societies (PFCS) emerged around Chilika as the grass root level fishery institutions.

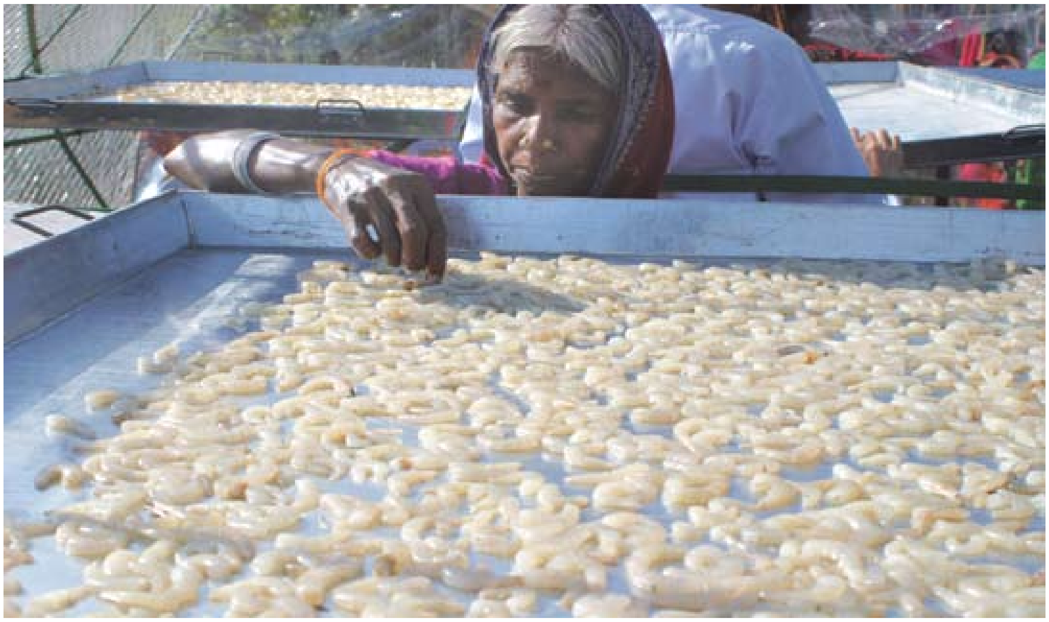
Dr. Mitra also played an instrumental role in drafting the Chilika Development Plan (subsequently included in the First Five Year Plan of Odisha) which focused on strengthening the cooperatives for sustainable management of wild fisheries under a suitable lease system for fishery sources. Similar recommendations were given by Mr. A.F. Leide-Law, a Canadian expert commissioned by the state to suggest measures for managing diverse fishery sources and the age old traditional fishing systems. This led to the implementation of the Chilika Reorganization Scheme of 1959 which gave priority and precedence to the PFCS by recognizing the traditional right of the local fishers. A Central Fishers Cooperative Marketing Society (CFCMS) Limited was constituted in 1959 at Balugaon as an apex body for ensuring smooth management of fishery leases, marketing of fish catch, providing necessary infrastructure, and most importantly working capital to the affiliated fishers for purchase of fishing nets and boats. The existing 25 PFCS were affiliated to the CFCMS.

The CFCMS took the lease of various fishery sources from the State Revenue Department and subsequently sub-leased them to the member PFCS on annual basis with provision of 10% increase in lease value every year. One tenth of the lease value was retained by the CFCMS to cover the administrative costs. The government revised the lease principles in 1988 enhancing the lease period to three years. By 1988, the CFCMS managed 203 fishery sources within the lake and had 49 PFCS as registered members.

Degeneration of community managed fisheries

The community managed fisheries, were under pressure from entry of non-fishers, largely lured into the occupation in the interest of short term monetary gains. Fisheries of Chilika gained interest of Kolkata merchants in the early 19th century, who used to take lease from the fishing source owners and latter sub leased to fishers at higher rates. After abolition of estate, the non fishers were allotted a small share of dian and jano fisheries. Das Committe noted in its 1993 report that during the period 1959-1988, some PFCS had transferred fishing rights to non-fishers in violation of the lease terms and conditions. Till 1988, while 203 fishing grounds were leased to PFCS, 92 grounds were leased to non fisher sources.

Introduction of shrimp culture, however changed the whole picture of Chilika fisheries. A steady increase in global demand of fish provided significant impetus to aquaculture development since the 1970s. Especially, the demand of prawn from affluent societies of North America, Europe and Japan led to very high international prices. Prawn, which had very little commercial value till the 1970s came to be recognized as 'pink gold' (Kurien, 1992). Chilika, which had *P. monodon* naturally occurring in the



Chilika shrimp being dried for processing wetland system, caught attention of the aquaculture farmers in the 1980s.[14] In 1984-85 prawn culture was introduced to Chilika as a part of a supplementary income programme for low income families titled 'Economic Rehabilitation of Rural Poor' (Mohanty, 1988). Nearly, 120 ha of land on the shores of Chilika was allotted to households for shrimp culture, with each beneficiary household entitled to 0.2 ha of excavated shrimp culture tank. Economic factors contributing to the high economic profitability of shrimp farming included devaluation of the Indian Rupee (1991) and development of export markets. The value of shrimp increased from Rs. 35/kg (1980) to Rs. 550/kg (2001). Trade liberalization further expanded opportunities and export potential of shrimp farming (Shimpei and Shaw, 2009).

Prawn aquaculture was distinctly picked up as an economic opportunity by the non-caste fishers. The traditional fishers were unable to cash-in this trend primarily because of high capital investment, and dependence on trade chains for value realization. The non-fishers gradually encroached the capture fishing area using multiple means deploying economic and political methods. The government also provided impetus to prawn aquaculture, and as a first major indicator, sanctioned a project for establishment of shrimp farm over three hundred hectares of land at Panaspada at a total cost of 1.7 crores. The site was subsequently handed over to OMCAD Corporation by the State Government which failed to implement the project due to managerial issues. The project was finally launched as joint venture with Tata and OMCAD in the form of Chilika Aquatic Farms Limited (CAFL). In 1991, the government formally distinguished between culture and capture sources in the lake through its 1991 fishing policy. This led to further allocation of nearly 6,000 ha of capture fishing area to culture fisheries led by non-fishers.

[14] Till 1960s prawns had very low value and even used as fertilizers for coconut plantations

Fisher – Non fisher conflicts

Introduction of shrimp culture as well as overall decline in fisheries brought about changes in institutions and freedoms of the fisher communities. The traditional caste-occupation relationships broke down with the introduction of new fishing gears and increased profitability through prawn farming. Introduction of nylon nets and mechanized boats in the 1970s posed a major challenge to the traditional crafts and gears of fishers, enabling higher catch per unit effort and enhanced capability to cover additional fishing grounds per fishing excursion. The economic return generated by prawn aquaculture led to a massive influx of individuals from the farming communities into this fishery and even attracted the interest of investors from outside the basin (Pattanaik, 2008). Due to low agricultural productivity of soils in the coastal tracts, many individuals from farming communities also took up fishing as a livelihood strategy (Samal, 2002). This led both to occupational displacement and loss of fishing grounds by the traditional fishing communities, and resentment between traditional fishers and the immigrants, described as *ana-matsyajibi* or non-fishers by the fishers (Dujovny, 2009).

Chilika fisheries gradually converted from a "community managed fishery" to "contested-common" wherein non-fishers gradually exerted pressure for more fishing rights. In 1990, the non-fishers' petition in the Odisha High Court challenging the traditional rights to fishing grounds held by fishers resulted in direction by the court to abolish the traditional system, and reallocate fishing grounds to fisher and non-fishers in a ratio of 60:40 (Ghosh *et al.,* 2006). This decision was challenged by traditional fishers demanding a review of the judgement. The fact finding committee established in response by the government

Kalupadaghat one of the largest landing centres in Northern sector recognized the prevalence of a coercive culture fishing structure which impinged on the rights of traditional fishers, yet reiterated that the livelihood needs of non-fishers also needed to be addressed by the fisheries policy. Following a public interest petition challenging the prawn culture on environmental grounds, the Supreme Court subsequently banned all aquaculture within 1,000 meters of the lake. This officially ended aquaculture, but illegal prawn culture still continues along more than 60% of the shoreline especially in the southern sector and on islands.

The CAFL also witnessed an unprecedented resistance from traditional fishers, non-fishers and others concerned on the environmental conditions of the wetland. The Chilika Bachao Andolan, a mass movement set against the project. Meet The Student, a student forum was one of the key supporters of the movement. The movement led to several padyatras, gheraos, symbolic demolition of embankments and gherao of State Legislative Assembly. The project was finally abandoned by the Tatas.

The commission agents have institutionally occupied the same functions as was expected from the PFCS, albeit with a mandate of profit-seeking. The PFCS were crowded out by the merchants and shrimp farmers through sub letting of fishing rights, encroachments, and use of muscle and political power. In 2001, the lease policy was again drastically revised. The diverse fisheries were broadly classified into prawn and non-prawn sources. *Bahani, jano,* prawn grounds, *dian* and *utthapani* were merged into the prawn category and the rest into the latter. The lease term was once gain reduced to one year, and a single value fixed irrespective of the productivity and area (Rs.9,300 for non prawn sources, and Rs.27,900 for prawn sources). The District Collectors leased the fishery sources to the FISHFED (which replaced CFCMS as the apex agency in 1992, holding a similar mandate and objective) every year and in turn, FISHFED sub-leased to PFCSs with 10% increase in the annual lease value. During 2001-2004, although 127 fishery sources were leased out by to FISHFED, 15 were surrendered since many PFCS were not interested to take sub-lease due to unproductive nature and disputes on the source. Again, from the remaining 112 sources, nearly 30% were forcibly encroached by non-fishers and outsiders for illegal ghery operation.

Community institutions existing at present

By 2009-10, of the 104 PFCS registered under the FISHFED, 11 became moribund and defunct. The performance of FISHFED itself took a severe beating with decline in marketing activities and financial support to the member PFCS. The survey data indicates that only 62% fishers were members of PFCSs.

Building social capital in the form of functioning and effective community institutions is a necessary pre-condition for managing Chilika fisheries. CDA has identified rejuvenation of the PFCS as an important component of the overall strategy for fisheries management. The state government has laid down a blue print for re-activation of the fisheries cooperatives with an aim to promote sustainable fisheries in Chilika and improve the well-being of fishers. The plan, formulated in 2009-10, forms a part of the long term 10 years perspective plan for fisheries sector of Odisha. Under the aegis of the CDA, the plan envisages judicious revision of leasing policy for fishery sources after stakeholders consultations and commensurate with the principles of sustainable fisheries and fisheries resource management plan.

The plan also envisages establishing an apex central society in the cooperative structure in Chilika fishery to act as re-activating agency for the sick and dormant PFCSs by providing financial, infrastructural and institutional support with the core objectives of better marketing management of their catches to enhance

Zero nets being burnt by CDA

financial stability and working efficiency. The Central Society will play the pivotal role in strengthening the member primaries, promoting responsible fisheries and implementing fisheries resources management plan (FRMP) in Chilika with the active involvement of PFCSs. The society shall be funded with adequate seed money by the State Government for providing working capital loan to the PFCSs using a revolving fund mechanism. This is aimed to release the fishers from the credit trap and support development of fish marketing channels with the help of Central Society. The Assistant Registrar, Fishery Cooperatives, Chilika Circle of the Department of Fisheries and the Central Society will function as an unified body to effectively coordinate the function of the Primaries (election, audit, book keeping, etc.) with the marketing management and proper operation of lease sources.

With a view to making a beginning in this direction, State Government has established a new Central Fishermen Cooperative Society called Chilika Fishermen Central Cooperative Society (CFCCS) Ltd. with its head quarter at Balugaon in July 2010. Its core objectives are:

- To provide working capital loan as revolving fund to the member PFCSs to improve their financial situation through fish marketing business and gradually become debt-free.
- Smooth management of leasing of fishery sources (Sairats) in accordance with the proposed revised lease policy with effective monitoring of lease operation.
- To introduce effective marketing system for the catches of member PFCSs to fetch higher return that can help improve the financial condition of the PFCSs.
- Supply of fishing requisites to the member PFCSs at fair prices.
- To set up support service units under PPP mode to introduce cold chain systems for fish quality management and improving marketing system.
- To promote production and marketing of value added fish products through women Self Help Group (SHG) of PFCSs.
- To promote fresh fish retailing business in modern sales outlets for the consumers in the nearby cities and towns.
- To organize capacity building training programmes at the community / PFCS levels to educate the fishers to follow "Do's or Don'ts in regulated fishing operation to achieve the goal of sustainable fisheries and fish quality management.

Community institutions in tourism sector

The hydrological intervention in Chilika Lake led to a significant recovery of overall aesthetic features, most notably decline in freshwater weeds and improvement in population and habitat use by waterbirds and dolphins. As a consequence, there has been resurgence in Chilika tourism providing an opportunity for livelihood diversification and asset building.

As with fisheries, collective management of tourism emerged as a strategy to avoid competition and conflicts. The uptake was the fastest amongst outer channel villages, which had to lose their traditional fishing grounds due to opening of the new mouth. The communities initially engaged in protests, but were soon to invest into tourism building on the fact

Box 4: Revitalizing PFCS through access to credit and cold chain facilities

Availability of credit at equitable terms plays an important role in economic viability of the PFCS. Under a pilot initiative, CDA through the Fisheries and Animal Resources Development Department is providing Rs. 7 Lakh as revolving fund to PFCSs to revive the institutions and ensure fair access to credit to the member fishers. The results have so far been encouraging. Jayantipur PFCS is one of the early cooperative societies to stop depending on middlemen for credit. It currently receives around Rs. 20,000 monthly through loan repayment from fishers, which is being used to build back the seed capital for second cycle of loans.

Lack of appropriate storage facilities force the fisher to sell their catch to the middlemen who exploit their vulnerability by paying low prices and manipulating weights. CDA through support of Marine Products Export Development Authority (MPEDA) has launched an initiative to provide ice boxes to the fishers so that the catch could be maintained for a longer time and fishers could choose their preferred point of sale. A 70 litre box costs Rs.2,200, of which 50% is subsidized by MPEDA, 30% by CDA and the rest is borne by the fisher. This scheme has been very warmly received and thus far 1,000 boxes have already been distributed with fishers reporting atleast 30% increase in sale proceeds. The scheme is financed through Rs. 16.40 lakh funding support provided by MPEDA alongwith Rs.10 lakhs from CDA's special problem grant under the 12th finance commission.

Resurgence of tourism has also spurred growth in small time trade

that there was an increase in habitat use by dolphins within the outer channel as the disturbances due to fishing activity were drastically reduced. Eight new fisher associations were registered since 2000 (Table 14). Mostly called the tourist motorboat associations, these community institutions have taken up the task of assigning tourist to the member boats, liaising with the taxi drivers to ensure a steady inflow of tourists[15] to the association and in certain cases maintaining infrastructure as boat jetties, fast food joints, toilets and other amenities. The members of the association are mostly caste fishers (90% of the membership). Similarly, 60% of the boats go out for fishing in the night (or if there are no tourists to cater to). The degree of trust in certain new associations is still not fully developed, as was evident in a very violent conflict at Satapada on the rights to attend the tourists.

Financial Capital

Financial capital denotes the financial resources that communities employ to achieve their livelihood objectives. It forms an important component of the livelihood building block, namely the availability of cash or equivalent that enables people to adopt various livelihood strategies. The conventional description of the financial capital includes inflows (incomes, transfers, remittances etc.) as well as stocks (savings and credit).

Income

An analysis of average household incomes within the sample villages indicates a high degree of difference between various occupation categories (Table 15). The average annual household income was assessed to be Rs. 26,403[16], or a per capita annual income of Rs. 4,632[17]. Farming, fishing and petty business formed the lowest income groups, whereas the middlemen and shrimp farmers fare the highest. Amongst livelihood systems that are related to fisheries, fishing yields the lowest income whereas those which relate to higher value chain, i.e trading and fish-agents have significantly higher average incomes (30% and 124% higher than fishing respectively). Shrimp farming, which is an illegal practice within the lake system, also yields higher incomes (104% higher than fisheries).

Comparison of incomes across various sectors indicates that the fish agents have the highest incomes while the agriculture farmers have the lowest incomes (except in northern sector). Shrimp farmers form the next highest income group in all sectors, except in the northern sector wherein government service returns marginally higher incomes. Fishers invariably fall within the last three income categories. Within all occupation categories, high values for standard deviations are indicative of high individual differences

An analysis of the income distribution indicates high degree of variance amongst all occupation groups (Map 32). Half of the population earns one-fifth of the maximum income. Fish agents (middlemen)

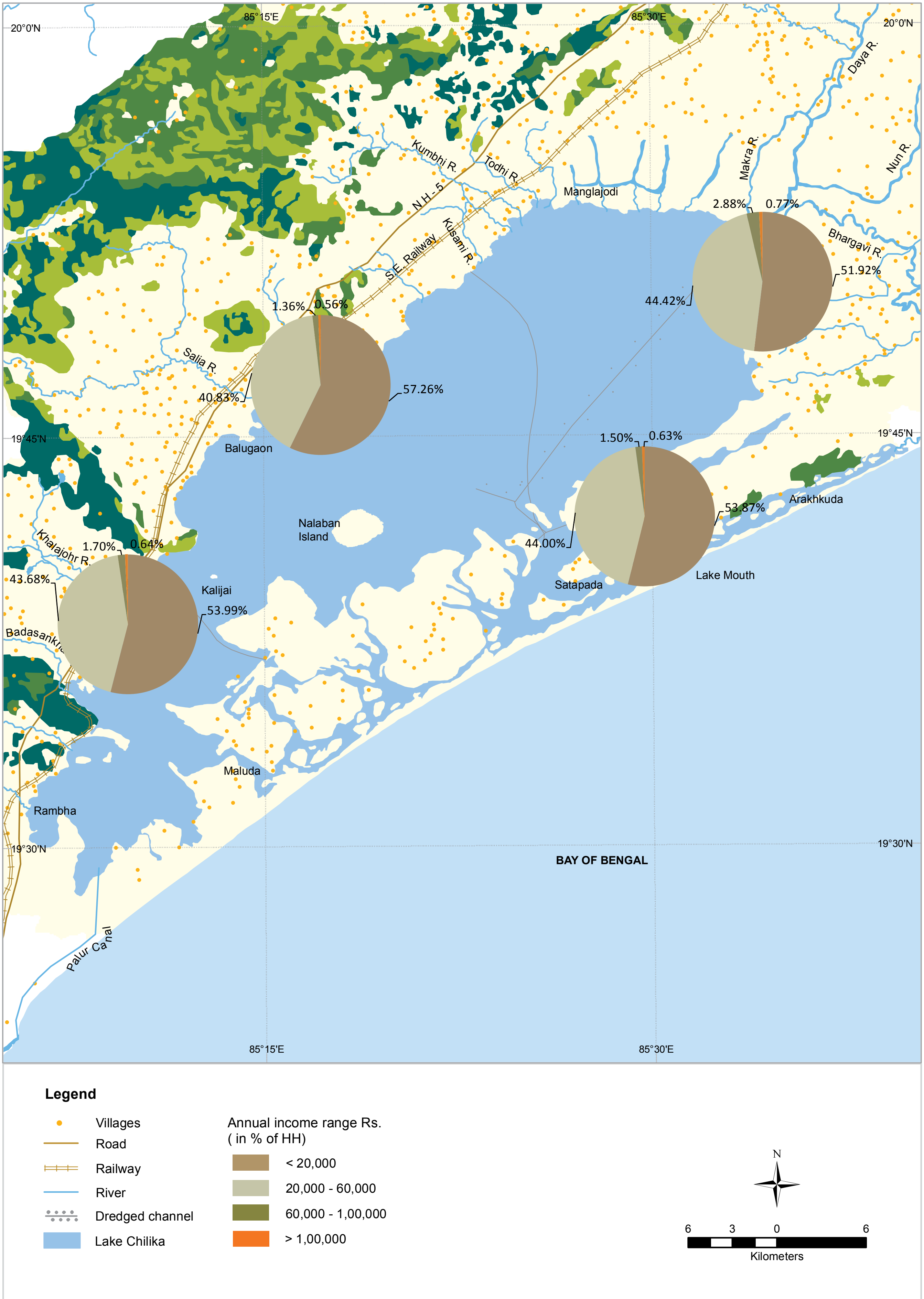
[15] Surveys revealed that the association pays out an incentive of Rs. 500 to each taxi for getting tourists to their boats.

[16] Standard deviation = Rs. 20,517

[17] The per capita Net State Domestic Product at factor cost for the State of Odisha was Rs. 14,371 in 2006-07 (Source: Statistical Abstract of Odisha, 2008)

Table 14: Tourist associations in Lake Chilika

Association name	Number of members	Number of boats	Number of members from fisher community	Number of exclusive tourist boats
Sipakuda Motorboat Association	167	167	147	107
Gabakunda Motorboat Association	80	80	80	40
Mirzapur Motorboat Association	130	130	130	60
Gangadharpur Motorboat Association	50	50	50	5
Satpada Motorboat Association	400	400	340	40
Maa Kalijai Motorboat Association, Barakul	109	109	108	91
Trade Union, Barakul	17	17	17	5
Kalijai Motorboat Association, Balugaon	120	120	103	82



Map 32: Income distribution pattern in villages along Lake Chilika shoreline (2009)

Table 15: Average annual household income (Rs.) by primary occupation categories (2009)

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Average
Fishing	23,071	23,276	25,392	24,381	24,006
	(18,516)	(15,396)	(15,006)	(16,583)	(16,244)
Fish trading	36,000	35,625	26,315	31,481	31,259
	(40,649)	(29,311)	(24,486)	(28,278)	(29,183)
Middleman	48,888	64,000	52,000	54,736	53,953
	(17,638)	(21,908)	(19,321)	(19,823)	(19,289)
Shrimp farmer	45,000	50,000	51,425	48,888	49,166
	(10,000)	(17,320)	(28,284)	(15,000)	(16,659)
Agriculture farming	28,127	15,919	17,907	17,978	24,335
	(19,309)	(16,191)	(15,669)	(15,534)	(18,808)
Petty Business	26,066	29,546	28,333	21,526	25,449
	(22,006)	(40,997)	(39,243)	(21,957)	(28,898)
Govt. Service	46,666	35,294	20,715	46,000	36,666
	(16,329)	(37,933)	(149,17)	(14,653)	(25,796)
Pvt. Service	33,442	21,429	21,327	19,792	23,878
	(20,321)	(27,859)	(26,267)	(23,016)	(25,219)
Others	30,588	31,667	21,250	33,182	30,508
	(23,577)	(26,572)	(15,526)	(12,867)	(19,776)

(Values in bracket indicate standard deviation)

and shrimp farmers exclusively comprise the income group above Rs. 60,000 per annum. The lowest income group (with an annual income of Rs. 20,000) comprises 54% fishers, 52% fish traders, 57% agriculture farmers and 64% of fish traders. Fig. 19 presents the cumulative frequency of income against population.

Incomes are strongly correlated to asset ownership. Fishing within the lake is collective activity. A typical fishing expedition involves 4-6 fishers per boat, each getting an equal share of the catch value. Owners of boat and net stand to get an additional share of the proceeds. In case of rented equipment, the rent is deducted from the catch value and the rest shared equally. Thus, boat and net owners have a higher income than crew members.

The dependence of fisher households on fisheries is not complete, and 23% of the respondent households indicated having an alternate income source. Of this, 8% engaged in agriculture, followed by shrimp farming (5%), and petty trade (4%). Additionally, 5% of the adult population of fisher households migrated seasonally for labour and other alternate income generation purposes. The average annual income generation for fisher households through these activities was estimated as Rs. 8,125. Thus, the total household income of fisher households from all sources was assessed to be Rs. 32,131.

Agricultural land provides an important means of asset diversification to the households. Presently, 30%

There has been resurgence of tourism in Chilika after 2000

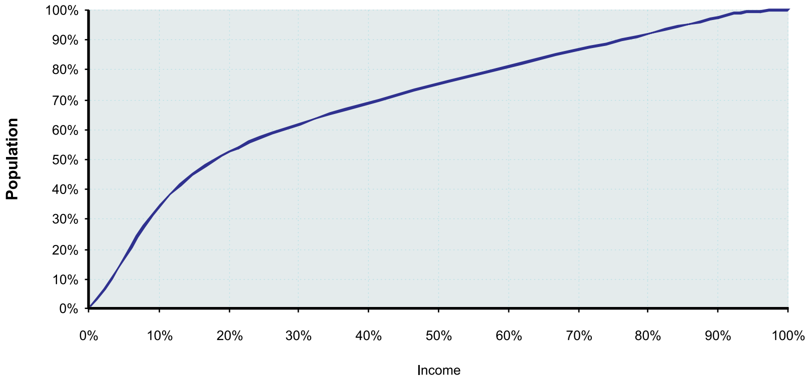


Fig. 19: Pattern of income distribution

of the households own land, average landholding being 1.5 acres / household. Fish agents have the maximum proportion of households owning land (92%), followed by agriculture farmers (40%). Among the fishers and traders, proportion of households owning land have been assessed as 33% and 19% respectively. In terms of land-holding sizes, the highest was observed within the agriculture farmers (1.76 acres), followed by fisher agents (1.25 acres). Fishers and fish traders have landholding less than 1 acre (0.93 and 0.73 acre respectively).

There is very little systematic assessment of income and consumption expenditures within Chilika communities. The 1999 assessment indicated the per capita income of Rs. 3,780 and consumption expenditure to be Rs. 3,840. The current per capita income for fisher household (from all sources) at Rs. 5,020[18] is 31% higher, which can be singly attributed to the increase in fish catch. There is also an indication of diversification of income through alternate sources.

Credit

The pattern of credit within the sample households of Chilika is presented in Table 16. On an average, 69% of the households are indebted. Indebtedness is particularly very high amongst the agriculture farmers (83%) and fishers (74%). No distinct pattern is discernible on differences within the sectors.

[18] Rs. 32,131 for an average household size of 6.4 = Rs. 5,020 per capita

Further assessment of the pattern of indebtedness amongst fisher households highlights some key trends. Loans are usually taken for fishing related purposes (purchase/ repair of fishing implements as boats/ nets etc). However, most of the loan is sourced from informal credit sources, i.e local money lenders (74%) and friends and relatives (24%).

The average amount of loan taken per indebted household was estimated to be Rs. 24,232 which is almost comparable to the annual household income from fisheries (Rs. 24,006). Of this, on an average 83% was provided by informal sources (majority being local money lenders (68%), followed by relatives and friends).

The local money lenders are mainly fish agents or middlemen, and the loans taken are often tied to the commitment of selling the entire catch to the agent at prices determined by the latter. This is validated from the data on fish buyers from the fisher boats. As can be seen in Table 17, 83% of the respondents confirmed selling the catch directly to the fish agents. Only 9% of the catch is sold to the godowns, and a meagre proportion (9%) sold to families and friends.

Extrapolating from the data on primary occupation, it can be concluded that fisher agents and traders numbering around 2,900 deal with the catch of over 34,700 fishers, which gives them immense advantage on setting the overall terms of trade. Due to very limited presence of formal credit institutions and weak asset base, the fishermen are forced to take loans

Table 16: Extent, sources and purpose of indebtedness in Lake Chilika fishers (2009)

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Average
Source of loan					
Local money lender	66%	71%	81%	78%	74%
Banks	32%	28%	14%	29%	26%
Self Help Groups	6%	9%	4%	6%	6%
Relatives and Friends	18%	22%	23%	32%	24%
Others	3%	1%	1%	1%	2%
Average debt/source (Rs.)					
Local money lender	30,783	28,119	28,529	28,893	29,081
Banks	14,805	19,674	18,978	20,523	18,495
Self Help Groups	9,048	9,144	16,703	7,670	10,641
Relatives and Friends	19,851	18,712	20,544	19,533	19,660
Others	10,435	8,850	9,727	11,875	10,222
Purpose of loan					
Related to fishing	81%	73%	83%	79%	79%
Related to agriculture	2%	1%	0%	0%	1%
Related to shrimp culture	1%	0%	1%	3%	1%
Related to household needs	8%	6%	8%	11%	8%
Others	7%	20%	8%	7%	11%
Average annual rate of interest	**40.86%**	**38.12%**	**41.75%**	**50.43%**	**42.79%**

and advances from the middlemen at a higher interest rate of 10-12% lower than the market. At the same time, the purchase from the fishers is through a biased weights and measures systems (middlemen recording lower weight of the catch to the fishers) which leads to further reduction in catch value by 15-18%. Through this process the fishers loose nearly 30-32% of the catch value and end up paying a return in excess of 40-50% per annum on the loan amount (as compared to institutional rates of less than 10%).

The current pattern of indebtedness assessed through the survey is almost similar to the 1999 status assessed by Samal and Meher (2003). There has been nearly no impact on the pattern of indebtedness, as 85% of the fisher households report to be under debt, primarily through informal sectors. The average household debt at current prices has increased by 85% during this period.

Human capital

Human capital represents the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. At a household level human capital is a factor of the amount and quality of labour available; this varies according to household size, skill levels, leadership potential, health status, etc. In several circumstances, ill-health or lack of education as core dimensions of poverty and thus overcoming these conditions may be one of their primary livelihood objectives.

The current assessment focused on the dimensions of education and health. The overall adult literacy amongst various occupation groups and sectors is presented in Table 18. The adult literacy rate amongst villages in Chilika was assessed to be 77%. Fishers, fish traders and petty traders households had literate adult populations below average. While almost all the villages had primary school, the proportion of villages with middle and high school was 81% and 73% respectively. There were 17 institutions imparting technical / vocational courses.

The communities living in and around the lake have evolved a very good understanding of the ecosystem behaviour and dynamics over the ages. Fisher communities in particular have very rich understanding of fish species behaviour. There have been several circumstances of use of this knowledge system by the CDA for various research and assessment purposes. The 2000 hydrological intervention was based on extensive community consultations. Similarly, the environmental flows assessment carried out for defining allocation of water to Chilika from Naraj was based on community understanding of hydrological regime dynamics. More recently, CDA has commissioned reassessment of fish migration pathways wherein the local fishers play an important role in helping the scientists design the study and set up experiments.

Since the last decade, building on the success of participatory wetland restoration, CDA has undertaken several interventions for building capacity of the communities for enabling good stewardship. Members of boatmen associations have been trained in safe dolphin watching. In collaboration with Whale and Dolphin Conservation Society (WCDS), CDA has been able to implement guidelines

Table 17: Fish buyers from boats

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Average
Money lenders / Middlemen	85%	83%	79%	82%	83%
Godowns	11%	8%	3%	12%	9%
Sale within family	3%	8%	17%	5%	8%
Others	1%	1%	0%	1%	1%
Respondent	1756	1391	882	806	

Table 18: Adult literacy in Lake Chilika villages (2009)

	Northern Sector	Central Sector	Southern Sector	Outer Channel	Total
Fisherman	70%	63%	70%	69%	68%
Fish Trader	95%	67%	61%	67%	67%
Middleman	89%	75%	100%	75%	88%
Shrimp farmer	57%	83%	92%	75%	77%
Agri farmer	73%	68%	68%	70%	72%
Petty Business	67%	74%	69%	74%	70%
Govt. Services	100%	100%	100%	100%	100%
Pvt. Service	67%	59%	60%	60%	62%
Other	100%	100%	100%	100%	100%

Kalijai temple attached with cultural values of communities around Chilika

for Dolphin Watching in Chilika Lagoon. This has led to near total elimination of accidental deaths of dolphins due to chasing by tourist boats. Similarly, several waterbird protection committees have been formed in the northern sector. In Manglajodi village in the northern sector, the poachers have turned into bird watchers and protectors.

Physical capital

Physical capital refers to the basic infrastructure and producer goods needed to support livelihoods. Infrastructure includes changes to physical environment that help people meet their basic needs and to be more productive; whereas producer goods are the tools and equipment that people use to function more productively. Sanitation conditions are known to influence health and thereby the ability of communities to deploy capitals. Poor access to sanitation and clean drinking water facilities often have a disproportionate impact on women of the household. Table 19 presents information on the presence of toilets, separate drainage, bathrooms and kitchens within the sample households. The coastal areas of Odisha in general have very low sanitation. Within the survey, this was reflected in low proportions of households having separate toilets (22%), separate kitchen (45%), drainage (23%) and separate bathrooms (30%). Income and asset ownership had distinct influence on these indicators. Relatively well-off households (middlemen and those engaged in service sector) had better sanitation infrastructure as compared to fishers and agriculture farmers. Spatially, the outer channel households were the worst off in terms of all indicators assessed.

Information on water supply sources and usage patterns indicates that only 15% of the respondent households had access to piped drinking water supply, the rest sourcing it from wells, ponds and rivers. Given inadequate sanitation and very limited access to safe drinking water, there is high rate of incidence of water borne diseases as gastroenteritis, diarrhoea and dysentery in the villages.

In terms of energy resource use, there is a high dependency on fuelwood, with 95% of the respondent households identifying it as the main source of energy. The degree of penetration of kerosene and LPG with

Table 19: Selected parameters related to household sanitation in Lake Chilika villages (2009)

	% households				
	Semi-permanent	Have separate kitchen	Have drainage	Have separate toilet	Have separate bathroom
Total respondent households	48%	45%	23%	22%	30%
Fisherman	59%	20%	9%	5%	18%
Fish Trader	48%	26%	12%	14%	20%
Middleman	16%	68%	48%	43%	72%
Agriculture farmer	61%	24%	9%	2%	16%
Services (Government / Private)	47%	84%	50%	45%	66%
Northern Sector	53%	51%	23%	24%	30%
Central Sector	48%	42%	28%	21%	28%
Southern Sector	37%	50%	22%	25%	36%
Outer Channel	52%	36%	18%	18%	27%

these villages is very low. Nearly half (49%) of the houses are electrified, and 27% have access to fair-weather road. In a ranking of most strenuous and hardest jobs for the womenfolk carried as a part of socio-economic survey by JICA, drawing drinking water for household use and fuel-wood collection were rated the highest within all sectors.

There has been a rapid development of fisheries related infrastructure. The number of fish landing centers has increased from 12 in 1999 to 18 at present. There are 21 ice manufacturing units in and around the lake.

It is difficult to assess the trend in physical infrastructure due to absence of trend data. The only information available is through the socio-economic survey conducted in 1999. As per the assessment, 50% of the permanent (or pucca) houses and 7.5% of the semi-permanent (*kutcha*) houses had individual toilets. The survey recorded near complete absence of any drainage facilities in the villages. Also, no piped water supply facilities were reported to be present in the villages. Definitive data on roads and transport is not presented, however the assessment concluded that fair-weather roads were present in only a few villages, boats being the most common mode of transport from one to other part of the lake (Map 33). Considering, the 1999 data as the baseline, physical infrastructure seems to have improved on all counts. However, the overall condition of water, sanitation and hygiene remains precarious.

Vulnerability Contexts

The picture of change in livelihood assets that emerges from the trend data indicates non-uniform changes (Fig 20). The period till 2000 was of declining natural resource productivity and diminishing social and financial capital. The hydrological restoration led to increase in fisheries and thereby natural resource productivity better than 2000 conditions. However, returns per active fisher and per boat do not compare with the situation as described in the 1950s and 1960s. The stranglehold of coercive market structures led to further diminution of social capital. In terms of financial assets, though there has been an increase in income, indicators suggest that there has been almost no impact on the patterns of indebtedness. Trends in human capital are positive. Similarly, there has been betterment of several components of physical capital; however, the aspects of water, sanitation and hygiene remain a cause of concern.

The overall information base on livelihood systems is incomplete in several respects. The gender dimensions of asset base have not been assessed, thereby limiting appraisal of gender dynamics. Other information gaps include consumption behaviour, indigenous knowledge systems, social dynamics towards usage of water and sanitation infrastructure, health status, disease patterns, skills and capabilities and perceptions on various practices detrimental to wetland management. At a wider scale, the connectivity between the livelihood systems dependant on riverine fisheries and coastal fisheries also needs to be assessed and interpreted in the wetland context.

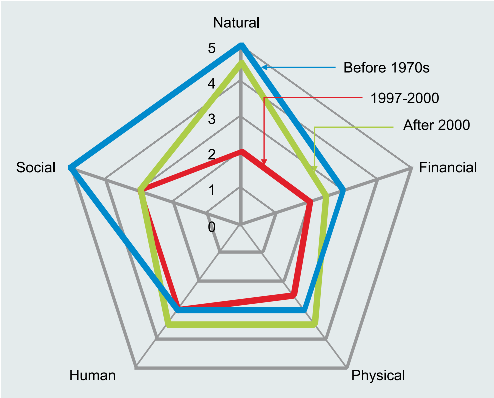
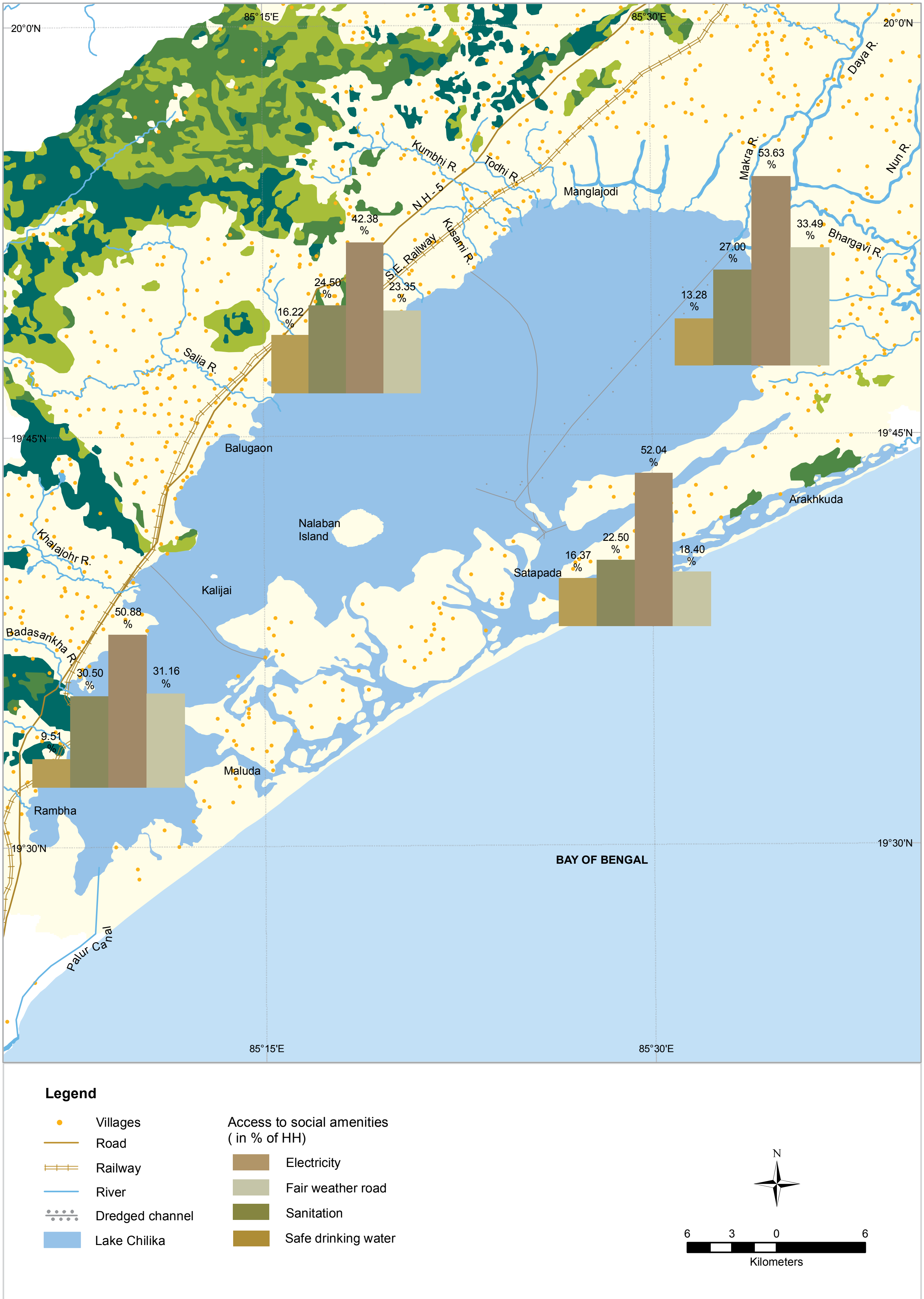


Fig. 20: Trend in livelihood assets of Chilika communities

Based on the current analysis, the following emerge as the major vulnerability contexts:

- **Increasing pressure on wetland resources:** Since the 1950s, while the overall fish catch has doubled, the number of fishers has increased four folds. Though the current production remains around projected maximum sustainable yield, a faster increase in effort as compared to production is likely to increase competition over limited resource base. Similarly, tourism development within Chilika needs to be assessed in terms of overall carrying capacity of the wetland ecosystem considering the ecological sensitivities alongwith community livelihood needs.
- **Declining community fisheries management institutions:** Fishing institutions in Chilika which evolved synergistic to the wetland ecological processes and functions have given way to rent and profit seeking institutions which are aligned towards consumer preferences. The nexus of fisheries agent and middlemen financed debt is a major threat to sustainability of Chilika fisheries and equitable benefit sharing.
- **Limited water, sanitation and hygiene (WASH) infrastructure:** Limited access to appropriate WASH infrastructure is a high risk to Chilika communities, which impacts their ability to labour, deploy livelihood assets, and in the long terms their ability to play an effective role in wetland management. Women and children are more vulnerable to the impacts of the inadequate WASH infrastructure.



Map 33: Access to social amenities in villages around Lake Chilika (2009)

2.2.6 Ecosystem services

Lake Chilika provides a range of ecosystem services that play a critical role in sustaining life and livelihoods of communities living in and around. The key provisioning services include commercial fisheries, aquatic vegetation for economic use, and means for inland navigation. The ability to regulate hydrological regimes is an important regulating service provided by Chilika. Cultural services in the form of religious as well as touristic values are important contributions to livelihood capitals.

Provisioning services

Commercial Fisheries

Lake Chilika harbours 62 fish, prawn and crab species of commercial value. The annual average harvest of 11,961.37 MT (average for 2001-11) supports livelihoods of 0.14 million fishers living in 152 villages spread around Chilika. The number of active fishers was estimated to be 34,700 in 2007. Of the total landing, 24.26% is sold in and around Chilika, 21.08% in Odisha State, 46.7% exported to states outside Odisha and 7.79% exported to international markets (CDA, 2004). Fishing is organized along a complex market chain, wherein a sizeable proportion of the trade is controlled by 2,900 middlemen and commission agents.

While the fish catch has increased significantly since the hydrological intervention of 2000, there are indicators of stagnation in catch per boat and per active fisher. The annual fish catch per boat rapidly declined from 2,427 kg to 388 kg during 1957 to 1999, and recovered to 2,398 kg post hydrological restoration. Similarly, the annual fish catch per active fisher declined from 708 kg to 62 kg during 1957 to 1999, and recovered to 297 kg in 2010. The annual catch is also hovering around the maximum annual sustainable yield of 12,636-13,896 MT, which indicates the need for careful management. Increased usages of gears capable of harvesting juveniles threaten long term sustainability.

Aquatic vegetation

Chilika Lake supports a rich diversity of aquatic vegetation, several species of which are harvested for use by the communities living in and around the lake and its associated floodplains. *Schoenplectus litoralis* (Sipala) is used by the fisher communities located near the Bhushundpur village for making mats, *Phragmites karka* (Nala dala) is used as fuel by villages on the northern shores; whereas *Potamogeton pectinatus* and *Naja* sp. (Chari dala) as preservation material for the fishes, crabs and prawns. *Paspaldium* sp. is used as fodder for milch cattle. *Gracelaria*, an agar producing algae is another sp. of economic importance. Three seaweed derivatives viz. agar, alginates and carrageen are currently utilized for economic purposes. Besides they have great ecological value as natural habitat for crabs and other related species. As per assessment of 2007, over 58,000 MT of vegetation is harvested for above mentioned uses.

Inland Navigation

Chilika is used as mode of inland navigation especially by the island villages for several of which this is the only mode of communication. This is a source of revenue generation for the government, as well as the private boat operators who ferry the passengers from one sector of the lake to the other. During 2003-06, 35,670 passengers used this mode of transport on an average annually, generating a revenue of 0.72 million.


Fishing nets stacked near the shoreline

Regulating services

Regulation of hydrological regimes

Lake Chilika, with an enormous storage capacity of 1200 MCM of water (with a water level variation in excess of a meter) provides a huge capacity downstream thereby reducing floods.

The salinity gradient maintained by Chilika supports high biodiversity within the lagoon ecosystem. This is particularly important for fisheries.

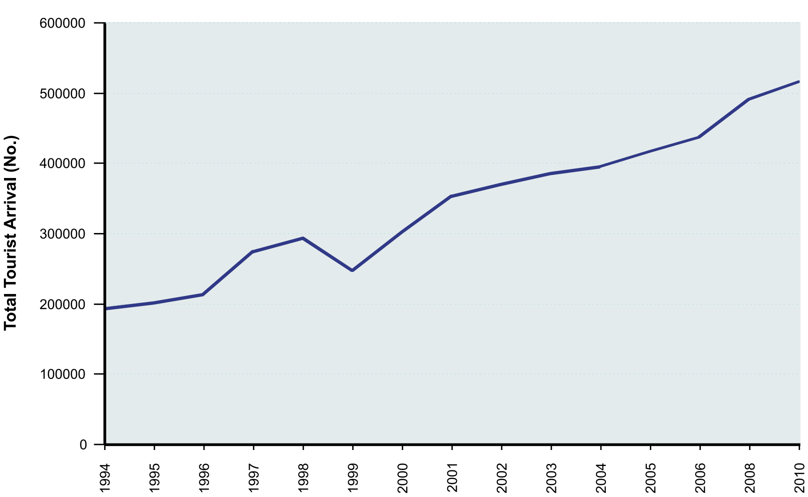
Apart from fisheries, the extent and condition of seagrass beds is also dependant on the salinity gradient. The presence of seagrass is considered to be a useful integrative indicator of ecological health of the lake. Seagrasses are an important food for various bird and crab species, provide a substrate for epiphytic algae that are also an important food source, help raise oxygen levels in water and provide refuge habitat for numerous small aquatic animals.

Beacon island-an important tourist spot in Chilika

Cultural services

Chilika Lake with its rich biodiversity and scenic beauty, is one of the important tourist destination of Odisha, and accounts for 8-10% of the total tourist arrival of the state. Balugaon, Satpada and Rambha are main touristic locations in and around the lagoon. Of particular interest to the domestic tourists are the religious sites. Numerous temples and holy springs are present around Chilika and on its islands. Kalijai temple is situated on an island considered to be the abode of the island goddess Kalijai. She is particularly venerated by local boatmen. Babakundaleswar Temple located near Manikapatna; Narayani, Bhagbati and Dakshya Prajapti Temples located near Barakul are other important religious sites located in and around Chilika.

Fig. 21 : Trends in tourist arrival in Chilika



Bird island is a rocky island located within the southern sector of the lake, and is characterized by huge hanging rocks. The island is covered with herbs, shrubs, trees and creepers. It plays host to numerous resident and migratory bird species. Somolo and Dumkudi, located within the central and southern sectors of lake and inundated remnants of Eastern Ghats present a picturesque sight with Khalikote hill range as a backdrop. Similarly, Parikud, a complex of islands including Baranikuda, Malatikuda, Badakuda and Sankuda made of entrenched sand dunes are ideal spots for nature lovers. Dolphin sightings near Satpada are an important component of nature lover's visit to the lake (Map 34).

The trend of tourist arrival at Chilika for the period 1994-2006 is indicated in Fig. 21. The lowest tourist inflow was recorded in 1999 and has been increasing thereafter registering an annual increase of 9%. Based on the flow trends, year 1999 also divides the inflow records into two phases; a pre 1999 phase wherein the number of tourists after reaching a peak in 1997 gradually declined with an average growth rate for the period being 4%. The period after 1999 has seen a continuous increase in the tourists, averaging 8% annual growth for the period.

Domestic tourists account for 99% of the total tourists, and the trend has broadly remained constant over the period. However, the rate of growth of foreign tourists, particularly after 1999, has been almost double to that of the domestic tourists. The average domestic and foreign tourist inflow during the period 1999-2006 was 1.60 and 1.99 times respectively the average for the preceding phase, i.e. 1994-1999.

Map 34 : Tourist spots in Lake Chilika

Box 5: Economic Valuation of Lake Chilika Ecosystem Services

Wetlands support human wellbeing through a range of ecosystem services, yet continue to be lost and degraded at rates more rapid than other ecosystems. This is largely attributed to policy decisions that fail to internalize and factor in the values of wetland ecosystem services in a manner that supports their retention or rehabilitation. In many cases the tangible and financial benefits arising through wetland degradation or conversion are taken into account when making such decisions; however, the substantial value arising from wetland ecosystem services which are not traded into formal markets and thereby do not generate cash flows are not. Incomplete knowledge of the value of these services can lead to perverse incentive systems which favour degradation and conversion of wetlands without considering the consequent loss of human welfare and impacts on human health and overall well-being. Quantifying and valuation of wetland ecosystem services in a way that makes them comparable with the returns derived from alternative uses can facilitate improved policy and decision making.

WISA and CDA conducted an economic valuation of Lake Chilika ecosystem services with an aim to assess and quantify the economic contribution made by wetland ecosystem into local and regional economy and to further support its conservation and wise use. Values were generated for fisheries, tourism, inland navigation, and aquatic vegetation. The non-consumptive values linked to Chilika were also estimated.

Fisheries: Fisheries of Lake Chilika is traded within domestic, national and international markets leading to sizeable economy for the fishers and those employed in ancillary industries. The market value of the Chilika fish has been estimated to be Rs. 768.82 million annually. The international markets though consuming only 10.4% of the total landing contributes 22% of the total value. As nearly 65% of the catch is traded beyond the local markets and landing centers, there is an incremental value additional of 38% value addition over landing center prices. The ancillary industry which is based on Chilika fisheries is estimated to be valued at Rs. 215 million per annum.

Tourism: The economic value of tourism related to Chilika was estimated using the Individual Travel Cost Method (ITCM). Demand curves relating the annual site visitation rate to the visit costs, income, and other socioeconomic characteristics were developed separately for the domestic and foreign tourists. Individual consumer surplus was aggregated to the total site arrival for estimation of the overall consumer surplus for the site. Data for computation of the demand curve was elicited through a survey of 433 tourists carried during the months of October 2006 – January 2007. The average consumer surplus for the domestic and international tourists was estimated to be Rs. 5,806 and Rs 120,480 respectively, which based on the arrival records translates into a value of Rs. 2,336 millions.

Inland Navigation: Communities living around Chilika, particularly in the island villages depend majorly on water transport. During 2003-07, every year 35,600 persons used ferry service operational in Chilika through the Chilika Development Authority, yielding a revenue of Rs. 0.72 million.

Aquatic vegetation for economic use: Based on surveys conducted during 2007, the local communities harvested 58,000 MT of aquatic vegetation for use for making mats, roofing and thatch, and as packing material for transporting fish and crab. Valuing these based on the value of finished product as well as using opportunity cost of time as surrogate yields an economic value of Rs. 34.7 million per annum.

Non-Use Values: Communities attach a range of non-use values to Chilika which are not linked with current use of the resource. These values may reflect the value lost due if the resource ceased to exist, or generated by the motivation of bequeathing the resource to future generations. Estimation of consumer surplus derived from non-use benefits derived from lagoon ecosystem is based on analysis of the closed ended data to generate the mean willingness to pay for Chilika. The WTP was assessed using a logit model to identify the determinants of the responses to the question: " Yes, I am willing to pay Rs. X" or " No, I am not willing to pay Rs. X", where X refers to the amount of closed bid in each case. The aggregate non-use value estimated by extrapolating the willingness to pay estimates to the overall basin households, and has been assessed at Rs. 858.78 millions.

These value however reflect only a small range of services delivered by Chilika. Further work is required on valuing the regulating services, for example role of wetland system in providing flood protection.

An important aspect of ecosystem services is their overall distribution within various stakeholder groups. This is influenced by institutional arrangements, such as property rights, which mediate the linkages between wetland ecosystem services and human societies. The complexity of property rights has an influence on the way costs and benefits of ecosystem services are distributed and shared across societies and thereby have an important influence on the way priorities on ecosystem services are generated, managed and trade-offs negotiated.

The breakdown of community managed Chilika fisheries due to introduction of illegal prawn culture has had a significant influence on the benefit sharing patterns in the fisheries sector. Computation of net value added to fishers and retailers indicates that the economic returns earned are almost equivalent to the prevailing wage rate in agricultural sector. In contrast, commission agents earn a much higher (Rs. 0.11 million) surplus, giving them an incentive to maintain and further deepen the coercive structure of markets. CDA has therefore introduced a programme for strengthening community institutions and ensuring availability of credit at fairer terms to enable them getting better incentives through sustainable management (refer Box 4, Page 76 for further details).

2.3 Ecological character description

Wise use of wetlands is defined within the text of Ramsar Convention as "the maintenance of their ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development". Contracting Parties to the Convention are expected to manage their Ramsar Site, so as to maintain their ecological character, and in doing so, retain those essential ecological and hydrological function which ultimately secure ecosystem services. Ecological character therefore is an indicator of health of the wetland ecosystem. Changes to ecological character of the wetlands, outside natural variation may signal that uses of the site are unsustainable, and may lead to the breakdown of the ecological, biological and hydrological functioning of the wetland system (Ramsar Convention 1996, Resolution VI.1).

The core of definition of ecological character is the description of components, processes and ecosystem services at a given time (for example while listing as a Ramsar Site). From management perspective, ecological character definition allows identification of critical components, processes and services, and identify changes thereof, which require management intervention. Frameworks for ecological character definition are provided in Ramsar Resolution X.15 adopted by the Contracting Parties in Changwon, 2008. Besides the Convention, the Government of Australia developed a national framework and guidance for Ecological Character Description (Department of the Environment, Water, Heritage and the Arts, 2008).

Lake Chilika is a nested socio-ecological system, wherein its ecological character stands influenced and modified by the way livelihood systems are linked to wetland resources, choices and trade-offs they make and governance systems that influence their behaviour. The social construct of the ecological character of wetlands reflects its interlinkages with livelihood systems, and thereby provides key insights into the ways ecological character connects with livelihood capitals, institutions and finally human wellbeing.

The framework used for describing ecological character of Chilika Lake builds on the Ramsar Framework described in Resolution X.15 and the National framework used in Australia modified to the context of Chilika. The status and trends in components processes and services, derived from evaluation of features is discussed in this section. The conceptual model used is presented as Fig. 22.

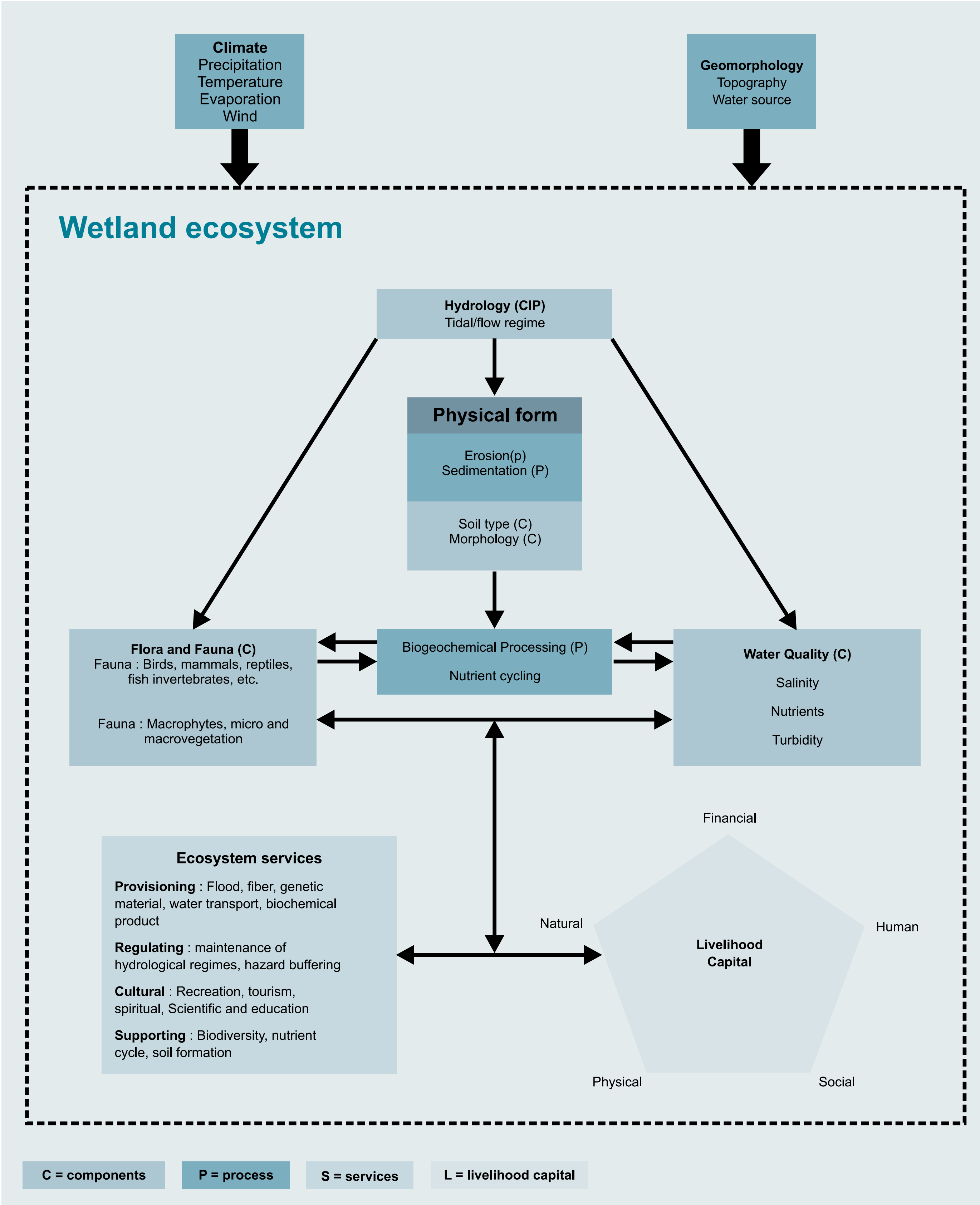


Fig. 22 : Framework for Ecological Character Description

2.3.1 Status and trends in components, processes and services

Ecological Components

Ecological Components	Status	Data assessment year and source	Trend
1. Physical Form			
a) Area	Reported to fluctuate between 1165 km² and 906 km² (World Bank 2004). Lake area computed to be 987.2 km² based on satellite imagery of January 2011.	2011, Remote sensing imagery	Tripati and Vora (2005), based on comparison of topographical maps and remote sensing imageries report a decline in area from 860 km² to 605 km² during 1929-1988. There is a high likelihood of a gradual shrinkage owing to deposition of alluvial sediments in the northern sector. Marginal impacts are also likely from shrimp farms on the lake periphery and enclosures inside the wetland.
b) Bathymetry	Latest assessments conducted in 2007-08 indicates water holding capacity of 1,206.89 MCM at a maximum surface area of 987.796 km². The southern sector has an average depth of (-2 to -3 m amsl), and is the deepest part of the wetland. The northern sector and the outer channel are the shallowest portion, with depth ranging between -2 to + 2 m amsl	2007-08, CDA	No previous bathymetric records are available. However, sedimentation studies of 2004 indicate 0.85 m and 0.49 m deposition in northern and southern sectors.
c) Shape	Pear shape		No discernible trend.
2. Wetland Soils			
a) Texture	Lake sediment is loamy-sandy in texture. Percentage of coarse sand higher towards outer channel (28.31-98.47%), silt higher in southern sector (17.53-89.44%) and fine sand in northern (28.67- 53.02%) and central sector (45.06-51.59%)	2003-04, CIFRI (2006)	The only available past record is of 1995-96 (Banerjee *et al.*,1998), which indicates silty loam in northern sector, silty in central sector and sandy clay in southern sector. Change in soil texture in the northern and outer channel sectors can be attributed to silt flows from deltaic rivers and tidal action respectively.
b) Chemical properties	Lake sediment is alkaline with rich organic carbon, high conductivity, high available nitrogen and low available phosphorus. • pH: 7.0-9.28, low pH in northern sector in weed infested areas. • Organic carbon: 0.27-3.25 %, organic carbon high in central sector during winter due to guano droppings of birds. • Specific conductivity: 1.4-21.7 millimhoscm^{-1}, maximum in central sector and minimum in outer channel during winter. • Available nitrogen: 7.28-56 mg/100g of soil, higher during monsoon. • Available phosphorus: 0.64- 4.04 mg/100g of soil	2003-04, CIFRI (2006)	Comparison with studies of 1995-96 (Banerjee *et al.*, 1998) suggests an increase in available nitrogen (from 3.3-34.2 mg/100g of soil during 1996) and decline in available phosphorus (1.2-10mg/100g of soil). However, the 2003-04 as well as 1995-6 assessments are based on one year observations. Long term monitoring is required to assess the changes.
c) Biological properties	Assessments yet to be carried out		No previous assessments available.
3. Physico-chemical Water			
a) Nutrients	The Lake is rich in nutrients. Assessments of 2003-04 indicate the following levels: • Nitrate: 0.036-0.324 ppm, high in central sector during winter. • Phosphate: 0.002-0.252 ppm high in outer channel during winter and low in southern sector due to maximum utilization by macrophytes • Silicate: 0.5-10.3 ppm	2003-04, CIFRI (2006)	Comparison with assessment of 1959-61 (Banerjee and Roychoudhury,1966) and 1995-96 (Banerjee *et al.*,1998) indicate considerable reduction in nitrate implying effective utilisation for lake productivity (trace to 0.19 ppm during 1959-61, 0.03-3.6 ppm during 1995-96) There is a negligible reduction in phosphate (traces-0.18 during 1959-61, 0.04-0.28 ppm during 1995-96) and increase in silicate (0.4-1.6 ppm during 1995-96)
b) Conductivity	The dissolved salt concentration in the lake ranges from 3.3-32.2 millimhos/cm² being highest in outer channel	2003-04, CIFRI (2006)	Comparison with 1995-96 assessment (Banerjee *et al.*,1998) indicate a decline in specific conductivity (1.25-95 millimhos/cm² during 1995-96).

Ecological Components	Status	Data assessment year and source	Trend
c) Cations and Anions	Information on Na and K and anions available from CDA for 2001, and for the rest from CIFRI (2006). The values are as follows: • Calcium: 16.03-376.75 ppm • Magnesium: 28.8-1,655.6 ppm • Sulphate: 4.33-107 ppm • Chloride: 0.3-17.2 ppm • Sodium: 10-10,300 ppm • Potassium: 0-650 ppm	2000-01, CDA and 2003-04, CIFRI (2006)	Comparison with 1995-96 assessment (Banerjee *et al.,* 1998) indicate an increase in Ca and Mg and decrease in Na and K concentrations. The 1995-96 values are as follows: • Calcium: 1.2-26 ppm • Magnesium: 2.3-99.4 ppm • Sodium: 3-36 000 ppm • Potassium: 140-1 100 ppm Further studies are required to assess the robustness and significance of these changes.
d) Temperature	Chilika is a tropical lake with surface water temperature ranging from 18.9-35.2°C. Being shallow, their is no evidence of thermal stratification.	2000-2011, CDA	Current values are comparable to the 1985-88 assessments (Siddiqui and Rao,1995), Satyanarayan (1999), Banerjee *et al.,* (1998); and for 1995-00 by Bhatt and Pattnaik (1998) • 20-36°C (1985-88) • 23-36.5°C (1995-2000)
e) Dissolved Oxygen	The lake is well oxygenated. DO ranges from 0.3-13.8 ppm.	2000-2011, CDA	Current values are comparable to the 1985-88 assessments (Siddiqui and Rao ,1995), Satyanarayan (1999), Banerjee *et al.,* (1998); and for 1995-00 by Bhatt and Pattnaik (1998) • 2-19.6 ppm during 1985-88 • 0.6-12.5 ppm during 1995-2000
f) pH	Lake water is overall alkaline. pH ranges between 6.6-10.1 with limited variations in sectors. Lower pH values observed during monsoon due ingress of organic matter with runoff and its subsequent decomposition.	2000-2011, CDA	Current values are comparable to the 1985-88 assessments (Siddiqui and Rao, 1995), Satyanarayan (1999), Banerjee *et al.,* (1998); and for 1995-00 by Bhatt and Pattnaik (1998) • 7.0-10.0 (1985-88) • 6.3-10.0 (1995-2000)
g) Nutrient cycling	Assessments yet to be carried out		No previous assessments available.
h) Transparency	High sectoral and seasonal variation in transparency, ranging between 3-400 cm. Maximum transparency in southern sector during winter and minimum in northern sector during monsoon	2000-2011, CDA	Assessments are available for 1985-88 (Siddiqui and Rao, 1995) and 1995-99 (Satyanarayan, 1999; Banerjee *et al.,* 1998; Bhatt and Pattnaik 1998). A trend of increase in transparency is indicated as compared to 0-220 cm reported during 1985-88. Low transparency during 1995-2000 (0-267 cm) was due to *Oscillatoria* bloom
i) Salinity	Lake Chilika maintains a spatial and temporal salinity gradient throughout the lake; freshwater in northern sector, brackish in central and southern sector and marine in outer channel. The values range between 0-37 ppt and are highest during summer in outer channel and lowest during monsoon in northern sector.	2000-2011, CDA	Salinity levels have been assessed since 1957 (1957-60 by Jhingran, 1963; during 1985-90 by Biswas, 1995; Satyanarayan, 1999; Ghosh and Pattnaik, 2005; CDA, 2008; Nayak *et al.,* 2010). In general, the lake went through a phase of declining average salinity during 1995-2000. The hydrological intervention has served to increase the average salinity. However, the values of 1950 till 1980s need to be interpreted with caution, as simultaneous records for freshwater flows are not available. High salinity values are also linked to low monsoon flows amongst other factors. Historical values of average salinity in Chilika are: • 0.16-36.02 ppt (1957-60) • 0.6-15.1 ppt (1985-90) • 0.5-25.9 ppt (1990-95) • 0.0-36.1 ppt (1995-00)

Ecological Components	Status	Data assessment year and source	Trend
4. Biota			
a) Wetland plants	Primary survey on wetland plants carried out in 1999-2000 (Pattnaik, 2003) and CIFRI (2003-04, limited to macrophytes of northern sector). The assessments indicate the presence of 729 angiosperms belonging to 454 genera under 120 families including 401 species of dicots and 143 monocots Northern sector is dominated by emergent and submerged type most notably *Phragmites karka, Hydrilla verticillata, Vallisneria spiralis.* Central and southern sectors dominated by submerged brackish water type mostly *Najas, Potamogeton* and *Halophila.* The outer channel area has very less vegetation in comparison to other sectors and is represented by submerged stands of *Potamogeton pectinatus.* Two new records of sea grass, *Halodule uninervis* and *H. pinifolia* (Kumar & Pattnaik, 2010)	1999-2000, Patnaik (2003); 2003-04, CIFRI (2006)	Comprehensive historical record of wetland plant distribution and extent are not available, and hence trends cannot be discerned. Biswas (1932) reported presence of 11 benthic algae species. Panda and Patnaik (1988) recorded 352 angiospermic plants. Further, Rout and Durani (1993) recorded 14 species of submerged plants. One of emerging stresses on ecological character of Chilika is changes in composition of macrophytes, particularly after the hydrological intervention of 2000. While the opening of new mouth and subsequent changes in salinity regimes have led to drastic decline in area under water hyacinth (*Eichhornia crassipes*), *Phragmites karka* (locally called Nala dala) has rapidly invaded north and north-western segments of lake. Its area in Chilika has significantly increased from 76.4 km^2 in 2000 (the survey for assessing current spread was still in progress at the time of writing this report).
b) Vertebrate fauna			
• Fish	The recent assessment indicates presence of 314 species of fish, 29 species of prawn, and 35 species of crab. 56 species are new records since the hydrological intervention of 2000, and include 43 fish species, 4 prawn, 7 crab and 2 Indian spiny lobster species.	CDA monitoring records (2012)	Fish diversity of Chilika has been assessed since 1957-60 (Jhingran and Natarajan ,1966). Overall, 112 species of fish, 24 species of prawn, 26 species of crab have been recorded in this assessment. Survey carried by ZSI (1995) recorded 216 species of fish, 25 species of prawn and 31 species of crab 6 species, namely *Megalops cyprinoides, Elops machnata, Rhinomugil corsula, Chanos chanos, Tenualosa hilsa, Acanthopagrus berda,* not recorded in 1999-2000 assessment have reappeared in the lake.
• Amphibians	The diversity of amphibians is based on survey by ZSI of 1985-88 (ZSI, 1995). The survey recorded presence of 7 species.	1985-88, ZSI (1995)	The earliest assessment of amphibian diversity is of 1914 (Annadale and Kemp, 1915), in which only 4 species were reported.
• Reptiles	The diversity of reptiles is based on survey by ZSI of 1985-88 (ZSI, 1995). The survey recorded presence of 30 species.	1985-88, ZSI (1995)	The earliest assessment of reptiles diversity is of 1914 (Annadale and Kemp, 1915), in which only 22 species were reported.
• Waterbirds	Chilika is an important birding site and field monitoring station of BNHS. Recent assessments indicate presence of 224 bird species which includes 129 waterbirds. Chilika hosts 97 intercontinental migrants from Arctic Russia, West Asia, Europe, North East Siberia and Mongolia The wetland regularly supports 0.7-0.95 million waterbirds annually. For 45 species population at Chilika exceeds the 1% threshold population. Nalaban and Mangalajodi host maximum population of the winter visitors owing to the presence of invertebrates and submerged macrophytes The guano droppings add considerable quantity of nitrogen and phosphorus (33.8 t of nitrogen and 10.5 t of phosphorous for ducks and geese) to the lake which helps for lucrative fisheries in Chilika.	2001-11, CDA	BNHS, during eighties recorded 150 species of birds in the lake of which 90 species were confined to Nalaban (Mohapatra and Hussain, 1988). The overall population of migratory birds have seemed to maintain a range since 2000. This is significant since 62% of waterbird population with known trends in Asia are known to decline (Li et al., 2009). Bird congregation areas are spreading towards northern sector in general.
• Mammals	The diversity of mammals is based on survey by ZSI of 1985-88 (ZSI, 1995), which recorded presence of 19 species.		The earliest assessment of mammals is of 1914 (Annadale and Kemp, 1915), in which 18 species were reported.

Ecological Components	Status	Data assessment year and source	Trend
• Dolphins	Chilika is one of the only two lagoons in the world hosting population of Irrawaddy Dolphins. Annual census is carried out to assess their population. The population of Irrawaddy Dolphins in Chilika in February 2011 stood at 156, which included 4 calves, 21 subadults and 131 adults. Their presence, which was observed to be confined to outer channel till the 1990s, is now also seen in southern and central sectors. The first genetic study on *O. brevirostris* from Chilika was conducted by Jayasankar *et al.,* (2011) which reported closest proximity to haplotypes of Thailand.	2000-2011, CDA	The population of Irrawaddy Dolphins declined sharply till 1990s. Annadale and Kemp recorded 50 individuals in 1914 (Annadale and Kemp,1915) which was reduced to 20 individuals in1990 (Dean and Saaltink, 1991). The population has steadily increased since 2000. The habitat use has also increased as per annual monitoring records of CDA.
c) Phytoplanktons	Most recent assessment of phytoplankton diversity is of 2003-04 (Jha, 2009). 399 species belonging to 181 bacillariophyceae, 79 euglenophyceae, 50 dinophyceae, 44 cyanophyceae, 29 chlorophyceae, 11 xanthophyceae and 5 species of chrysophyceae have been recorded. Their abundance has been assessed to be 5680-12500 no./l, with higher values in outer channel (1780-8320 no./l). Three peaks in phytoplankton abundance are observed during winter, summer and monsoon dominated by bacillariophyceae, dinophyceae and chlorophyceae respectively.	2003-04 (Jha, 2009)	Assessment conducted during 1950s recorded 43 species (Devasundarum and Roy (1954). Raman and Satyanarayan (1998) during 1995-96 reported 42 species of mostly freshwater bloom forming algae *Oscillatoria. Bacteriastrum, Biddulphia, Ditylum, Lauderia, Triceratium, Thalassiothrix* were not reported in the study. Phytoplankton abundance recorded during 1995-96 was 261-35726 no./l by Banerjee *et al.,* (1998). Comparison with 1995-96 assessments indicate an increase in phytoplankton diversity and decrease in abundance. Since the 2000 hydrological intervention, there has been a reappearance of marine and brackish water forms (eg. *Bacteriastrum, Biddulphia, Chaetoceros*) (Patnaik , 2010)
d) Aquatic macro-invertebrates	Most recent assessment of macro-invertebrates is that of 2003-04 (Patnaik *et al.,* 2009) which reported 44 macrobenthic species. The abundance was assessed to be 5014-29433 no/m^2 being higher in central sector (29433no/m^2)	2003-04 (Patnaik *et al.,* 2009)	Comparison with earlier assessments conducted by Sarma *et al.,* (1988) and Banerjee *et al.,* (1998) indicate a decrease in species diversity (from 117 in 1980s to 44 species in 2003-04) and increase in abundance (from 334-1516 no/m^2 during 1995-96 to 5014-29433 no/m^2 during 2003-04)
5. Climate			
a) Precipitation	Rainfall is concentrated during June-September (accounting for nearly 90% of the total annual rainfall). There are significant inter-annual variations, with the average for 2007-2008 being 1,190 mm (at Chandraput).	1951-2007 (Indian Meteorological Department)	Previous rainfall records of 1975-78 (JNU, 1978) and 1995-96 (Banerjee *et al.,*1998) are higher than the current average (1450 mm in 1975-78 and 1439mm in 1995-96) Odisha State level assessments based on downscaling of general circulation models indicate a decline in rainfall during the dry period (September-February) along with an increase in summer and monsoon rainfall coupled with an increase in maximum / peak rainfall. An increased incidence of hydrological extremes is projected (Ghosh and Majumdar, 2006)
b) Air Temperature	Highest temperature attained in May and the coolest in December. The air temperature recorded by CDA during 2000-08 ranges from 11.14- 35.64°C	2001-2011, CDA	Long term temperature records not available for Chilika region
c) Evaporation			180-240 cm annually during 1975-78 reported by JNU (1978)
d) Wind	Higher wind velocities in summer (south to southwest direction) and lower in winter (north to northeast). Average wind speed during 2007-08 recorded to 2.3-86.1 km/hr at Satpada and 0.6 to 49.04 km/hr at Chandraput.	2001-2011, CDA	Ranges comparable to previous assessment of 1983-89 (Nayak *et al.,* 1998)-0.18-57.43 km/hr
e) Humidity	Ranges between 15.62%-97.4%	2001-2011, CDA	No previous record available

Ecological Components	Status	Data assessment year and source	Trend
6. Geomorphology			
a) Topography	Lake Chilika is surrounded by several erosional and depositional landforms. The western catchment is marked by denudational hills of khondalite, charnockite, gneisses, anorthosite and granite. The northern periphery is fringed by large tract of alluvial plains extending to more than 600 km^2. A number of sandy beach ridges are present along the eastern margin separating Chilika from open sea. The open coast is marked by presence of a prominent spit connected to the mainland at its southern end.		
b) Connectivity to surface waters	Lake Chilika is connected to the sea by 32 km long channel opening into the sea at Sipakuda, and in the southern sector by Palur canal which links to Rishikulya estuary. Freshwater into the lagoon is received through 3 Mahanadi River distributaries and 8 streams of the western catchments.		Chilika seems to undergo a cyclical process of shifting towards freshwater state due with gradual choking of sea-inlet which is subsequently restored to brackish and high salinity conditions once the mouth is opened by natural processes as strong tidal action or cyclones. Based on landsat imageries, Tripati and Vora (2005) report 3 inlets in 1975, 2 in 1985 and 1 since 1986. In August 2008, an additional mouth was opened at Gabakunda due to strong tidal action.
c) Water sources	The overall annual freshwater flows into Lake Chilika from the river systems, based on average for 1999-2010, was 4,906 MCM Mahanadi Delta river system contributed 75% of the freshwater inflows and the rest by the western catchments. Detailed assessments of hydrological regime contribution from the sea needs to be carried out.	2001-2011, CDA	Trend data not available. Basin level assessments of impacts of climate change on hydrology also indicate an increasing variability of flows within Mahanadi River. The Mahanadi River has been predicted to have maximum impact on account of flood conditions. The basin is predicted to receive comparatively higher level of precipitation in future and a corresponding increase in evapo-transpiration and water yield. Flow duration curves indicate a marginal increase in dependable flows at all levels.
d) Soils	Nitisols in the hills of western catchments, lixisols in deltaic region, solonchaks along the northern sector and aerosols or sandy soils with very weak soil development in coastal zone of the Chilika.	Harmonised World Soil Database, 2009 version 1.1	No historical records / assessments available.
e) Erosion	Assessments yet to be carried out		
7. Hydrology			
a) Water balance	Analysis for inflows for 1999-2010 indicate that Mahanadi Delta river system contributed 75% of the freshwater inflows and the rest by the western catchments. Full water balance including marine flows has not been attempted.	1999-2010, CDA	No historical records / assessments available.
b) Groundwater infiltration and seepage	Assessments yet to be carried out		No historical records / assessments available.
c) Surface -groundwater interactions	Assessments yet to be carried out		No historical records / assessments available.
d) Tidal regime	CDA established the tide gauge stations at Sipakuda, Satapada and Magarmukha in Chilika lagoon. The tidal variations have been recorded on a hourly basis for the whole year. Analysis of monthly tidal variation data at Satpada indicates an increase from 0.36 m in 1999-2000 to 0.56 m in 2000-01 and 0.80 m in 2006-07	2001-2011, CDA	The hydrological intervention of 2000 has led to marked improvement in the overall tidal effect in the lake
e) Inundation regime	Inundation regimes are important for island habitats (especially Nalabana wherein inundation patterns impact the island vegetation and thereby food availability for birds) and northern sector, wherein exposed riverine sediment beds for put to various productive uses by farming communities. Inundation within the delta rivers plays a critical role in the sediment dynamics of the floodplains.	2001-2011, CDA	Trends in inundation patterns for island systems are not known. Inundation patterns in delta rivers has been greatly impeded by construction of embankments, which has served to restrict sediments within channels. Regional studies to assess impacts of these changes are unavailable.

Ecological Components	Status	Data assessment year and source	Trend
8. Energy - nutrient dynamics			
a) Primary production	Assessments by CIFRI in 2003-04 indicate high productivity ranging from 186-207.88 mgC/m^3/hr. Maximum during winter in central sector.	2003-04, CIFRI (2006)	Comparison with assessments of 1995-96 (Banerjee *et al.,* 1998) indicated increase in primary productivity during monsoon and winter by 56.77% and 58.64%. Values reported were in the range of 77.07-229.8 mgC/m^3/hr.
b) Nutrient cycling	Assessments yet to be carried out		No historical records / assessments available.
c) Carbon cycling	Assessments yet to be carried out		No historical records / assessments available.
d) Decomposition	Assessments yet to be carried out		No historical records / assessments available.
e) Oxidation -reduction	Assessments yet to be carried out		No historical records / assessments available.

Ecological processes

Ecological Processes	Status	Data assessment year and source	Trend
9. Process that maintain animal and plant population			
a) Fish recruitment	The most recent assessments conducted on fish recruitment is that of 2003-04 (CIFRI, 2006) which recorded 3,794-15,774,884 number/ ha-m fin fish and 0-586,348 number/ha-m of shell fish recruitment in the lake. Fin fish recruitment was maximum in northern sector (15,774,884 number /ha-m) during monsoon and minimum in southern sector (3,794 number/ha-m) during summer. Shell fish recruitment maximum in outer channel (586,348 no/ha-m) during winter and minimum in southern sector (no recruitment) during monsoon. Outer channel serves as an important pathway for recruitment of juveniles throughout the year	2003-04, CIFRI (2006)	Jhingran and Natarajan (1966) have undertaken assessment of recruitment patterns in 1957-65, providing an account of migration and recruitment of fish broods and juveniles in various sectors. Assessments undertaken by JICA in 2006 using survey questionnaires reaffirm the trends reported by Jhingran and Natarajan (JICA, 2009a). However, both of these studies do not provide quantitative assessments of recruitment.
b) Fish migration	70-75% of fish and 70 % prawn and crabs found in Chilika are of migratory origin (Banerjee *et al.,* 1998 and Mohanty, 2002). The lake serves as the breeding and feeding ground for 207 migratory fishes which includes 15 catadromous, 13 anadromous and 110 amphidromous species. 39 species being potamodromous and 36 being oceanodromous are even found in the lake in low and high saline regions respectively. Outer channel serves as the major migratory route for commercially important species of fin fish and shell fish throughout the year. Palur canal is a migratory route majorly for prawn species. *T. ilisha* migrates from sea to breed near river confluence area.	2001-11, CDA	Comparison of studies conducted during 1960s (Jhingran and Natarajan, 1966)with that of recent (JICA, 2009a) indicate a shift in breeding ground of *T. ilisha* which earlier ascended lower and middle stretches of Daya and other deltaic branches of Mahanadi. The new mouth being close to the lake and water inflow from lead channel have pushed the breeding and nursing grounds towards Magarmukh area.
10. Species interaction			
a) Competition	Assessments yet to be carried out		No historical records / assessments available.
b) Predation			
c) Succession			
d) Herbivory			

Ecological Processes	Status	Data assessment year and source	Trend
11. Physical processes			
a) Stratification	Assessments yet to be carried out		No historical records / assessments available.
b) Mixing	Assessments yet to be carried out		No historical records / assessments available.
c) Sedimentation	Range of values of sedimentation has been reported. Pattnaik (2002) based on 1996-97 data indicate an annual sediment loading into Chilika to be 1.8 MT. Assessments based on modelling of 31 years flow data (carried as a part of the Environmental Flows Assessment) indicate an average annual loading of 2.35 MT of which 2.13 MT is from Mahanadi River alone (World Bank, 2004). Data for 1999-2007 indicates the average annual sediment loading of 1 million MT, of which Mahanadi system contributed 75%.	World Bank (2004), Young (2004)	Sediment coring of the lake bed confirms that the lake is filling with sediment (CWRDM, 2004, 2005). The coring suggests that sedimentation is now 3-5 times as fast as 100 years ago at the margins of the northern and southern sectors, and 30% higher at the margins of the central sector. This suggests flushing of sediment from the central sector through the mouth is reasonably efficient, but that sediment transport into the central sector from the northern and southern sectors is not efficient. Analyses for the coring data by Young (2004) estimate current sedimentation rates at 1.8 and 1.4 cm yr^{-1} at single coring locations in the northern and southern sectors respectively, and data show an increasing trend in sedimentation rate. Total depths of sedimentation at these locations are estimated to be 85 and 49 cm respectively, with most of this having occurred post-1950. However, these coring locations are very close to river exits and so are likely to represent the most extreme values of sedimentation in the lake.
d) Erosion	Soil erodibility can be indirectly inferred through soil, landuse and slope characteristics. Within lake basins, the crest watersheds have been identified as being highly erosion prone. Quantitative assessments are required to further assess extent and changes in erosion patterns		Trends based on land use assessments indicate decrease in dense forest cover from 567.75 km^2 to 287.99 km^2, and increase in open forest cover from 77.55 km^2 to 403.99 km^2 during 1972-2011. There has been increase in areas under irrigation. All these changes are indicative of increasing erosion, which need to be confirmed with quantitative assessments.

Ecosystem Services

Ecosystem Services	Status	Data assessment year and source	Trend
12. Provisioning Services			
a) Fisheries	Lake Chilika supports 62 fish, prawn and crab species of economic importance. The average landing for the period 2001-11 stood 11,961.37 MT. The landing constitutes 3.5%[19] of the state's production of the total landing 24.26% is sold in and around Chilika, 21.08% within Odisha State, 46.7% exported to states outside Odisha and 7.79% exported to international markets (CDA, 2004)	2001-11, data till 2004 published as CDA Bulletin No. 3., rest sourced from CDA monitoring records	Lake fisheries underwent a rapid decline since 1990, with decreasing average yield for the period 1991-2000.
	Fisheries form the base of livelihoods of 23,100 households with an overall population of 0.14 million living within 152 villages in and around Chilika The number of active fishers in Chilika has been assessed to be 34,700 which use a range of fishing gears and 5600 boats for fishing		There has been a gradual increase in the number of fishers as well as boats within Chilika. The number of active fishers and boats in Chilika was 8,060 and 2,351 respectively in 1957 (Biswas, 1995) Over 15 different types of gears were reported to be used for Chilika fishing in 1954, with distinct association with fisher caste, species and fishing ground (Jones and Sujansinghani, 1954; Sekhar, 2004). However currently 80 % of the catch is from Khonda and gill net alone. Gradual diminution of community fisheries has led to conflicts and loss of stewardship opportunities.

[19] The average fish production (including prawns) for the Odisha State for the period 2003-11 is reported to be 339,171 MT (Source: Economic Survey of Odisha, 2012)

Ecosystem Services	Status	Data assessment year and source	Trend
b) Use of aquatic vegetation for economic purposes	Schoenplectus litoralis used by fisher for making mats, *Phragmites karka* used as fuel, *Potamogeton pectinatus* and *Najas* sp. used as preservation materials for crabs and prawns Over 58,000 MT harvested from Lake Chilika annually for the above mentioned uses	2007-08 based on household survey	No historical records / assessments available.
c) Water transport	Inland navigation within Chilika forms the main mode of transport for inland villages. During 2003-06, 35,670 passengers used the inland mode with a revenue generation of Rs 0.72 million.	2003-06 (CDA)	No historical records / assessments available.
d) Biochemical products	Piloting cultivation of Gracillaria verucosa at Langaleswar and Samal for commercial extraction of agar (Rath and Adhikary, 2004; Padhi *et al.,* 2011)		No historical records / assessments available.
13. Regulating Services			
a) Maintenance of hydrological regimes	The water holding capacity of the lake (1206.89 MCM) provides huge storage capacity and thereby flood protection to upstream regions.		Prior assessments indicate increasing sedimentation, likely to have an impact on water holding capacity and thereby decline in ability to regulate hydrological regimes
14. Cultural services			
a) Recreation and tourism	Chilika Lake with its rich biodiversity and scenic beauty is one of the important tourist destinations of the State and accounts for 8-10 % of the total tourist arrival of the State. Balugaon, Satpada and Rambha are the main tourist locations in and around the lagoon. Chilika is visited by 0.3 million domestic and foreign tourists annually, which forms a sizeable economy for communities living in and around. The aggregate consumer surplus generated through tourism has been assessed to be Rs 2,336 millions of which 57% is directly spent within Chilika. There are 8 registered tourist motorboat associations with 1073 members.	2001-11, State Tourism Department	Trends indicate increasing touristic activity in Chilika. Restoration of Chilika since the hydrological intervention has seen a rapid growth in tourist averaging nearly 8% during 2000-06, as compared to 4% during 1994-99. The number of tourist boats has increased from 780 in 2001 to 1073 in 2009. Five new tourist boat associations have registered since 2000.
b) Spiritual	Chilika is closely intertwined with religious and cultural beliefs of the communities living in and around. There are numerous temples present around Chilika and on its islands. Kalijai temple id situated on an island considered to be the abode of the island goddess Kalijai. She is particularly venerated by local boatmen. Babakundaleswar temple located near Manikapatna, Narayani, Bhagabati and Dakshya Prajapati temples located near Barkul are other important religious sites around Chilika		
c) Scientific and educational	A number of scientific investigation and research are conducted on the lake. During the year 2008-10, 5 major capacity building programmes, 5 research activities, consultation workshops and exposure visit were conducted		Chilika is attaining increasing importance for scientific and educational purposes.

2.3.2 Threats to Ecological Character

Based on the analysis of wetland features and status and trends of components, processes and services, threats to ecological character have been identified. The threats have been further linked to the likely influence on ecological character, and the likelihood of changed ranked as high, medium or low. The analysis, further read alongwith the review of institutional arrangements provides an insight into the capability of management institutions to respond to the threats

Key threats	Likely influence on ecological character (C= Component, P= Process and S= Services)	Likelihood of changes in ecological character in near term (High, Medium, Low)
High rates of siltation		
Assessments of current siltation rates as well as results from analysis of sediment cores indicate that Lake Chilika is receiving elevated silt loads. Changes in land use within Chilika Basin aggravate this trend. Further fragmentation of floodplains have also led to changes to overall fluvial dynamics of the deltaic system, with the aggraded channels also being a source of silt into the lake.	Loss of water holding capacity (C) and thereby ability to regulate hydrological regimes (S)	High
Changes in surface-water connectivity		
Maintaining lagoon-sea connectivity is a challenge owing to high littoral drift, basin sedimentation and tidal influence. The inlet condition is rendered unstable due to reduction in tidal prism with increasing length of the channel. While the lagoon is known to go through phases of closure of sea-mouth, these changes have high implications for ecosystem services. Additionally, trends indicate increasing demands for upstream water uses, which would impact spatial as well as temporal availability of water resources downstream. This is likely to induce changes in salinity regimes, with concurrent changes in biota and ecosystem services.	Changes in hydrological regimes (C), water balance (C), species migration patterns between sea-lake (P), ability to sustain fisheries (S), and regulate hydrological regimes (S)	Medium
Regional Climate change		
Mahanadi River Basin level climate modelling studies indicate changes in precipitation patterns, impacting temporal variability of the freshwater flow regimes. These changes will have an impact on salinity gradient, which is a key determinant for wetland biota and ecosystem services.	Changes in hydrological regimes with associated changes in several components and processes	Medium to High
Invasion of *Phragmites karka*		
Rapid increase in area under *Phragmites karka* is likely to enhance siltation in northern sector, stress fish breeding grounds, shift vegetation belts and create health hazards for communities.	Increased siltation in northern sector (C), stress on fish breeding grounds (P) and community livelihoods (S)	High
Increasing tourist pressure		
Restoration of overall aesthetics of Chilika post hydrological intervention has led to increased touristic pressure. Unmanaged tourism beyond carrying capacity of the wetland system would create stresses on biota (for example Irrawaddy Dolphins) and ecosystem services.	Stress on biota (C) and ecosystem services (S)	High
Increasing pressure on lake fisheries		
Analysis of historical trends indicates a rapid increase in number of active fishers as well as fishing boats deployed in the wetland system. The overall catch is also hovering near the recommended sustainable yield levels. If not managed suitably, there is a high risk of overexploitation of fisheries resources with severe impacts on community livelihoods	Stress on biota (C) and ecosystem services (S)	High
Continued incidence of destructive fishing practices		
Chilika is subject to several detrimental fishing practices which pose major threats to its sustenance. Shrimp aquaculture on the shorelines of the central, southern and outer channel impedes inundation patterns and stresses the breeding and feeding grounds of fishes and prawns. Prevalence of *Khonda* fisheries on migration pathways leads to loss of valuable biodiversity including juveniles which are destroyed in the process, and creates obstruction to natural recruitment. Cast net operation near new mouth is affecting brood fishes of mullets. Indiscriminate propelling of boats churn lake bottom leading to increased turbidity. Use of fish mesh seine nets in large scale throughout the lake blocks migratory routes of fish and prawns and leads to killing of juveniles. Indiscriminate shrimp post larvae collection has severe implications for biodiversity lost in the by-catch.	Stress on biota (C) and ecosystem services (S)	High
Skewed resource benefit sharing patterns		
The current fish marketing system prevalent in Chilika leads to higher returns to middlemen and commission agents who exploit the vulnerability of fishers to gain undue returns from the enterprise. Even with increase in efforts, the return to fishers remains insufficient with respect to livelihood needs.	Stress on biota (C) and ecosystem services (S)	Medium

2.3.3 Knowledge gaps and monitoring needs

The current description of ecological character is based on hydrological and ecological monitoring records available through 47 hydro-meteorological stations in the lake basin and 30 stations within the wetland. The monitoring system is being continually upgraded and made more sophisticated through deployment of better equipment and training of research staff. Further, CDA has also initiated the following studies which will provide important information for wetland management:

- **Ecosystem health assessment:** In 2012, CDA initiated development of an Ecosystem Health Assessment Indicator system under the UNEP/GPA supported Global Partnership on Nutrient Management. The initiative aims at development of a nutrient health report card that could be used for monitoring and stakeholder dialogue. The index builds on six water quality and biotic parameters (chlorophyll-a, DO, transparency, submerged aquatic vegetation, and biotic integrity parameters for benthic and phytoplankton communities).
- **Regional coastal processes study:** In 2012, a regional coastal processes study for the entire coast of Odisha under the Integrated Coastal Zone Management Project supported by the World Bank has been initiated. This project will lead to development of baseline information on the sediment shell, in particular sediment budget for the coastline, and will thereby be of critical importance to understanding the overall sediment related processes in Chilika. The expected results of the project include development of sediment transport models to provide causes of erosion and accretion and prediction of trends of erosion, maps indicating areas of coastal erosion and accretion; hydrodynamic models useful in pollution dispersion studies, and coastal circulation models to help in locating suitable area for development of ports and harbours. Based on the output of the study, the shoreline management plan for Odisha will be prepared in a strategic management approach for economic development, protection against coastal erosion, promote sustainable use and conservation of the coastal zone's natural resources.
- **Assessing livelihood vulnerability to changing climate:** This three year research project aims to enhance climate preparedness of wetland management through developing of response options and strategies for reducing climate related risks as well as increasing community preparedness for changes in wetland ecosystem services. The project is supported under the Climate Change and Water Programme of International Development and Research Center (IDRC). The specific objectives of the project include: development of scenarios of change in ecosystem components, processes and services of Chilika Lagoon due to climate change; assessing current coping and adaptation mechanisms within wetland communities in the context of climate change; demonstrating options for enhancing livelihood resilience in changing climate through pilot interventions; formulating a "climate smart" plan for wetland management identifying adaptation options, intervention strategies, priority actions and investment required; and, building capacity of wetland managers to develop response strategy to climate change, particularly addressing livelihood resilience.

The ecological character description in section 2.3.1 clearly indicates that the current knowledge on status and trends is not complete for several elements. The current section focuses on the knowledge gaps that exist derived from a review of the information on wetland features. Firstly, an assessment of criticality of the ecological character elements is stated based on the available information on trends and generic understanding of the Chilika ecosystem functioning. This is followed by a summary of the coverage of current monitoring system. The knowledge gaps are stated next, followed by additional monitoring needs. It is recommended that these elements are added to the current monitoring framework. The resulting monitoring outcomes would be a key basis on which the management plan is reviewed and adapted.

Ecological Components / Processes and Services	Criticality for management plan monitoring	Coverage of current monitoring system	Knowledge Gaps	Monitoring need (additional to the existing system)
1. Physical Form - Area - Bathymetry - Shape	High	Temporal information on area is available. Bathymetric information is based on a single year assessment	Trends in bathymetry, shoreline changes	Bathymetry (every five years) Shoreline changes (atleast decadal) Currently proposed to be covered under Regional Coastal Processes Study
2. Wetland soils - Texture - Chemical properties - Biological properties	Medium (Soil information provides useful insights into nutrient cycles)	Not covered in regular monitoring. Current knowledge is based on single year research studies.	Trends in biological properties of soil.	Seasonal monitoring of chemical properties
3. Physico-chemical water - Nutrient - Conductivity - Cations and anions - Temperature, - Dissolved oxygen - pH - Transparency - Salinity	Medium High for nutrients, particularly in the context of *Phragmites* invasion	Covered in current monitoring system. Reporting on nutrient however is limited to specific research studies.	Long term trends and criticality of parameters observed in the context of management objectives	Collation of the data and analysis for discerning trends Currently proposed to be covered under Ecosystem Health Assessment
4. Biota - Wetland plants - Vertebrate fauna • Fish • Amphibians • Reptiles • Waterbirds • Mammals • Dolphins - Phytoplanktons - Aquatic macro-invertebrates	High	Current monitoring is focused on wetland macrophytes, fish, dolphins, and waterbirds (population and diversity)	Limited knowledge on trends in succession in and between various biota groups. Species invasion risk and conducive factors	Comprehensive survey of biota aleast once in a decade. Specific assessments on succession and risks of species invasion Proposal under development with ZSI
5. Climate - Precipitation - Air temperature - Evaporation - Wind - Humidity	High	Covered in the current monitoring system	Long term climate trends and impacts on hydrological regimes, physic-chemical properties of water and biota.	Climate change modelling for Chilika, linking scenarios with changes in ecological character Proposed to be taken up under climate vulnerability assessment project
6. Geomorphology - Topography - Connectivity to surface waters - Water sources - Soil - Erosion	High	Connectivity with surface waters assessed through hydrological mentoring. Information on topography is based on few research studies, and hydrological monitoring	Regional patterns in geomorphology (covering the Mahanadi Delta within the Bay of Bengal systems) and linking to changes to hydrological regimes, sedimentation patterns and biota.	Regional studies on geomorphology and linkages with Chilika basin and sub basin changes

Ecological Components / Processes and Services	Criticality for management plan monitoring	Coverage of current monitoring system	Knowledge Gaps	Monitoring need (additional to the existing system)
7. Hydrology - Water balance - Groundwater infiltration and seepage - Surface groundwater interactions - Tidal regimes - Inundation regimes	High	Assessment of water inflows and outflows is done through monitoring stations Tide monitoring stations are in pance for assessing tidal observations	Water balance, with overall contribution of freshwater and marine sources Surface-groundwater interactions (highly relevant to assessment impacts of agriculture on hydrological regimes	Specific studies related to: - Long term changes in water balance - Surface groundwater assessments
8. Energy – nutrient dynamics - Primary production - Nutrient cycling - Carbon cycling - Decomposition - Oxidation – reduction	Medium – Low	Primary production assessments are based on single year research	Trends in primary production Nutrient cycling and relationship with wetland macrophytic invasion	Seasonal assessments of primary productivity and nutrient cycles
9. Processes that maintain animal and plant population - Fish recruitment - Fish migration	High	Fish recruitment and migration information through specific studies	Likely impacts of climate change	Need to continue assessments and link to changes in physico-chemical water parameters. Undertake climate linked scenario modelling for changes in processes maintaining fish populations
10. Species interaction - Competition - Predation - Succession - Herbivory	Medium		Limited information available on these processes in Chilika	
11. Physical processes - Stratification - Mixing - Sedimentation - Erosion	Medium / High	Knowledge limited to sedimentation quantity	Source of sediments Stratification and mixing patterns for freshwater and sea water	Sediment coring assessments Stratification and mixing pattern studies
12. Provisioning services - Fisheries - Aquatic vegetation - Water transport	High	Level of fish catch, appropriation at various market levels	Linkages of productivity with sharing at various market chain levels; social implication of fisheries policy; opportunities for community stewardship	Sustainability of present fisheries system Economic utilization of aquatic vegetation (potential as well as actual)
13. Regulating services - Maintenance of hydrological regimes	High		Role played by Chilika as a downstream flood storage	Modelling studies on hydrological functions of Lake Chilika
14. Cultural services - Recreation and tourism - Spiritual - Scientific and educational	High	Levels of tourist inflow, number of boats , usage of infrastructure	Carrying capacity of Lake Chilika for tourism	Carrying capacity assessments

A Red wattled lapwing on the shore of Lake Chilika

Scientist hostel at Chandraput, Odisha

3. Institutional Arrangements

3.1 Current institutional arrangements[1]

CDA is the key institution mandated by State Government to undertake conservation and management of Lake Chilika. The Authority was constituted in 1991[2] under the aegis of Department of Forest and Environment of the Government of Odisha. It is formed as a society under the Societies Registration Act (of 1860), which enables governance as per its memorandum of association and rules and regulation. At inception, the primary mandate of the authority was to undertake measures for protection of lake ecosystem through actual intervention, survey and research, collaboration and networking. The authority presently describes its mandate as: a) to protect the lagoon ecosystem with all its genetic diversity; b) to formulate management plan for integrated resource management; c) to execute multi-dimensional and multidisciplinary developmental activities either itself or through other agency; and d) to collaborate with various national and international institutions for development of the lagoon.

The authority is chaired by the Chief Minister, which signifies the high priority accorded by the government to wetland conservation. Secretaries to the state government departments of forests and environment, fisheries and rural husbandry, tourism, revenue and finance; members of legislative assemblies of Bramhagiri and Chilika; collectors of Puri, Khurda and Ganjam; Agriculture Production Commissioner and Director, WISA are the current members of the Governing Body. The Chief Executive of the authority is the member secretary. The Governing Body is entrusted with the task of general superintendence of the affairs of the Authority. The Executive Committee chaired by the Principal Secretary (Forest and Environment) is responsible for taking executive decisions pertaining to CDA. The Chief Executive of the CDA is entrusted with implementation of various programmes and workplans, and management of the the CDA Office (Fig. 23).

The CDA has its office in Bhubaneswar, the capital of Odisha State. Amongst other departments, the office hosts a GIS unit which functions as a centre for spatial information analysis and management. CDA has also established the Wetland Research and Training Center at Chadraput located on the Chilika shoreline (equipped with state of the art lake monitoring laboratory and connected to a network of 47 stream gauging and 30 lake monitoring stations). The center serves to be the key in-site wetland monitoring hub

Wetland Research and Training Centre, Chandraput

[1] The section mainly focuses on formal institutional arrangements. A detailed discussion on community institutions, particularly related to Chilika fisheries is presented in Section 2.2.5 on Livelihood Systems.

[2] Resolution No. 20369/Forest and Environment dated 20th November 1991.

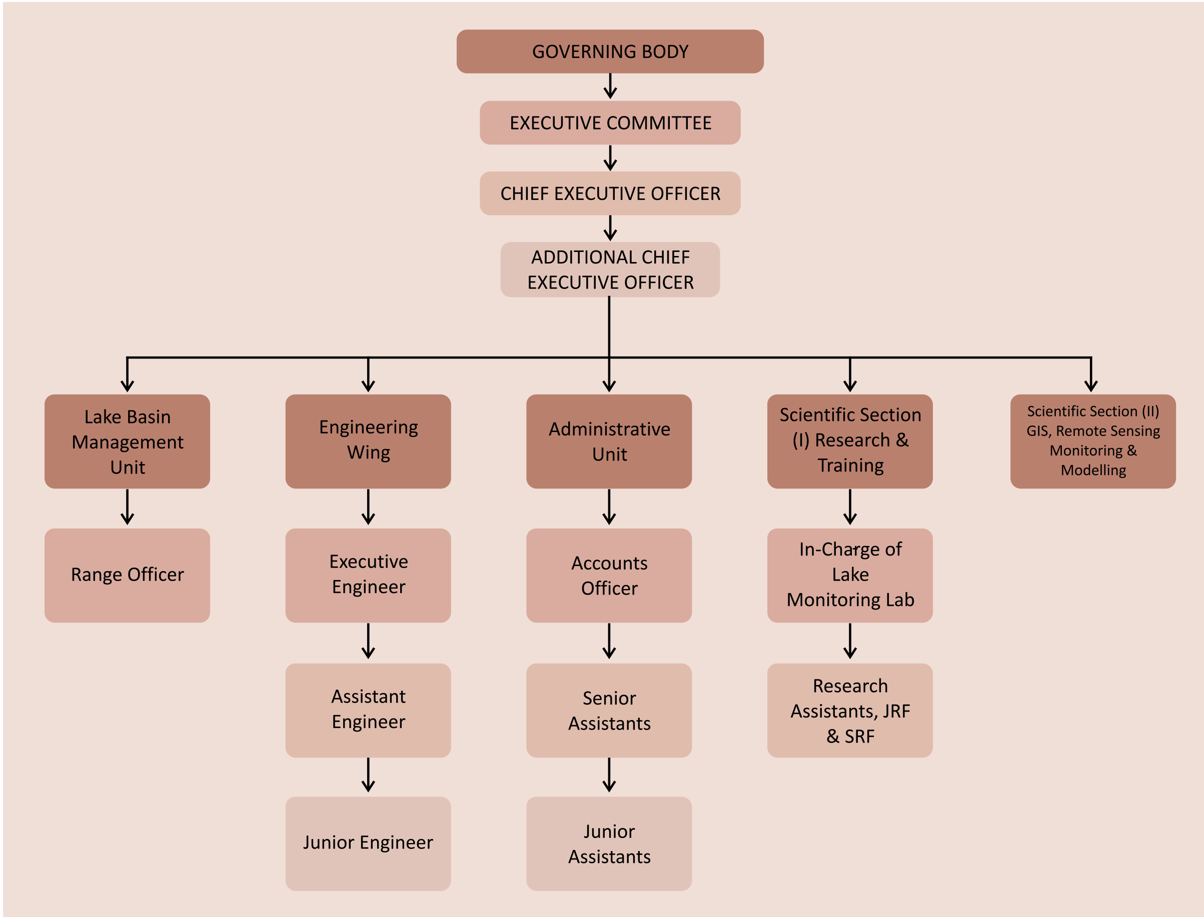


Fig. 23 :Organogram of Chilika Development Authority

Visitor centre at Satapada

and research station. The authority has also established a visitor information and interpretation center at Satpada, a key tourist entry point. The center serves as the primary vehicle for raising awareness on functions and values of Chilika. Facilities as multimedia presentations, touch screens, exhibits, diorama, aquarium, observatory and discovery room for children are available at the center. An eco-park has also been developed at Satpada over an area of 1.72 acres with models and displays to showcase Chilika ecosystem.

In 2010, the State Government of Odisha has taken a proactive step to constitute the State Wetland Authority, bringing convergence in management of various wetland sites under a single institutional umbrella. The Odisha Wetland Development Authority is framed on lines similar to the CDA with a mission to rejuvenate, revitalize and restore the wetlands in the state and protect them against degradation. It is envisaged to link CDA to the state wetland authority through appropriate arrangements.

Despite having very limited human resources to deliver its functions, CDA has effectively adopted a model of networking wherein it coordinates delivery of various elements of implementation plan through the various state government agencies. An extensive partner and a collaborator network also helps provide strategic input to wetland management (Fig. 24).

A crucial feature of the current institutional arrangements is the linkage with grass root level community organizations in wetland management. CDA has facilitated federation of local NGOs and CBOs at multiple levels which support the organization in delivering its various programmes, primarily those related to livelihoods and outreach. Some of the main federations are:

- **Campaign for Conservation of Chilika Lagoon (CCCL):** CCCL is a federation of NGOs working in and around Chilika Lake, registered as a trust in Bhubaneswar in 2003. There are currently 12 NGO partners to the CCCL which meet annually to decide on the plan of implementation. The partners have a defined work area and cover almost the entire lake, including its islands.
- **Boatmen Associations:** There are 8 boatmen associations. The member boatmen have a distinct identification and have been trained in handling domestic and international tourists. They follow the various guidelines laid by CDA for tourists, and also work towards general maintenance and cleanliness of the jetties through which they operate.

Fig. 24 : Network of organizations linked to CDA

- **Bird Protection Committees:** CDA has facilitated establishment of 12 bird protection committees primarily in the northern and central sector of the lake, wherein there have been instances of poaching. The committees take stewardship of the birds which come into their villages and protect their nests. CDA has also instituted a "Friends of Birds" award as an incentive for community based organizations to undertake bird protection. The committee members are also being trained in bird identification and general behaviour to enable scientific monitoring as well.
- **Watershed Associations:** CDA and the Forest Department have also facilitated formation of watershed associations in 12 catchment villages. These associations function to management the forests, water resources and implement developmental projects for overall welfare of communities.

In 2010, the CDA undertook a major initiative in the form of establishing Chilika Fishermen Central Cooperative Society Limited as an apex organization to meet the credit and infrastructure needs of fishers in Chilika and thereby warding-off the notorious nexus between profiteering middlemen and poverty entrapped primary producer community. The CEO, CDA has been elected the Chief Executive of the Society, which will enable the Authority to undertake institutional strengthening measures, building on the experiences of the past management of fisheries cooperative societies.

3.2 Legal and regulatory setup

With India as a contracting party to the Ramsar Convention and Chilika a designated Ramsar Site, there are specific commitments for conservation and wise use of the wetland under the various articles of the Convention.

The legal and regulatory basis for management of Lake Chilika are set by several national and state level acts and rules. The Environment (Protection) Act (1986), The Indian Wildlife Protection Act (1972 and amended upto 1993)[3], Biological Diversity Act (2002) are some of the key national legislations that pertain to protection of biodiversity and environment of Chilika. **The Wetland (Conservation and Management) Rules, 2010** sets out the regulatory framework for a range of protected wetlands in the country. Wetlands designated as Ramsar sites are identified as a category of protected wetlands. The act forthrightly prohibits reclamation; setting up of new industries and expansion of existing industries; manufacture or handling or storage or disposal of hazardous substances; dumping of solid wastes; discharge of untreated wastes or effluents from industries, cities and towns; and any construction of permanent nature except for boat jetties within 50 m from mean high flood level for past 10 years since the data of commencement of rules. Prior approval of state governments is deemed necessary for any withdrawal of water and impeding flows, treated effluent discharge, grazing, harvesting of living and non-living resources, plying of boats in a manner not detrimental to the biotic resources, dredging, and agriculture, aquaculture and horticulture activities within the wetland. A Central Wetland Regulatory Authority has been constituted at the national level for the purpose of implementation of the said rules.

As Chilika forms a part of the coastal zone, its management also needs to adhere to T**he Coastal Regulation Zone (CRZ) Notification, 1991,** most recently modified in 2011 under the Environment Protection Act, 1986. As per the notification, the wetland falls under the coastal regulation zone wherein several developmental activities are prohibited including establishment and modification of industrial units (except those explicitly mentioned); land reclamation, bunding or disturbing natural course of seawater; waste and effluent disposal; reclamation for commercial purposes etc. are prohibited. The Ministry of Environment and Forests has constituted the Odisha Coastal Zone Management Authority (vide order dated July 21, 2008, SO 1759(E)) to undertake measures for the improvement of overall coastal environment within the framework of the notification.

The **Odisha Marine Fisheries Regulation Act and Rules (1988)** are important state level regulations direction at control of detrimental fishing practices. The Act regulates fishing within the two important migratory pathways, i.e within Palur Canal throughout the year and within Outer Channel during the period July-January. Net fishing is completely restricted throughout the year in the channel. Harvesting of

[3] Irrawaddy Dolphin is a Schedule (I) species as per the Wildlife (Protection) Act. Penalty for violation of the law are imprisonment for a term not less than three years, which may extend upto seven years with a fine not less than Rs. 10,000. For the second and subsequent offences, the fine is not less than Rs. 25,000.

juveniles of prawn (*P. monodon*) and certain fin-fishes (*M. cephalus* and *L. calcarifer*) is also banned. The Act also prohibits net sizes below 10 mm owing to their extensively detrimental impacts on fish stocks. A draft Chilika (Regulation of Fisheries) Act is also in advanced stages of adoption. Once enacted, the Act will vest CDA with the powers to allocate fishing grounds, as well take penal action for violation of the code of conduct as stated in the Act.

Further, The Supreme Court of India in its decision dated December 11, 1996 has banned any construction/setting of aquaculture industry/shrimp culture industry/shrimp culture ponds within 1,000 m of Chilika. Any use or conversion of agricultural land, salt pen land for shrimp pond within the said area is also prohibited.

The Nalaban Bird Sanctuary located within Chilika was notified as Wildlife Sanctuary in 1987 under the **Indian Wildlife (Protection) Act, 1972.** Management of Sanctuary is under a Divisional Forest Officer of the Wilidlife Division. The region has a separate management plan as stipulated under the Act. Funding for site based conservation activities is through CDA.

Apart from the formal rules and regulations, CDA has also developed voluntary guidelines for conserving Chilika's biodiversity. Guidelines for visitors for Irrawaddy Dolphin watching in Chilika have been developed and disseminated through the tourist boat associations. Similar tips are available for birdwatchers. These guidelines supplement the overall conservation efforts and have proved to be very effective.

3.3 Gaps

CDA has been one of the successful wetland management institutions in the country. Its track record include hydrological intervention for restoration in 2000, setting and maintaining an advanced wetland monitoring system, extensive education and awareness programmes, catchment conservation and creation of livelihood opportunities for wetland communities. Despite its lean structure, the authority has also been very adaptive, and continually investing into strategic areas to support wetland conservation.

However, continuous changes in Chilika environs are creating new institutional challenges. Foremost amongst these are management of destructive fishing practices (shrimp culture and khondas) and increasing inflow of tourists. The Authority, by its very nature of establishment under the Societies Act does not have sufficient regulatory powers to control/regulate activities detrimental to lake environment. The incessant continuance of shrimp culture gheries is an indicator of the need to provide CDA within regulatory powers, which would augment the efforts undertaken by the District Administration. The enactment of Chilika Bill is expected to provide an institutional redress to the issue.

Successful management planning calls for institutional mechanisms that integrate conservation and wise use of Chilika within the river basin and coastal zone management planning processes. The State Water Policy, 2007 provides a mandate for integrated river basin management as the basis for water resources planning and development. The policy also prioritizes water allocation for ecological purposes as being next only to drinking water and domestic use. However, institutional mechanisms for water management in the state are still function-oriented by nature, and are yet to evolve to a basin level convergence.

The recent spread of *Phragmites karka* within the northern sector has called for having a risk management strategy in place. The current wetland monitoring system needs to be reviewed in terms of its ability to detect and project changes in ecological character.

The CDA commissioned a perspective plan exercise aimed at assessing the present strategic intent, organizational structure and alignment with strategic goals. The assessment was done involving CDA staff as well as external stakeholders, and facilitated by Xavier Institute of Management. The assessment included a SWOT (Strength, Weakness, Opportunities and Threat) analysis of CDA which provides a very useful assessment of the efficiency of the current institutional arrangement and is summarized in Fig. 25.

In conclusion, the following need to be addressed for strengthening the current institutional arrangements for managing Chilika:

- Revising the organizational structure of CDA within a strategic intent framework that allows the organization to enhance its core competency while building on the expertise of partner organizations
- Strengthening the authority with regulatory powers to enable control of detrimental practices
- Revising wetland monitoring system to support evaluation of risks and changes to the ecological character (also as a part of measures for climate

change preparedness) and linking to an appropriate decision making structure

- Creating appropriate linkages with basin and coastal zone management institutions to ensure integration of full range of wetland ecosystem services in developmental planning
- Further revitalization and strengthening community institutions to enable local stewardship in management

A response strategy for strengthening institutions for managing Chilika is further outlined as a part of management planning framework.

Strengths	**Weaknesses**
• Independent institution within the Government of Orissa which provides flexibility to be multidisciplinary with focused mandate • Enjoys good reputation and has established credibility amongst stakeholders • Networked with specialist national and international organizations providing the organization to work with state of the art • Extensive liaison with the communities through NGO networks	• Small workforce, with several key disciplines absent in the core technical group (social sciences, coastal processes etc.) • Lack of clarity on institutional priorities • Lack of authority to regulate detrimental activities • Insufficient database on several aspects of lake ecology and socio-economics • Strategies for addressing climate change not yet in place
Opportunities	**Threat**
• Dynamic leadership responsive to changes in external environment with willingness to adapt • High priority accorded to conservation and management of Chilika within state as well as national policies and action plans • Established credibility among major stakeholders and track record of performance	• Increasing anthropogenic pressure on wetland and its resources (particularly fisheries and tourism) • Continued practice of illegal and detrimental resource use systems (eg. shrimp culture) • Risk of climate change driven changes in ecological character

Fig. 25. SWOT analysis of CDA[5]

[4] As on April 1, 2010, of the sanctioned strength of 39, only 17 were filled and the rest vacant. More than 50% of the existing workforce are support staff.

[5] Developed from the draft report on Developing a Perspective Plan, Organizational Structure and Manpower Plan for Chilika Development Authority submitted by Xavier Institute of Management, Bhubaneswar

4. Management Planning Framework

4.1 Management Plan Components

The management planning framework presented in this section outlines a response strategy to the threats identified to ecological character and the gaps within the current institutional arrangements.

The planning framework envisages ecosystem conservation and sustainable resource development and livelihood improvement supported by institutional development; communication, education and public awareness; and institutional development as the key management components (Fig. 26). The ecosystem conservation is proposed to address catchment conservation; water management and biodiversity conservation as its sub-components. Ecotourism development, sustainable fisheries development and micro-enterprise development / improvement of quality of life are subcomponents for sustainable resource development and livelihood improvement. The Action Plan for each of the component identifies performance indicators, knowledge gaps and broad activity sets. Wherever possible, quantitative targets have also been included.

4.2 Management Strategies

Key management strategies to be adopted include:

- **Ensuring hydrological connectivity** of Chilika with freshwater and coastal processes at basin level
- **Establishing hierarchical and multiscalar inventory** of hydrological, ecological, socioeconomic and institutional features and ecosystem services to support management planning and decision making
- **Promoting sustainable catchment management practices** to manage inflow of silt and nutrients into the wetland ecosystem

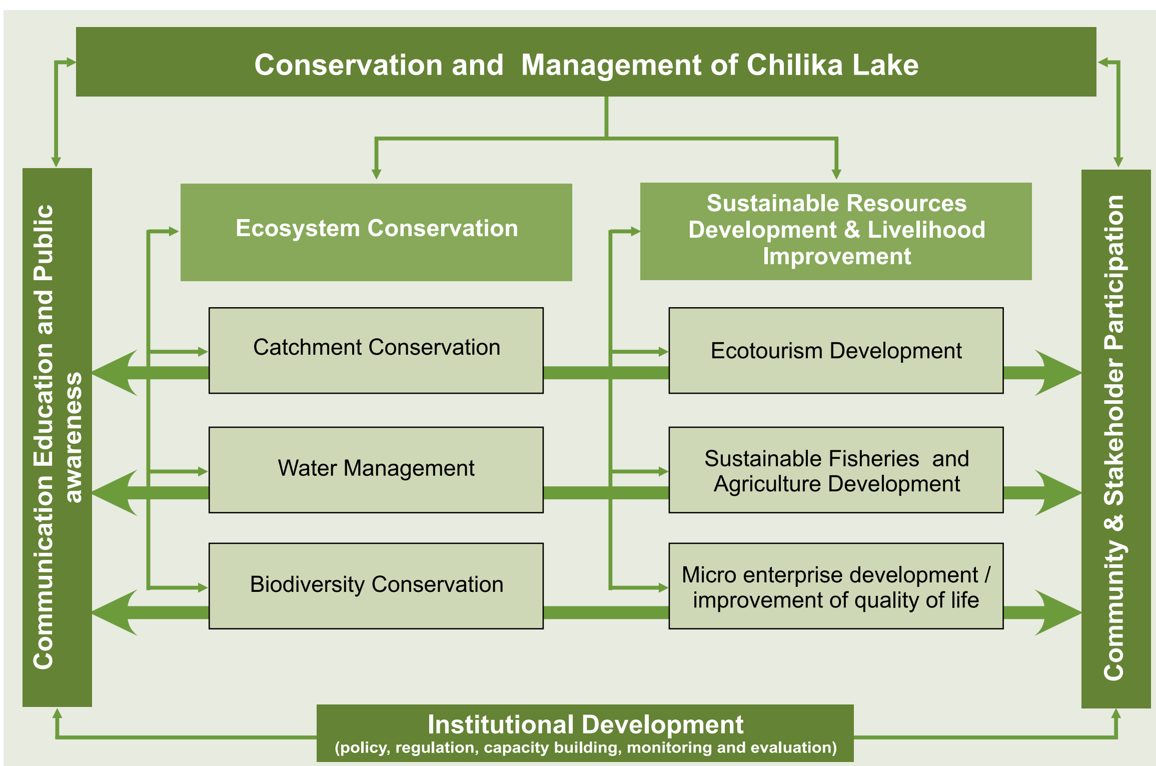


Fig. 26: Schematic diagram for formulation of Management Action Plan

- **Environmental flows** as basis for water allocation for conservation and developmental activities
- **Biodiversity conservation** through habitat improvement of endangered and indigenous species
- **Ecotourism development** for enhancing awareness, income generation and livelihood diversification
- **Promoting sustainable fisheries** for maintaining nutritional security while ensuring maintenance of biodiversity and equitable sharing of benefits
- **Poverty reduction** through sustainable resource development and utilization and livelihood diversification
- **Promoting institutional arrangements** enabling integration of wetland management planning and river basin and coastal zone management
- **Strengthening CDA** with adequate legal and administrative powers to regulate detrimental activities
- **Capacity building** at all levels for technical and managerial skills for implementation of integrated management planning
- **Communication, education, participation and awareness** at multiple levels and stakeholders to support management planning
- **Result oriented monitoring and evaluation** at activity, outcome and impact levels

4.3 Action Plan (Performance indicators, research needs, activities)

Component 1: Institutional Development

The component of institutional development is aimed at **enhancing the effectiveness of current institutional arrangements to ensure conservation and wise use of Lake Chilika.** Key performance indicators include:

- Legal and regulatory mandate with CDA to regulate and deter resource use practices having detrimental impacts on wetland ecosystem
- Presence of clear Strategic Intent and a business plan with CDA in line with the management needs for conservation and wise use
- Capability of CDA to mainstream Lake Chilika ecosystem services in developmental planning and decision making at river basin and coastal zone levels
- Ability of CDA to create and sustain networks of expertise to augment management capabilities and support review and adaptation
- Operationalization of hierarchical and mulitscalar inventory system for Chilika Lake Basin as a management decision support system (including monitoring and evaluation based on review of ecological character description)

Activities

1.1 Reorganization of CDA

- Focus on more efficient and integrated operations, including a clear directive for implementation of Management Action Plan. Creation of a smaller , results based management structure
- Development of strategic business plan to better define mission, responsibilities, level of service and revenue systems
- Creation of Scientific and Technical Advisory Group and Community Advisory Group as independent agencies for strategic review and advice on action plans
- Reorganizing implementation units below Chief Executive Chilika into following wings:
  - Project management: responsible for consolidating annual plans, developing implementation strategies, project monitoring and evaluation
  - Wetland research and training: responsible for monitoring and evaluation, research, capacity building and training
  - Regulation, enforcement and legal: Responsible for allocation of fisheries rights, monitoring for restricted fishing and other illegal practices
  - Community Livelihoods: Responsible for sustainable fisheries, ecotourism, agriculture and microenterprise development programmes
  - Partnership management: responsible for liaison with external stakeholders
  - General administration: responsible for finance and administration
- Staffing for all above positions with clear line management, terms of reference and performance evaluation systems

1.2 Legal and regulatory mechanisms

- Enactment of Chilika Bill as a basis for regulation of detrimental fishing practices
- Create mechanisms for integration and dovetailing of development sector schemes with the management action plan

- Scope possibilities for application of innovative financial mechanisms, as payments for ecosystem services for supporting implementation of management action plan
- Creation of a multi-stakeholder forum for conflict resolution

1.3 Wetland inventory, assessment and monitoring system

- Creating a hierarchical inventory system with data and metadata layers for:
  - o Mahanadi Basin and Mahanadi Delta coastal zone at 1: 250,000 resolution
  - o Wetlands of Mahanadi Delta at 1:100,000 resolution
  - o Lake Chilika Basin at 1: 50,000 resolution
  - o Lake Chilika at 1: 25,000 resolution
- Regular updation of the inventory system
- Revision of the wetland monitoring protocol addressing needs identified in Section 2.3.3
- Creation of a results based framework to support and guide management plan implementation. The results based framework would identify targets, performance indicators, means of verification and mechanism for review and adaptation at multiple results level-i.e. activity, output, outcome and goal / impact

1.4 Communication, Education, Participation and Awareness (CEPA)

- Convergence of ecotourism and CEPA to create awareness on ecosystem services of Chilika at multiple scales, role of communities in ecosystem conservation, various efforts for management planning
- Development of a communication kit on management planning, summarizing the assessments, intervention rationale and action programmes
- Publication of newsletters and brochures
- Celebration of important environment related events-including World Wetland Day, Environment Day etc.
- Introduction of information on Chilika environment into school curriculum in villages in and around Chilika

1.5 Capacity building

- Creation of additional expertise on wetland hydrology and socioeconomics within CDA to augment existing capacities on ecology, watershed management, and GIS and remote sensing
- Development and implementation of a regional wetland manager's training programme to be implemented through the Wetland Research and Training Center, Chandraput
- Professional training in integrated lake management, water management and community based natural resource management to officials and community groups involved in management plan implementation

Component 2: Ecosystem Conservation

The objective of this component is to **ensure maintenance of critical ecosystem components and processes of Lake Chilika, which form the basis of provision of ecosystem services.** The ambit includes: a) catchment conservation; b) water management and c) biodiversity conservation.

Performance indicators

- Reduction in rates of siltation from western catchments and delta rivers
- Reduction in nutrient loading of Lake Chilika
- Maintenance of lake-sea connectivity and salinity gradients appropriate to maintenance of biodiversity spectrum
- Environmental flows for Lake Chilika used as a basis for upstream water allocation decisions
- Management of Phragmites invasion achieved through ecologically and socially efficient approaches
- Maintenance of key biodiversity habitats and migratory pathways
- Impacts of climate change on wetland ecological character assessed and response strategies integrated in implementation

Research needs

- Long term trends in physio-chemical properties of water, and criticality for wetland management
- Long term water balance (based on atleast 20 years of hydrological information), and spatial and temporal trends in freshwater and brackish water contribution
- Long term nutrient balance for the wetland system with clear identification of sources
- Regional geo-morphological patterns for Lake Chilika Basin with reference to the deltaic processes

- Trends and sources of silt input into wetland, circulation and mixing patterns
- Species succession and risk of invasion
- Research needs with respect to Phragmites invasion in Chilika :
  - o History of species in Chilka
  - o Extent of removal required and feasible , also considering the role of Phragmites in nutrient dynamics and contribution to ecosystem services
  - o Expected pattern of species habitat replacement
  - o Impact of *Phragmites* removal on wetland processes, eg., hydrological (impacts on water circulation and mixing patterns, sediment exchange), ecological processes (nutrient cycles, impacts on other species, phyto-sociology)
  - o Life cycle assessments focused on identification of factors creating conducive environments for invasion, impacts of various stressors (eg. Glyphosate in repeat applications and differing concentrations), growth and propagation patterns, associated biodiversity, extent and condition of degradability
  - o Alternate (economic) uses of harvested biomass
- Fish migration pathways (including migration to and from sea as well as river systems, specific reference to the role of Palur Canal and Rishikulya estuary)
- Impacts of climate change on wetland components, processes and services and adaptation options

Activities

2.1 Catchment Conservation

Control of soil erosion

- Treatment of 57,072 ha of degraded catchments through afforestation in 13,200 ha, aided regeneration in 17,400 ha, bamboo plantation in 12,000 ha to stablilize stream banks and small scale soil conservation measures.
- Control of soil erosion from delta fraction through:
  - o creation of silt traps at delta apex
  - o realigning embankments to allow silt distribution within floodplains
  - o rejuvenating floodplains and reducing hydrological fragmentation
- Creation of watershed management committees in the target micro-watersheds to implement soil conservation measures.

Sustainable agriculture management

- Assessing the extent of nutrient loading into the wetland from agricultural lands
- Promoting water and nutrients efficient agricultural practices within the lake catchments

2.2 Water Management

Enhancing hydrological regimes

- Removal of freshwater inflow impediments through selective desilting and dredging at the mouths of 52 inflowing streams.
- Maintenance of the dredged channel between Muggermukh and Daya and Bhargavi Rivers to reduce waterlogging in the northern sector and also to flush out the massive sedimentation contributed though the Mahanadi River.
- Removal of shrimp gheries (97.9 km^2) which impede water circulation within the lake.

Maintenance of coastal inlets

- Maintenance of coastal inlet through a mix of approaches including engineering stabilization; periodic dredging; and periodic cutting of new mouth (projected approximately once in 10 years). Intervention on cutting of a new mouth to be guided by research / modelling on relationship between the location of coastal inlet with the salinity regime.
- Dredging of Palur Canal and removal of encroachments.

Balancing water allocation for human and ecological purposes

- Implementation of the recommendations of the Environmental Flow Assessment for Chilika Lake. Major implementation steps to include: a) defining an operating rule for Naraj Barrage based on scenario recommendations; b) implementation of the operating rule; c) post implementation monitoring; d) review; e) research to further inform refinements and adaptation to barrage operating rules.

2.3 Biodiversity Conservation

Habitat improvement for waterbirds

- Creation of bird habitats closer to shoreline
- Creation of artificial nesting sites (floating platforms / earthen mounds) for breeding terns
- Management of heterogeneity of vegetation particularly in Nalaban to enhance waterbird diversity
- Strengthening bird protection committees

Declaration of outer channel as a Community Reserve for dolphins

- Community consultations on the need to declare Outer Channel as migratory channel
- Agreements on implementation of alternate livelihoods strategies in response to banning existing fishing practices
- Implementation of monitoring and evaluation programme

Management of Phragmites invasion

- In-situ control interventions implemented based on the outcomes of pilot testing of following:
  - Chemical control (use of different products, as imazapyr and concentrations)
  - Habitat management (cutting and submergence for 4-6 months, breaking monospecific stands and managing salinity in northern sector)
  - Economic use by creating linkages with paper industry and scoping other options with business models
- Implementation of risk management strategy to enable prediction of species invasion risks and introducing appropriate response options

Component 3: Sustainable Resource Development and Livelihood Improvement

The component is aimed **at ensuring sustained provision of Lake Chilika ecosystem services for well-being of wetland dependent** communities. Promoting Chilika as a part of natural infrastructure within the livelihood capital endowment, the component would seek sustainable use of wetland resources as a basis for promoting community stewardship.

Performance indicators

- Tourism in Lake Chilika regulated within carrying capacity of the wetland ecosystem
- Tourism managed by community institutions on sustainability principles, ensuring equitable returns and fair participation opportunities to local communities
- Fishing effort (number of boats and active fishers) and catch maintained below maximum sustainable yield
- Significant minimization of detrimental fishing practices
- Complete abolishment of shrimp aquaculture in any form within Lake Chilika and its periphery
- Functioning Primary Fisher Cooperative Societies in Lake Chilika which ensure access to capital as well as equitable return on catch
- Comprehensive access to water, sanitation and hygiene infrastructure to communities living in and around Chilika
- Reduction in overall livelihood dependence on Chilika through appropriate micro-enterprise development

Research needs

- Carrying capacity of Lake Chilika for tourism
- Optimal management scenarios for fisheries effort (number of fishers, crafts and gears)
- Levels of by-catch, impacts of detrimental fishing practices
- Opportunities for value addition to resource base
- Trends in human well being indicators of Chilika communities-necessary materials for good life, health, social relations, freedoms and choice

Activities

3.1 Ecotourism Development

- Carrying capacity assessment of Lake Chilika for tourism
- Introducing appropriate management strategies for regulating tourist pressure below carrying capacity levels
- Infrastructure augmentation including construction of log huts (5 nos.), boardwalks (3 nos.) and nature trails (3 nos.)
- Improvement of signage
- Training of nature guides / boatmen
- Development of tourist guidance on dos and donts for nature tourists

3.2 Sustainable fisheries development

3.2.1 Continuation of ecosystem-based research on Chilika fisheries

- Collection of fish catch statistics by employing statistical sampling method to generate time series data and to evaluate CPUE, productivity, economic valuation of landings etc.
- Breeding biology, spawning ground survey and stock assessment of target species.
- Breeding biology of mud crab (*Scylla serrata* & *S. tranquebarica*).
- Length-frequency data collection for target species.
- Tagging experiment on target species to assess migration routes, distribution and growth rates.

- Close monitoring of environmental variables.
- New studies on fish yield potential and MSY after 6 years of the first study.
- New study to evaluate Nalaban island as potential spawning area for several fish species.

3.2.2: Implementation of Fisheries Resources Management Plan

The following major activities identified under the Fisheries Resource Management Plan (FRMP) are proposed to be taken up for implementation

- Capacity development & training to resource users for wise use of fishery resources.
- Decreasing fishing pressure on the lake by providing alternative livelihood options to the resource users.
- Improving the livelihood of fishery resource users.
- Providing Food security to the lake community dependent on the resources of the lake.
- Capacity development among the fisheries personnel of CDA on ecosystem management, societal issues, biological & ecological studies.
- Integrating resource management activities and alternative livelihood options
- Continuing fishery resources survey for reviewing FRMP.
- Promoting self-effort of fishers for wise use of fisheries resources.
- Enforcing regulatory measures for prohibitive activities.

3.2.3: Training and capacity development

Training and capacity development of fishers, fish workers and other stakeholders in the following areas:

- scientific information/evidences of fisheries of Chilika lake,
- conservation and management of fisheries resources,
- responsible fisheries,
- co-management of fisheries,
- hygienic handling and quality maintenance of fish on-board and at the landing centres,
- use of cold chain,
- working under cooperative system,
- marketing management,
- value addition to fish and fish products,
- operation of leased out fishing sources following the terms and condition in the lease agreement, and
- alternative livelihood programmes

3.2.4 Development of interactive training centre at the Wetland Research and Traning Center, Chandraput (Balugaon)

3.2.5 Upgradation of fish landing centres (FLCs) and introduction of cold chain system

- Four major FLCs at Bhusandpur, Kalupadaghat, Soran & Balugaon to be upgraded in modern lines along with 16 small FLCs improvement.
- 5000 fishing boats to be supplied with insulated ice boxes.
- Four flake ice plants at four major FLCs and one 10 t. cold storage at Balugaon and four 5 t. chill room at four major fish landing centres.

3.2.6 Setting up of pilot hatcheries for mud crabs and seabass in Chilika

3.2.7: Reactivation of fishery cooperatives in Chilika

3.2.8: Clear-cut demarcation of fishery sources (Sairats) using GPS and mapping with Lat-Long references on GIS Platform

3.3 Promoting diversification of livelihoods and enhancement of quality of life

- Introduction of dairying, duck farming, dry fish marketing, vegetable marketing, vegetable dying, and ornamental fish culture projects as alternate livelihoods for 3,200 households. Priority be accorded to interventions in outer channel which is expected to undergo loss in incomes due to declaration of community reserve.
- Provision of total sanitation coverage to villages living in and around Chilika through construction of 11,000 community toilets. Programme to be supported through social engineering approaches focused on shifting community attitudes to sanitation and enhancing awareness on impacts of unsafe sanitation.
- Provision of safe drinking water supply to 12,000 households through use of appropriate technology.
- Strengthening disaster risk reduction infrastructure

and improve coping mechanism, particularly in the northern sector, which is frequently impacted by floods

4.4 Budget

Based on quick estimates, an overall budget of Rs. 370 crores would be required over 5 years for implementation of the management plan. Of the total, 58% would be required for the component on ecosystem conservation, with 41% allocated to catchment conservation, 9% to water management and 8% to biodiversity conservation. Component on sustainable resource development and livelihood improvement is allocated 37% of the total budget, with 17% to ecotourism development, 7% to sustainable fisheries development ad 14% to livelihood diversification and enhancement of quality of life of Chilika communities. The component on institutional development is allocated 5% of the overall budget.

	Component	Amount (in Rs. Millions)		
	Component 1: Institutional development		**185**	**185**
1.1	*Reorganization of CDA*	10		
1.2	*Legal and regulatory mechanism*	5		
1.3	*Wetland inventory, assessment and monitoring system*	50		
1.4	*Communication, Education, Participation and Awareness*	20		
1.5	*Capacity Building*	100		
	Component 2: Ecosystem Conservation			**2,140**
2.1	Catchment conservation		1,525	
	Research and monitoring	75		
	Treatment of western catchments	900		
	Control soil erosion from delta fraction			
	Creation of silt traps at Delta apex	250		
	Realigning embankments	100		
	Rejuvenating floodplains	200		
2.2	Water management		315	
	Research and monitoring	100		
	Enhancing hydrological regimes	100		
	Maintenance of coastal inlets	100		
	Water allocation	15		
2.3	Biodiversity conservation		300	
	Research and monitoring	100		
	Habitat improvement for waterbirds	50		
	Declaration of outer channel as a Community Reserve for Dolphins	50		
	Management of *Phragmites* invasion	100		
	Component 3: Sustainable resource development and livelihood improvement			**1,375**
3.1	Ecotourism development		620	
	Carrying capacity assessment	10		
	Infrastructure augmentation	500		
	Improvement of signage	100		
	Training and capacity building	10		
3.2	Sustainable fisheries development		255	
	Continuation of ecosystem based research on Chilika fisheries	25		
	Implementation of Fisheries Resource Management Plan	50		
	Training and capacity development	10		
	Upgradation of Fish landing centres and introduction of cold chain system	130		
	Setting up of pilot hatcheries for mud crabs and sea bass	20		
	Reactivation of fishery cooperatives	5		
	Demarcation of fishery sources	15		
3.3	Livelihood diversification and enhancement of quality of life		500	
	Microenterprise development for fishers	250		
	Creation of comprehensive water, sanitation and hygiene infrastructure	250		
				3,700

References

Alongi, D.M. 1990. The ecology of tropical soft-bottom benthic ecosystems. *Oceanography Marine Biology Annual Review* 28:318-496.

Annandale, N. & S. Kemp 1915. Fauna of Chilika Lake, reptiles and batrachia, India. *Memoirs of Indian Museum* 5:163-174.

Balachandran, S., A.R. Rahmani & P. Sathiyaselvam 2005. Habitat evaluation of Chilika Lake with special reference to birds as Bioindicators. Final Report (2001-2005). Bombay Natural History Society, Mumbai, India.

Balachandran, S., P. Sathiyaselvam & S. Panda 2009. Bird Atlas of Chilika. BNHS, Mumbai & CDA, Bhubaneswar, India.

Banerjee, A.C. & N.C. Roychoudhury 1966. Observations on some physico-chemical features of the Chilika Lake. *Indian Journal of Fisheries* 13(1&2):395-429.

Banerjee, R.K., P.K. Pandit, S.K. Chatterjee, B.B. Das & A. Sengupta 1998. Chilika Lake: Present and Past, Bulletin No. 80. Central Inland Fisheries Research Institute, Barrackpore, Kolkata, India.

Bhat, B.V. 1979. Studies on meroplanktonic Larvae with reference to hydrography of Nethravati-Gurupur Estuary, Mangalore, Dakshina Kannada. M.F.Sc. Thesis, University of Agricultural Science, Bangalore, India, 214pp.

Bhatta, K.S. & A.K. Pattnaik 1998. Environmental monitoring of Chilika Lagoon. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 95-113.

Bhatta, K.S. 2003. Environmental Monitoring to access the impact of desiltation of the Outer Channel on the eco-system of the Chilika lagoon. Interim report MoEF sponsored project, CDA, Bhubaneswar, India, pp.1-32.

Biswas, K. 1932. Algal flora of the Chilika Lake. *Memoirs of the Asiatic Society of Bengal* 11:165-198.

Biswas, K.P. 1995. Ecological and Fisheries Development in Wetlands: A study of Chilika Lagoon. Daya Publishing House, Delhi, India. 192pp.

Boyd, C.E. 1982. Water management for pond fish culture. *Development of aquaculture and fisheries science* 9:231.

Brown, S. 1981. A Comparison of the Structure, Primary Productivity and Transpiration of Cypress Ecosystems in Florida. *Ecological Monographs* 51:403-427.

Carney, H.J., M.W. Binford, A.L. Kolata, R.R. Marin & C.R. Goldman 1993. Nutrient and Sediment Retention in Andean raised-field agriculture. *Nature* 364:131-133.

CDA 2002. Collection and estimation of Fish, Prawn and Crab landing statistics in the Chilika lagoon. Annual report 2001-02: Bulletin No. 02. Chilika Development Authority, Bhubaneswar, Odisha, India.

CDA 2004. Estimation of Fish, Prawn and Crab landing statistics in the Chilika lagoon. Annual report 2002-03 & 2003-04. Bulletin No. 3. Chilika Development Authority, Bhubaneswar, Odisha, India.

CDA 2011. Annual Report 2010-2011. Chilika Development Authority, Bhubaneswar, Odisha, India.

Chandramohan, P. & B.U. Nayak 1994. A study for the improvement of the Chilika lake tidal inlet, East Coasts of India. *Journal of Coastal Research* 10:909–918.

CIFRI 2006. Assessment of fish yield potential of Chilika Lake. Central Inland Fisheries Research Institute, Barrackpore, Kolkata, India, pp.1-25.

CWRDM 2004. Estimation of rate and pattern of sedimentation in Chilika Lake, Odisha, using environmental isotope tracers. Report from the Centre for Water Resources Development and Management (Kozhikode, Kerala) to the Chilika Development Authority,19 pp.

CWRDM 2005. Estimation of rate and pattern of sedimentation in Chilika Lake, Odisha, using environmental ^{137}Cs isotope technique. Report from the Centre for Water Resources Development and Management (Kozhikode, Kerala) to the Chilika Development Authority, 13 pp.

Das, S. 2004. Effect of substratum on the community structure of macrobenthic fauna from southern sector of Chilika Lake. *Indian Journal of Fisheries* 51(3):375-380.

Dean, P.B. & H.J. Saaltink 1991. Chilika Lake conservation and development project, Odisha, India.

Department of the Environment, Water, Heritage and the Arts 2008. National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of the National Guidelines for Ramsar Convention in Australia. Australians Government Department of the Environment, Water, Heritage and the Arts, Canberra, Australia.

Devasundaram, M.P. & J.C. Roy 1954. A preliminary study of the plankton of the Chilika Lake for the years 1950 and 1951. *Symposium on Marine and Fresh-Water Plankton in the Indo-Pacific, IPFC Publication* pp. 48-54.

Donk V.E., R.D. Gulati, A. Ledema & J. Meulemans 1993. Macrophyte-related shifts in the nitrogen and phosphorus contents of the different trophic levels in a biomanipulated shallow lake. *Hydrobiologia* 251:19–26.

Dujovny, E. 2009. The deepest cut: political ecology in the dredging of a new sea mouth in Chilika Lake, Odisha, India. *Conservation & Society* 7(3):192-2004.

FAO/IIASA/ISRIC/ISSCAS/JRC 2009. Harmonized World Soil Database (version 1.1). FAO, Rome, Italy and IIASA, Laxenburg, Austria.

Feruguson, A., C. Hatfield, D. Hay, D. Levy & S. Vettivel 1992. Chilika Lake project feasibility and design report prepared for Canadian International Development Agency Environment division and Indian Desk.

Finlayson, C.M., N. Davidson, D. Pritchard, G.R. Milton & H. MacKay 2011. The Ramsar Convention and ecosystem-based approaches to the wise use and sustainable development of wetlands. *Journal of International Wildlife Law and Policy* 14:176-198.

FishBase 2010. A global information system on fishes. Available www.fishbase.org/home.htm. Accessed on 26.10.2010.

Ghosh, A.K. & A.K. Pattnaik 2005. Chilika Lagoon: Experience and lessons learned. Brief prepared for GEF Lake Basin Management Initiative. pp 115-132.

Ghosh, A.K., A.K. Pattnaik & T.J. Ballatore 2006. Chilika Lagoon: Restoring ecological balance and livelihoods through re-salinization. *Lakes & Reservoirs: Research & Management* 11(4):239-255.

Ghosh, S. & P.P. Majumdar 2006. Future rainfall scenario over Odisha with GCM projections by statistical downscaling. *Current Science* 90:396-404.

Gosain, A.K., S. Rao & D. Basuray 2006. Climate change impact on hydrology of river basins. *Current Science* 90:346-353.

Govt. of Odisha 2008. Statistical Abstract of Odisha. Directorate of Economics and Statistics Odisha, Bhubaneswar, India.

Govt. of Odisha 2012. Economic Survey 2011-12. Planning and Coordination Department, Odisha, India.

Harkantra S.N. & A.H. Parulekar 1985. Community structure of sand dwelling macrofauna of an estuarine beach in Goa, India. *Marine Ecological Progress Series* 30:291-294.

Ingole, B. 2002. Increased macrobenthic density and diversity: indicator of recovery of Chilika lagoon from environmental degradation. In: *The national seminar on Creeks, Estuaries and Mangroves pollution and conservation*, pp. 213-215.

Ingole, B.S. & A. H. Parulekar 1998. Role of salinity in structuring the intertidal meiofauna of a tropical estuarine beach, field evidence. *Indian Journal of Marine Science* 27:356-361.

IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. Avialable www.iucnredlist.org. Accessed on July 2011.

Iwasaki, S., B.H.N. Razafindrabe & R. Shaw 2009. Fishery livelihood and adaptation to climate change: A case study of Chilika lagoon, India. *Mitigation, Adaptation, Strategies and Global Change* 14:339-355.

Jayadesan, P. 1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pazhayaru- South east coast of India. Ph. D. thesis, Annamalai University, Tamil Nadu, India.

Jayasankar, P., A. Patel, M. Khan, P. Das & S. Panda 2011. Mitochondrial DNA diversity and PCR- based sex determination of Irrawaddy dolphin (*Orcaella brevirostris*) from Chilika Lagoon, India. *Molecular Biology Reports* 38:1661-1668.

Jha, B. C. 1986. Ecology and biodiversity of periphytons with special reference to diatom flora in River Swarnrekha and Getalsud Reservoirs, Ranchi, Bihar. Ph.D Thesis, Ranchi University, Ranchi, India.

Jha, B.C. 2009. Algal Biodiversity of Chilika Lake. Central Inland Fisheries Research Institute (CIFRI) Barrackpore & Chilika Development Authority (CDA) Odisha, India.

Jhingran V.G. 1958. Observations on the Seaward Migration of *Mugil cephalus* (Linnaeus) from the Chilika Lake for Breeding. *Current Science* 27:181-182.

Jhingran V.G. 1959. On the breeding migration of *Mugil cephalus* (Linnaeus) from the Chilika Lake to the Sea. *Proceedings of the Indian Science Congress* 46 pp.

Jhingran, V.G. 1963. Report on the Fisheries of the Chilika Lake (1957-1960). *Bulletin of National Research Institute* 1:113.

Jhingran, V.G. 1991. Fish and Fisheries of India. Hindustan Publishing Corporation, Delhi, 954, pp. 848-856.

Jhingran, V.G. & A.V. Natrajan 1966. Final Report on the Fisheries of the Chilika Lake (1957-1965). Bulletin No 8:1-12, Central Inland Fisheries Research Institute, Barrackpore, Kolkata, India.

Jhingran, V.G. & A.V. Natarajan 1969. A study of the fisheries and fish populations of the Chilika Lake during the period 1957–1965 India. *Journal of Inland Fisheries Society* 1:49-126.

Jhingran, V.G. & A.V. Natarajan 1979. Improvement of fishery resources in inland waters through stocking. In: T.V.R. Pillay & W.A. Dill (eds). *Advances in aquaculture.* Farnham, Surrey. Fishing News Books Ltd., for FAO, 532pp.

JICA 2009a. The Biological and Ecological Characteristics and the *Current* Status of Fisheries and Resources of Commercially Important Species in Chilika Lagoon-The project for Conservation and wise use of Natural resources of the Chilika Lagoon through Community Participation in India. Odisha Govt., India.

JICA 2009b. Socio-Economic Condition of Fishers in and around Chilika- The project for Conservation and wise use of Natural resources of the Chilika Lagoon through Community Participation in India. Odisha Govt., India.

JNU 1978. Geology, geography and landuse pattern of the catchment area around Lake Chilika. Report on Chilika physiography and geochemistry, pp. 15-30.

Jones, S. & K.H. Sujansingani 1951. The Hilsa fishery of the Chilika Lake. *Journal of Bombay Natural History Society* 50(2):264-280.

Jones, S. & K.H. Sujansinghani 1954. Fish and fisheries of the Chilika Lake with statistics of the fish catches for the years 1948-50. *Indian Journal of Fisheries* (1&2):256-344.

Kowtal, G.V. 1965. On the breeding of *Eleutheronema tetradactylum* (Shaw) in the Chilika Lake. *Science and Culture* 31(5):262-263.

Kowtal, G.V. 1967. Occurrence and distribution of pelagic fish eggs and larvae in the Chilika Lake during the years 1964 and 1965. *Indian Journal Fishing* 14:198-214.

Kowtal, G.V. 1970. A note on early development of *Nematalosa nasus* (Bloch) from the Chilika Lake. *Journal of Inland Fisheries Society of India* 2:155-158.

Kowtal, G.V. 1972. Observations on the breeding and larval development of Chilika Sahala *Eleutheronema tetradactylum* (Shaw). *Indian Journal of Fisheries* 19(1&2):70-75.

Kumar, K. 1993. Studies on copepods occurring in coastal waters of Parangipettai. Ph.D. Thesis, Annamalai University, Tamil Nadu, India, 166pp.

Kumar, R. & A.K. Pattnaik 2010. Assessing ecosystem services of Chilika. Chilika Newsletter Vol-5, Chilika Development Authority and Wetlands International-South Asia, New Delhi, India.

Kumar, R., P. Horwitz, G.R. Milton, S.S. Sellamuttu, S.T. Buckton, N.C. Davidson, A.K. Pattnaik, M. Zavagli & C. Baker 2011. Assessing wetland ecosystem services and poverty interlikages: a general framework and case study. *Hydrological Sciences Journal* 56(8):1602-1621.

Kurien, J. 1992. Ruining the Commons and Responses of the Commoners: Coastal Overfishing and Fishworker's Actions in Kerala State, India. In: Ghai, D. & J.M. Vivian, (eds.). *Grassroots Environmental Action: People's Participation in Sustainable Development*. London: Routledge.

Lal, M., T. Nozawa, S. Emori, H. Harasawa, K. Takahashi, M. Kimoto, A. Abe-Ouchi, T. Nakajima, T. Takemura & A. Numaguti 2001. Future Climate Change: Implications for Indian summer monsoon and its variability. *Current Science* 81:1196-1207.

Li, Z.W.D., A. Bloem, S. Delany, G. Martakis & J.O. Quintero 2009. Status of Waterbirds in Asia - Results of the Asian Waterbird Census: 1987-2007. Wetlands International, Kuala Lumpur, Malaysia.

Mahapatro, D., R.C. Panigrahy, S. Panda & R.K. Mishra 2009. Influence of monsoon on macrobenthic assemblage in outer channel area of Chilika lagoon, East coast of India. *Journal of Wetlands Ecology* 3:56-67.

Meyerson, L.A., K. Saltonstall & R.M. Chambers 2009. *Phragmites australis* in eastern North America: a historical and ecological perspective. In: B.R. Silliman, E. Grosholz & M.D. Bertness. (eds.). *Salt marshes: Global Siege.* University of California, Press, pp. 57-82.

Mitra, G.N. & P. Mahapatra 1957. Bulletin on the Development of Chilika Lake: Survey Report on the Fishing Industry, Odisha Government Press, Cuttack, India.

Mohanty, P.K. & S.N. Otta 2008. Population of Irrawaddy Dolphin in Chilika Lagoon. Dolphins of Chilika Odisha Review, India, pp. 24-25.

Mohanty, S.K. 1975. The breeding of economic fishes of the Chilika Lake – A review. *Bulletin, Department of Marine Sciences*, University of Cochin 7(3):543-559.

Mohanty, S.K. 1988. Rational utilization of brackishwater resources of the Chilika lagoon for aquaculture. In: S.N. Patro, B.N. Sahu, K.V. Rama Rao & M.K. Misra (eds.). *Chilika: The pride of our wetland heritage*. Odisha Environmental Society, Bhubaneswar, pp. 36-39.

Mohanty, S.K. 2002. Fisheries biodiversity of Chilika Lake. Chilika Newsletter 1:11-12.

Mohanty, S.K., A. Mohapatra, Rajeeb K. Mohanty, K.S. Bhatta & A.K. Patnaik 2006. Occurrence and biological outlines of two species of *Scylla* (De Haan) in Chilika Lagoon, India. *Indian Journal of Fisheries* 53(2):191-202.

Mohanty, S.K., K.S. Bhatta, H.S. Badapanda & R.K. Mohanty 2004. On shrimp Gherys of Chilika lagoon. *Fishing chimes* 24(8):41-44.

Mohapatra, A., R.K. Mohanty, S.K. Mohanty, K.S. Bhatta & N.R. Das 2007. Fisheries enhancement and biodiversity assessment of fish, prawn and mud crab in Chilika lagoon through hydrological intervention. *Wetlands Ecology and Management* 15(3):229-251.

Mohapatra, K.K. & S.A. Hussain 1988. Avifauna of Chilika Lake. In: S.N. Patro, B.N. Sahu, K.V. Rama Rao & M.K. Misra (eds.). *Chilika: The Pride of Our wetland heritage*. Odisha Environment Society, Bhubaneswar, pp. 89-95.

Mohapatra, K.K. 1998. Food and feeding habits of important aquatic birds of Chilika Lake Odisha. Final report. Bombay Natural History Society, Mumbai, pp. 1-150.

Nayak, B.U., L.K. Ghosh, S.K. Roy & R.S. Kankara 1998. A study on hydrodynamics and salinity in the Chilika Lake. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 31-47.

Nayak, S., G. Nahak, G.C. Nayak & R.K. Sahu 2010. Physicochemical parameters of Chilika Lake water affecting opening a new mouth to Bay of Bengal, Odisha, India. *Continental Journal of Environmental Science* 4:5-65.

Nwankwo, D.I. 1996. Phytoplankton diversity and succession in Lagos Lagoon, Nigeria. *Archiv Fur Hydrobiologie* 135(4):529-542.

Padhi, S., P.K. Swain, S.K. Behura, S. Baidya, S.K. Behera & M.R. Panigrahy 2010. Cultivation of *Gracilaria verrucosa* (Huds) Papenfuss in Chilika Lake for livelihood generation in coastal areas of Odisha State. *Journal of Applied Psychology* 23(2):151-155.

Panda, P.C. & S.N. Patnaik 1998. An enumeration of the flowering plants of Chilika Lagoon and its immediate neighbourhood. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 122-141.

Panday, P.N., B.C. Jha & B.K. Gorai 2005. Economics of Fisheries. APH Publishing Corporation, New Delhi.

Panigrahy, R.C. 1998. Environmental aspects of the Chilika Lagoon-A sensitive coastal ecosystem of Odisha. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 60-73.

Panigrahi, S. 2006. Seasonal variability of phytoplankton productivity and related physico-chemical parameters in the Chilika Lake and its adjoining Sea. Ph.D. thesis, Berhampur University, India

Parulekar, A.H. & S.N. Dwivedi 1974. Benthic studies in Goa estuaries. Part 1- Standing crop and faunal composition in relation to bottom salinity distribution and substratum characteristics in the estuary of Mandovi River. *Indian Journal of Marine Science* 3:41-45.

Patnaik, D.A. 1966. On the biology of *Mugil cephalus* (Linnaeus) of the Chilika lake. *Proceedings second All-India Congress Zoology* 2:457-464.

Patnaik, P. 2010. Impact assessment of new mouth on the ecology and fisheries of Chilika Lake. Ph.D Thesis submitted to Vidyasagar University, West Bengal, India.

Patnaik, P., B.C. Jha & B.C. Patro 2009. Seasonal influence on sectoral variation in macro-benthic profiles of Chilika Lake. *e-planet* 7(1):10-19.

Patnaik, P.K. 1986. On the spatial distribution of zooplankton in Chilika lake (Brackish water lagoon). *Geobios new Reports* 5:31-34.

Patnaik, S. 1970. A contribution to the fishery and biology of the Chilika "Sahala" *Eleutheronema tetradactylum* (Shaw). *Proceedings of the Indian National Science Academy* 36(1):33-61.

Patnaik, S. 1971. Observation on the Fishery and Biology of Chilika "Jagili", *Jerres setifer* (Hamilton). *Journal* of the *Inland Fisheries Society of India* 3:25-56.

Pattanaik, S. 2008. Conservation of environment and protection of marginalized fishing communities of Lake Chilika in Odisha, India. *Journal of Human Ecology* 22(4):1-12.

Pattnaik, A.K. 1998. Chilika Lake - An Overview. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon,* 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 12-21.

Pattnaik, A.K. 2003. Phytodiversity of Chilika Lake, Odisha, India. Ph.D. Thesis, Utkal University, Odisha, India.

Pattnaik, A.K., S.K. Mohanty & R.N. Samal 2004. Environmental Flow Assessment for Chilika Lagoon: Biological-Environment Modelling. Chilika Development Authority. Bhubaneswar, Odisha, India.

Pattnaik, P.K. & A.L.N. Sarma 1997. Qualitative and quantitative composition of zooplankton communities of Rambha Bay (Chilika Lake, Bay of Bengal). *Journal of Marine Biology Association India* 39(1&2):49-58.

Pattnaik, S.S. 2002. Estimation of sediment flow into Chilika Lake. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 83-87.

Phleger, F.B. 1969. Some general features of coastal lagoons. In: A.A. Castanares, & F.B. Phleger (eds.). *International Symposium on Coastal Lagoons: Origin, Dynamics and Productivity*. Mexico City, Mexico Universidad Nacional Autonoma, pp. 5-26.

Pravakar Rao, A.V. 1967. Some observations on the biology of *Penaeus indicus* (H. Milne-Edwards) and *Penaeus monodon* (Fabricius) from the Chilika Lake. *Indian Journal of Fisheries* 14(1&2):251-270.

Pushparajan, N. & P. Soundarapandian 2010. Recent Farming of Marine Black Tiger Shrimp, *Penaeus monodon* (Fabricius) in South India. *African Journal of Basic & Applied Sciences* 2 (1-2):33-36.

Rajasegar, M. 1998. Environmental inventory on Vellar estuary (Southeast coast of India) in relation to shrimp farming. Ph.D. Thesis, Annamalai University,Tamil Nadu, India.

Ramakrishnaiah, M. 1972. Biology of *Hilsa Ilisha* (Hamilton) from the Chilika Lake with an account on its racial status. *Indian Journal of Fisheries* 19(1&2):35-53.

Raman, A.V. & Ch. Satyanarayan 1998. Water quality and phytoplankton changes in Chilika Lake, a brackish water lagoon on the eastern coast of India. In: *The proceeding of International workshop on Sustainable Development of Chilika Lagoon*, 12-14 December 1998. Chilika Development Authority, Bhubaneswar, India, pp. 77-80.

Ramsar Convention Secretariat, 2010. Data and information needs: A Framework for Ramsar data and information needs. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 14. Ramsar Convention Secretariat, Gland, Switzerland.

Rao, K.N. & N. Sadakata 1996. Morphology and evolution of lagoons on the east coast of India. *Laguna* 3:141–149.

Rath, J. & S.P. Adhikary 2004. Effect of alkali treatment on the yield and quality of agar from red alga *Gracilaria verrucosa* (Rhodophyta, Gracilariales) occurring at different salinity gradient of Chilika Lake. *Indian Journal of Marine Sciences* 33(2):202-205.

Rath, J. & S.P. Adhikary 2005. Algal Flora of Chilika Lake. Daya Publishing House, Delhi, India, pp. 127-130.

Rout, D.K. & P.K. Durani 1993. Production ecology of macrophytes of Chilika Lake. In: P.C. Mishra & Trivedy (eds.). *Ecology and pollution of Indian lakes and Reservoirs*, pp. 301-316.

Sahoo, D., N. Sahu & D. Sahoo 2003. A Critical Survey of Seaweed Diversity of Chilika Lake, India. *Algae* 18(1):1-12.

Samal, K. 2002. Occupational displacement of fishermen. *Economic and Political Weekly* 37(18):1714-1718.

Samal, K. & S. Meher 1999. Socio-Economic survey of villages in and around Chilika- A report of the research project sponsored by Chilika Development Authority, Bhubaneswar, India.

Samal, K. & S. Meher 2003. Fishing communities on Chilika Lake: Comparative socio-economic study. *Economic and Political Weekly* 38(31):3319-3325.

Santhanam, R., K. Krishnamurthy & V. Sundararaj 1975. Quantitative phytoplankton ecology. *Bulletin, Department of Marine Science*, University of Cochin 7(4):769-779.

Sarma, A.L.N., D.G. Rao, S. Satpathy & P.K. Patnaik 1988. Invertebrate community ecology in context of conservation and development of Chilika Lagoon (Bay of Bengal). National Seminar on Conservation and Management of Chilika, Department of Science, Technology and Environment, Govt. of Odisha, Bhubaneswar, India.

Satyanarayana CH. 1999 Hydrographic and phytoplankton characteristics of Chilika Lake: A brackishwater lagoon, on the east coast of India, Ph.D. thesis, Andhra University, Visakhapatnam, India.

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold (Publishers) Ltd., London, pp. 610.

Sekhar, N.U. 2004. Fisheries in Chilika Lake: How community access and control impacts their management. *Journal of Environmental Management* 73(3):257-266.

Sekhar, N.U. 2007. Social Capital and Fisheries Management: The Case of Chilika Lake in India. *Environment Management* 39:497-505.

Shanmugam, A., R. Kasinathan & S. Maruthamuthu 1986. Biomass and composition of zooplankton from Pichavaram mangroves, Southeast coast of India. *Indian Journal of Marine Science* 15:111-113.

Shimpei, I. & R. Shaw, 2009. Linking human security to natural resources: perspective from a fishery resource allocation system in Chilika lagoon, India. *Sustainability Science* 4(2):281-292.

Siddqui, S.Z. & K.V. Rama Rao 1995. Limnology. Fauna of Chilika Lake. Wetland ecosystem series 1: Zoological Survey of India, Kolkata, India. pp.11-136.

Sikoki, F.D., S.A. Hart, A.I. Hart & I.P. Adeleye-Wokoma 2001. Aspects of the reproductive biology of *Mugil cephalus* (Linnaeus) in Bonny Estuary. In: *14th Annual Conference of the Fisheries Society of Nigeria (FISON)*, 19-23 January 1998, Ibadan, Nigeria.

Singh V.P. 1960. Phytoplankton ecology of inland waters of Utter Pradesh. In: *Proceeding of all India Symposium on Algae*, ICAR, New Delhi, India, pp. 243-271.

Sinha R.K., C.L. Trishal & A.K. Pattnaik 2000. Status and conservation of the Irrawaddy Dolphins in the Chilika lagoon, Odisha, India, pp. 1-15.

Stacey, P.J. & S. Leatherwood 1997. The Irrawaddy dolphins, *Oracaella brevirostris*: A summary of current knowledge and recommendations for conservation action. *Asian Marine Biology* 14:195-214.

Swingle, H.S. 1967. Standardization of chemical analysis of water and ponds muds. *FAO Fisheries Report* 44:397-432.

TERI 1996. The economic impacts of a one-meter sea level rise on the Indian coastline: method and case studies. Report submitted to Ford Foundation.

Tripati, S. & K.H. Vora 2005. Maritime heritage in and around Chilika Lake, Odisha: Geological evidences for its decline. *Current Science* 88(7):1175-1181.

Unnikrishnan, A.S. & D. Shankar 2007. Are sea level trends along the North Indian Ocean coasts consistent with global estimates? *Global and Planetary Change* 57:301.

Warwick, R.M. & R.J. Uncles 1980. Distribution of benthic macrofauna associations in Bristol Channel inrelation to tidal stress. *Marine Ecological Progress Series* 3:97-103.

Wetzel, R. G. 1990. Detritus, macrophytes and nutrient cycling in lakes. *Memorie dell Istituto Italiano di Idrobiologia* 47:233–249.

Wildish, D.J. & D.D. Kristmanson 1979. Tidal energy and sublittoral macrobenthic animals in estuaries. *Journal of Fisheries Research Board of Canada* 36:1197-1206.

WISA 2009. Integrated Management Planning for Chilika Lake, Odisha. Discussion Paper. Chilika Development Authority and Wetlands International-South Asia, New Delhi, India.

Woolcock, M. 2001. The Place of Social Capital in Understanding Social and Economic Outcomes. ISUMA. *Canadian Journal of Policy Research* 2 (1):11-17.

Woolcock, M. & D. Narayan 2000. Social Capital: Implications for Development Theory, Research, and Policy. *World Bank Research Observer* 15(2):225-250.

World Bank 2004. Environmental Flow Assessment for Chilika Lagoon: Biological-Environmental Modelling. Final Report 2004.

Xavier Institute of Management 2011. Developing a perspective plan, Organizational structure and Manpower Plan for Chilika Development Authority. Xavier Institute of Management, Bhubaneswar, Odisha, India.

Young, W.J. 2004 Environmental Flows for Lake Chilika via the Narraj Barrage. Final Report and Achievements of the Odisha Mission. Unpublished report to the OWRCP from the World Bank.s BNWPP Environmental Flows window. pp.13.

Zipper, C.E., E.F. Benfield, T.A. Dillaha III, T. J. Grizzard, Jr., C.H. Hershner, Jr., H.I. Kator, W.S. Lung, J.J. Ney, L.A. Shabman, E.P. Smith, L.A. Smock, J.L. Walker, E.R. Yagow, & T. Younos 2004. Freshwater Nutrient Criteria. Report of the Academic Advisory Committee to Virginia Department of Environmental Quality. Virginia Water Resources Research Center, Blacksburg, VA. 77 pp.

ZSI 1995. Fauna of Chilika Lake. Wetland ecosystem series 1: Zoological Survey of India, Kolkata, India.

Algal species in Lake Chilika

(Source: Sahoo *et al.*, 2003)

Chlorophyceae

1 *Enteromorpha compressa* (Linn.)
2 *Enteromorpha flexuosa* (Wulf.)
3 *Enteromorpha intestinalis* (Linn.)
4 *Ulva fasciata* (Delile.)
5 *Ulva lactuca* (Linn.)
6 *Chaetomorpha linum* (Muller.)
7 *Cladophora glomerata* (Linn.)
8 *Pithophora oedogonia* (Mont.)

Rhodophyceae

9 *Gracilaria verrucosa* (Hudson.)
10 *Gracilariopsis megaspora* (Dawson.)
11 *Grateloupia filicina* var. *luxurians* (Lamouroux.)
12 *Ceramium diaphanum* var. *elegans* (Roth.)
13 *Polysiphonia sertularioides* (Grateloup.)
14 *Polysiphonia subtilissima* (Montage.)

Vegetation of Lake Chilika
(Source: Pattnaik, 2003)

Dicotyledons

Magnoliaceae

1 *Michelia champaca* (Linn.)

Annonnaceae

2 **Alphonsea sclerocarpa* (Thw.)
3 *Annona reticulata* (Linn.)
4 *Annona squamosa* (Linn.)
5 *Polyalthia longifolia* (Sonn.)

Menispermaceae

6 *Cissampelos pareira* (Linn.) var. *hirsute* (Buch.-Ham.)
7 *Cocculus hirsutus* (Linn.)
8 *Stephania japonica* (Thunb.)
9 *Tiliacora acuminata* (Lam.)
10 *Tinospora cordifolia* (Willd.)

Nymphaeaceae

11 *Nymphaea nouchali* (Burm.f.)
12 *Nymphaea pubescens* (Willd.)

Papaveraceae

13 *Argemone mexicana* (Linn.)

Brassicaceae

14 *Rorippa indica* (Linn.)

Capparaceae

15 *Capparis brevispina* (DC.)
16 *Capparis roxburghii* (DC.)
17 *Capparis sepiaria* (Linn.)
18 *Capparis zeylanica* (Linn.)
19 *Cleome aspera* (Koenig.)
20 *Cleome monophylla* (Linn.)
21 *Cleome rutidosperma* (DC.)
22 *Cleome viscosa* (Linn.)
23 *Crateva adansonii* (DC.) spp. *odora* (Buch.-Ham.)
24 *Maerua oblongifolia* (Forssk.)

Violaceae

25 *Hybanthus enneaspermus* (Linn.)

Flaucourtiaceae

26 *Casearia elliptica* (Willd.)
27 *Flacourtia indica* (Burm.f.)

Polygalaceae

28 *Polygala arvensis* (Willd.)
29 *Salamonia ciliata* (Linn.)

Caryophyllaceae

30 *Polycarpaea corymbosa* (Linn.)
31 *Polycarpon prostratum* (Forsk.)

Potulacaceae

32 *Portulaca oleracea* (Linn.)
33 *Portulaca quadrifida* (Linn.)

Elatinaceae

34 *Bergia ammanioides* (Roxb.)

Clusiaceae

35 *Calophyllum inophyllum* (Linn.)

Bombacaceae

36 *Bombax ceiba* (Linn.)

Malvaceae

37 *Abelmoschus ficulneus* (Linn.)
38 *Abelmoschus manihot* (Linn.) spp. *tetraphyllus* (Hornem.)
39 *Abutilon hirtum* (Lam.)
40 *Abutilon indicum* (Linn.)
41 *Hibiscus ovalifolius* (Forsk.)
42 *Hibiscus rosasinensis* (Linn.)
43 *Hibiscus sabdariffa* (Linn.)
44 *Hibiscus tiliaceus* (Linn.)
45 *Pavonica odorata* (Willd.)
46 *Malachra capitata* (Linn.)
47 *Pavonia zeylanica* (Linn.)
48 *Sida acuta* (Burm.f.)
49 *Sida cordata* (Linn.)
50 *Sida cordifolia* (Linn.)
51 *Sida rhombifolia* (Linn.)
52 *Thespesia populnea* (Linn.)
53 *Urena lobata* ssp. *sinuta* (Linn.)

Sterculiaceae

54 *Helicteres isora* (Linn.)
55 *Melochia corchorifolia* (Linn.)
56 *Sterculia urens* (Roxb.)
57 *Waltheria indica* (Linn.)

Tiliaceae

58 *Corchorus aestuans* (Linn.)
59 *Corchorus capsularis* (Linn.)
60 *Corchorus fascicularis* (Lam.)
61 *Grewia obutusa* (Wall.)
62 *Grewia disperma* (Roth.)
63 *Grewia helicterifolia* (Wall.)
64 **Grewia rhamnifolia* (Heyne.)
65 *Grewia rothii* (DC.)
66 *Grewia sapida* (Roxb.)
67 *Grewia tiliifolia* (Vahl.)
68 *Triumfetta pentandra* (Rich.)
69 *Triumfetta rhomboidea* (Jacq.)

Linaceae

70 *Hugonia mystax* (Linn.)

Malpighiaceae

71 *Aspidopterys indica* (Roxb.)

Zygophyllaceae

72 *Tribulus terrestris* (Linn.)

Oxalidaceae

73 *Biophytum sensitivum* (Linn.)
74 *Oxalis corniculata* (Linn.)

Rutaceae

75 *Aegle marmelos* (Linn.)
76 **Atalantia monophylla* (Linn.)
77 *Citrus medica* (Linn.)
78 *Glycosmis mauritiana* (Lam.)
79 *Glycosmis pentaphylla* (Retz.)
80 *Limonia acidissima* (Linn.)
81 *Murraya paniculata* (Linn.)
82 *Murraya koenigii* (Linn.)
83 *Toddalia asiatica* (Linn.)

Ochnaceae

84 *Ochna obtusata* (DC.)

Meliaceae

85 *Azadirachta indica* (Juss.)
86 *Cipadessa baccifera* (Roth.)
87 **Walsura trifoliata* (Juss.)

Olacaceae

88 *Olax psittacorum* (Willd.)

Celastraceae

89 *Celastrus paniculatus* (Willd.)
90 *Maytnus emarginata* (Willd.)

Hippocratiaceae

91 **Ressantia indica* (Willd.)
92 *Salacia chinensis* (Linn.)

Rhamnaceae

93 *Colubrina asiatica* (Linn.)
94 **Rhamnus prostratus* (Jacq.)
95 *Scutia myrtina* (Burm.f.)
96 *Ziziphus mauritiana* (Lam.)
97 *Ziziphus oenoplia* (Linn.)
98 *Zizipus xylopyrus* (Retz.)

Vitaceae

99 *Ampelocissus latifolia* (Roxb.)
100 *Cayratia auriculata* (Roxb.)
101 *Cayratia pedata* (Lam.)
102 *Cayratia trifolia* (Linn.)
103 *Cissus adnata* (Roxb.)
104 *Cissus quadrangularis* (Linn.)
105 *Cissus vitiginea* (Linn.)

Sapindaceae

106 *Allophylus serratus* (Roxb.)
107 *Cardiospermum helicacabum* (Linn.)
108 *Dodonaea angustifolia* (Linn.)
109 *Lepisanthes tetraphylla* (Vahl.)
110 **Schleichera oleosa* (Lour.)

Anacardiaceae

111 *Anacardium occidentale* (Linn.)
112 *Lannea coromandelica* (Houtt.)
113 *Mangifera indica* (Linn.)

Fabaceae

114 *Abrus precatorius* (Linn.)
115 *Aeschynomene aspera* (Linn.)
116 *Aeschynomene indica* (Linn.)
117 *Alysicarpus monilifer* (Linn.)
118 *Alysicarpus roxburgianum* (Thoth. & Pramanik.)
119 *Alysicarpus scariosus* (Rottl.)
120 *Alysicarpus vaginalis* (Linn.)
121 *Atylosia scarabaeoides* (Linn.)
122 *Butea monosperma* (Lam.)
123 *Cajanus cajan* (Linn.)

124 *Canavalia virosa* (Roxb.)
125 **Canavalia gladiata* (Jacq.)
126 *Clitoria ternatea* (Linn.)
127 *Crotolaria albida* (Heyne.)
128 *Crotolaria juncea* (Linn.)
129 *Crotolaria nana* (Burm.f.)
130 *Crotolaria pallida* (Ait.)
131 *Crotolaria prostrata* (Rottl.)
132 *Crotolaria retusa* (Linn.)
133 *Crotolaria verrucosa* (Linn.)
134 **Dalbergia candenatensis* (Dennst.)
135 *Dalbergia rubiginosa* (Roxb.)
136 *Derris scandens* (Roxb.)
137 *Derris trifoliata* (Lour.)
138 *Desmodium gangeticum* (Linn.)
139 *Desmodium heterophyllum* (Willd.)
140 *Desmodium triflorum* (Linn.)
141 *Dicerma biarticulatum* (Linn.)
142 *Dolichos trilobus* (Linn.)
143 *Erythrina suberosa* (Roxb.)
144 *Erythrina variegata* (Linn.)
145 *Galactia tenuiflora* (Klein.)
146 *Gliricidia sepium* (Jacq.)
147 *Indigofera arrecta* (Hochst.)
148 *Indigofera aspalthoides* (Vahl.)
149 *Indigofera astragalina* (DC.)
150 *Indigofera glabra* (Linn.)
151 *Indigofera linifolia* (Linn.f.)
152 *Indigofera linnaei* (Ali.)
153 *Indigofera nummularifolia* (Linn.)
154 *Indigofera prostrata* (Willd.)
155 *Indigofera tinctoria* (Linn.)
156 *Lablab purpureus* (Linn.)
157 *Macrotyloma ciliatum* (Willd.)
158 *Macrotyloma uniflorum* (Lam.)
159 *Mucuna pruriens* (Linn.)
160 *Pongamia pinnata* (Linn.)
161 *Pseudarthria viscid* (Linn.)
162 *Rhynchosia capitata* (Heyne.)
163 *Rhynchosia minima* (Linn.)
164 *Rothia indica* (Linn.)
165 *Sesbania bispinosa* (Jacq.)
166 *Sesbania sesban* (Linn.)
167 *Sesbania procumbens* (Roxb.)
168 *Smithia conferta* (J. E.Sm.)
169 *Stylosanthes fruticosa* (Retz.)
170 *Tephrosia maxima* (Linn.)
171 *Tephrosia purpurea* (Linn.)
172 *Tephrosia villosa* (Linn.)
173 *Vigna mungo* (Linn.)
174 *Vigna radiate* (Linn.)
175 *Vigna sublobata* (Roxb.)
176 *Vigna tribolata* (Linn.)
177 *Zornia gibbosa* (Span.)

Caesalpiniaceae

178 *Bauhinia purpurea* (Linn.)
179 *Caesalpinia bunduc* (Linn.)
180 *Caesalpinia digyna* (Rottl.)
181 *Cassia absus* (Linn.)
182 *Cassia fistula* (Linn.)
183 *Cassia mimosoides* (Linn.)
184 *Cassia occidentalis* (Linn.)
185 *Cassia obtusifolia* (Linn.)
186 *Cassia tora* (Linn.)
187 *Delonix regia* (Hook.)
188 *Parkinsonia aculeate* (Linn.)
189 *Tamarindus indica* (Linn.)

Mimosaceae

190 *Acacia auriculiformis* (A. Cunn.)
191 *Acacia caesia* (Linn.)
192 *Acacia holosericea* (A. Cunn.)
193 *Acacia leucophloea* (Roxb.)
194 *Acacia nilotica* (Linn.) ssp. *indica* (Benth.)
195 *Acacia pennata* (Linn.)
196 *Albizia odoratissima* (Linn.f.)
197 *Dichrostachys cinerea* (Linn.)
198 *Leucaena leucocephala* (Lam.)
199 *Mimosa pudica* (Linn.)
200 *Mimosa himalayana* (Gamble.)
201 *Neptunia oleracea* (Lour.)
202 *Neptunia triquetra* (Vahl.)
203 *Pithecellobium dulce* (Roxb.)
204 *Prosopis juliflora* (Sw.)
205 *Samenea saman* (Jacq.)

Vahiliaceae

206 *Vahlia dichotoma* (Murr.)

Rhizophoraceae

207 *Cassipourea ceylanica* (Gaertn.)

Combretaceae

208 *Calycopteris floribunda* (Lam.)
209 *Combretum roxburghii* (Spreng.)
210 *Quisqualis indica* (Linn.)
211 *Terminalia arjuna* (Roxb.)

Myrtaceae

212 *Callistemon linearis* (DC.)
213 *Eugenia rothii* (Panigrahi.)
214 *Syzygium cumini* (Linn.)

Lecythidaceae

215 *Barringtonia acutangula* (Linn.)

Melastomataceae

216 *Osbeckia zeylanica* (Linn.)

Lythraceae

217 *Ammannia baccifera* (Linn.)
218 *Ammannia multiflora* (Roxb.)
219 *Nesaea lanceolata* (Heyne.)
220 *Rotala rotundifolia* (Buch.-Ham.)
221 *Rotala verticillaris* (Linn.)

Onagraceae

222 *Ludwigia adscendens* (Linn.)
223 *Ludwigia hyssopifolia* (G. Don.)
224 *Ludwigia octovalvis* (Jacq.)
225 *Ludwigia perrenis* (Linn.)

Turneraceae

226 *Ternera ulmifolia* (Linn.)

Passifloraceae

227 *Passiflora foetida* (Linn.)

Cucurbitaceae

228 *Coccinia grandis* (Linn.)
229 *Luffa acutangula* (Linn.) var. *amara* (Roxb.)
230 *Momordica dioica* (Roxb.)
231 *Mukia maderaspatana* (Linn.)
232 *Solena amplexicaulis* (Lam.)
233 *Trichosanthes cucumerina* (Linn.)
234 *Trichosanthes tricuspidata* (Lour.)

Cactaceae

235 *Cereus hexagonus* (Haw.)
236 *Opuntia stricta* (Haw.) var. *dillenii* (Ker-Gawler.)

Molluginaceae

237 *Gisekia pharnaceoides* (Linn.)
238 *Glinus lotoides* (Linn.)
239 *Glinus oppositifolius* (Linn.)
240 *Mollugo cerviana* (Linn.)
241 *Mollugo nudicaulis* (Lam.)
242 *Mollugo pentaphylla* (Linn.)

Aizoaceae

243 *Sesuvium portulacastrum* (Linn.)
244 *Trianthema portulacastrum* (Linn.)
245 *Trianthema triquetra* (Rottl.)

Apiaceae

246 *Centella asiatica* (Linn.)
247 *Hydrocotyle sibthorpioides* (Lam.)
248 *Seseli diffusum* (Roxb.)

Alangiaceae

249 *Alangium salvifolium* (Linn.f.)

Rubiaceae

250 *Benkara malabarica* (Lam.)
251 *Canthium parviflorum* (Lam.)
252 *Catunaregam spinosa* (Thunb.)
253 *Dentella repens* (Linn.)
254 *Hedyotis brachiata* (Wight. & Arn.)
255 *Hedyotis corymbosa* (Linn.)
256 *Hedyotis diffusa* (Willd.)
257 *Hedyotis erecta* (Manilal. & Sivarajan.)
258 *Hedyotis herbacea* (Linn.)
259 *Hedyotis graminifolia* (Linn. f). ssp. *arenaria* (Haines.)
260 *Hedyotis nitida* (Wt. & Arn.)
261 **Hedyotis ovatifolia* (Cav.)
262 *Hedyotis puberula* (G. Don.)
263 *Hydrophylax maritime* (Linn. f.)
264 *Ixora pavetta* (Anders.)
265 *Knoxia sumatrensis* (Retz.)
266 *Meyna spinosa* (Roxb.) var. *pubescens* (Robyns.)
267 *Mitracarpus villosus* (Sw.)
268 *Mitragyna parvifolia* (Roxb.)
269 *Morinda coreia* Buch (Ham.)
270 *Pavetta indica* (Linn.)
271 *Pavetta tomentosa* (Roxb.)
272 *Spermacoce articularis* (Linn. f.)
273 *Spermacoce pusilla* (Wall.)
274 *Spermacoce ramanii* (Sivarajan. & Nair.)
275 *Tamilnadia uliginosa* (Retz.)
276 *Tarenna asiatica* (Linn.)

Asteraceae

277 *Acanthospermum hispidum* (DC.)
278 *Ageratum conyzoides* (Linn.)
279 *Bidens biternata* (Lour.)
280 *Blainvillea acmella* (Linn.)
281 *Blumea lacera* (Borm. f.)
282 *Caesulia axillaris* (Roxb.)
283 *Centipeda minima* (Linn.)
284 *Chromolaena odorata* (Linn.)
285 *Eclipta prostrata* (Linn.)
286 *Elephantopus scaber* (Linn.)
287 *Emelia sonchifolia* (Linn.)
288 *Enydra fluctuans* (Lour.)
289 *Epaltes divaricata* (Linn.)

290 *Gnaphalium polycaulon* (Pers.)
291 *Grangea maderaspatana* (Linn.)
292 *Launea sarmentosa* (Willd.)
293 *Parthenium hysterophorus* (Linn.)
294 *Sphaeranthus indicus* (Linn.)
295 *Tridax procumbens* (Linn.)
296 *Vernonia cinerea* (Linn.)
297 *Xanthium indicum* (Koenig.)

Sphenocleaceae

298 *Sphenoclea zeylanica* (Gaertn.)

Campanulaceae

299 *Wahlenbergia emarginata* (Thunb.)

Lobeliaceae

300 *Lobelia alsinoides* (Lam.)

Plumbaginaceae

301 *Plumbago zeylanica* (Linn.)

Myrsinaceae

302 *Aegiceras corniculatum* (Linn.)

Sapotaceae

303 *Manilkara hexandra* (Roxb.)
304 *Mimusops elengi* (Linn.)
305 *Xantolis tomentosa* (Roxb.)

Ebenaceae

306 *Diospyros chloroxylon* (Roxb.)
307 *Diospyros ferrea* (Willd.)
308 *Diospyros montana* (Roxb.)
309 *Diospyros melanoxylon* (Roxb.)

Oleaceae

310 *Jasminum scandens* (Linn.)
311 *Jasminum sambac* (Vahl.)

Salvadoraceae

312 *Azima tetracantha* (Lamk.)
313 *Salvadora persica* (Linn.)

Apocynaceae

314 **Aganosma coryophyllata* (Roxb.)
315 *Alstonia scholaris* (Linn.)
316 *Anodendron paniculatum* (A. DC.)
317 *Carissa gangatica* (Stapf.)
318 *Carissa paucinervia* (A. DC.)
319 *Carissa spinarum* (Linn.)
320 *Cascabela thivetia* (Linn.)
321 *Catharanthus roseus* (Linn.)
322 *Holarrhena pubescens* (Buch.-Ham.)
323 *Ichnocarpus frutescens* (Linn.)
324 *Vallaria solanacea* (Roth.)
325 *Wrightia arborea* (Dennst.)

Asclepiadaceae

326 **Calotropis acia* (Buch.-Ham.)
327 *Calotropis gigantea* (Linn.)
328 *Caralluma adscendens* (Roxb.)
329 *Ceropegia candelabrum* (Linn.) ssp. *tuberose* (Roxb.)
330 **Cryptolepis sinensis* (Lour.)
331 *Gymnema sylvestre* (Retz.)
332 *Hemidesmus indicus* (Linn.)
333 *Leptadenia reticulata* (Retz.)
334 *Pentatropis capensis* (Linn.f.)
335 *Pergularia daemia* (Forsk.)
336 *Sarcostemma acidum* (Roxb.)
337 *Tylophora indica* (Burm.f.)

Loganiaceae

338 *Strychnos nux-vomica* (Linn.)

Spigeliceae

339 *Mitrasacme pygmaea* (R. Br.) var. *malaccensis* (Wight.)

Menyanthaceae

340 *Nymphoides hydrophylla* (Lour.)
341 *Nymphoides indica* (Linn.)

Hydrophyllaceae

342 *Hydrolea zeylanica* (Linn.)
343 *Hydrolea zeylanica* (Linn.) var. *erecta* (Haines.)

Boraginaceae

344 *Carmona retusa* (Vahl.)
345 *Coldenia procumbens* (Linn.)
346 *Cordia dichotoma* (Frost.f.)
347 *Ehretia laevis* (Roxb.)
348 *Heliotropium curassavicum* (Linn.)
349 *Heliotropium indicum* (Linn.)
350 *Heliotropium marifolium* (Retz.)
351 *Heliotropium strigosum* (Willd.) ssp. *brevifolium* (Wall.)

Convolvulaceae

352 *Argyreia cymosa* (Roxb.)
353 *Argyreia nervosa* (Burm.f.)
354 *Cressa cretica* (Linn.)
355 *Ericybe paniculata* (Roxb.)
356 *Evolvulus alsinoides* (Linn.)
357 *Evolvulus nummularius* (Linn.)

358 *Hewittia scandens* (Milne.)
359 *Ipomoea alba* (Linn.)
360 *Ipomoea aquatic* (Forssk.)
361 *Ipomoea carnea* (Jacq.) ssp. *fistulosa* (Mart.)
362 *Ipomoea dichroa* (Roem. & Schult.)
363 *Ipomoea nil* (Linn.)
364 *Ipomoea obscura* (Linn.)
365 *Ipomoea sepiaria* (Koenig.)
366 *Ipomoea pescaprae* (Linn.)
367 *Ipomoea pes-tigridis* (Linn.)
368 *Merremia emarginata* (Koenig.)
369 *Jacquemontia paniculata* (Burm.f.)
370 *Merremia emarginata* (Burm.f.)
371 *Merremia hederacea* (Burm.f.)
372 *Merremia tridentata* (Linn.)
373 *Merremia tridentata* (Linn.)
374 *Merremia umbellata* (Linn.)
375 *Merremia vitifolia* (Burm.f.)
376 *Porana paniculata* (Roxb.)

Cuscutaceae

377 *Cuscuta reflexa* (Roxb.)

Solanaceae

378 *Datura metel* (Linn.)
379 *Datura stramonium* (Linn.)
380 *Lycopersicon esculentum* (Mill.)
381 *Nicotiana plumbaginifolia* (Viv.)
382 *Physalis minima* (Linn.)
383 *Solanum melongena* (Linn.)
384 *Solanum nigrum* (Linn.)
385 *Solanum trilobatum* (Linn.)
386 *Solanum viriginianum* (Linn.)

Scrophulariaceae

387 *Adenosma indianum* (Lour.)
388 *Angelonia salicariifolia* (Homb. & Bonpl.)
389 *Bacopa monnieri* (Linn.)
390 *Centranthera tranquebarica* (Spring.)
391 *Limnophila heterophylla* (Roxb.)
392 *Limnophila indica* (Linn.)
393 *Limnophila repens* (Benth.)
394 *Lindernia anagallis* (Burm.f.)
395 *Lindernia antipoda* (Linn.)
396 *Lindernia ciliata* (Colsm.)
397 *Lindernia crustacea* (Linn.)
398 *Lindernia viscosa* (Hornem.)
399 *Mecardonia procumbens* (Mill.)
400 *Scoparia dulcis* (Linn.)
401 *Sopubia delphinifolia* (Linn.)
402 *Striga densiflora* (Benth.)
403 *Striga augustifolia* (D. Don)

Utriculariaceae

404 *Utricularia aurea* (Lour.)
405 *Utricularia polygaloides* (Edgew.)
406 *Utricularia stellaris* (Linn.)

Pedaliaceae

407 *Pedalium murex* (Linn.)
408 *Sesamum orientale* (Linn.)

Martyniaceae

409 *Martynia annua* (Houst.)

Acanthaceae

410 *Andrographis elongata* (Vahl.)
411 *Andrographis paniculata* (Burm.f.)
412 *Asystasia gangetica* (Linn.)
413 *Barleria longifolia* (Linn.f.)
414 *Barleria prionitis* (Linn.)
415 *Blepharis maderaspatensis* (Linn.)
416 *Blepharis repens* (Vahl.)
417 *Dicliptera bupleuroides* (Nees.) var. *roxburghiana* (Panigr. & Dubey.)
418 *Dipteracanthus prostratus* (Poir.)
419 *Ecbolium viride* (Forsk.) var. *dentata* (Klein.)
420 *Eranthemum capense* (Linn.)
421 *Hemiadelphis polysperma* (Roxb.)
422 *Hemigraphis hirta* (Vahl.)
423 *Hygrophila schulli* (Buch.-Ham.)
424 *Indineesiella echiodes* (Linn.)
425 *Justicia betonica* (Linn.)
426 *Justicia glauca* (Rottb.)
427 *Justicia quinqueangularis* (Koen.)
428 *Lepidagathis incurva* (D. Don.)
429 *Peristrophe paniculata* (Forsk.)
430 *Phaulopsis imbricata* (Forsk.)
431 *Rungia pectinata* (Linn.)
432 *Rungia repens* (Linn.)

Verbenaceae

433 *Clerodendrum inerme* (Linn.)
434 *Clerodendrum viscosum* (Vent.)
435 *Gmelina arborea* (Roxb.)
436 *Lantana camara* (Linn.)
437 *Lippia javanica* (Burm.f.)
438 *Phyla nodiflora* (Linn.)
439 **Premma latifolia* (Roxb.)
440 *Premma latifolia* (Roxb.) var. *mucronata* (Roxb.)
441 *Premma tementosa* (Willd.)
442 **Premma wightiana* (Schaulr.)
443 *Stachytarpheta jamaicensis* (Jacq.)
444 *Stachytarpheta involucratum* (Roxb.)
445 *Vitex negundo* (Linn.)

Lamiaceae

446 *Acrocephalus hispidus* (Linn.)
447 *Anisochilus carnosus* (Linn.f.)
448 *Anisomeles indica* (Linn.)
449 *Geniosporum tenuiflorum* (Linn.)
450 *Hyptis suaveolens* (Linn.)
451 *Leonitis nepetiifolia* (Linn.)
452 *Leucas lantana* (Benth.)
453 *Leucas indica* (Linn.)
454 *Leucas plukenetii* (Roth.)
455 *Leucas stricta* (Benth.)
456 *Ocimum basilicum* (Linn.)
457 *Ocimum gratissimum* (Linn.)
458 *Ocimum santum* (Linn.)
459 *Orthosiphon pallidus* (Royle.)
460 *Pogostemon benghalensis* (Burm.f.)

Nyctaginaceae

461 *Boerhavia chinensis* (Linn.)
462 *Boerhavia diffusa* (Linn.)
463 *Pisonia aculeata* (Linn.)

Amaranthaceae

464 *Achyranthes aspera* (Linn.)
465 *Aerva lanata* (Linn.)
466 *Aerva sanguinolenta* (Linn.)
467 *Allmania nodiflora* (Linn.)
468 *Alternanthera philoxeroides* (Mart.)
469 *Alternanthera pungens* (Kunth.)
470 *Alternanthera sessilis* (Linn.)
471 *Amaranthus spinosus* (Linn.)
472 *Amaranthus viridis* (Linn.)
473 *Celosia argentea* (Linn.)
474 *Centrostachys aquatica* (R. Br.)
475 *Digera muricata* (Linn.)
476 *Gomphrena serrata* (Linn.)
477 *Pupalia lappacea* (Linn.)

Chenopodiaceae

478 *Salichornia brachiata* (Roxb.)
479 *Suaeda maritima* (Linn.)

Basellaceae

480 *Basella alba* (Linn.)

Polygonaceae

481 *Polygonum barbatum* (Linn.)
482 *Polygonum hydropiper* (Linn.)
483 *Polygonum plebeium* (R.Br.)
484 *Polygonum pulchrum* (Bl.)
485 *Rumex maritimus* (Linn.)

Aristolochiaceae

486 *Aristolochia indica* (Linn.)

Piperaceae

487 *Peperomia pellucida* (Linn.)

Lauraceae

488 *Cassytha filiformis* (Linn.)
489 *Litsea glutinosa* (Lour.)

Hernandiaceae

490 *Gyrocarpus americanus* (Jacq.)

Loranthaceae

491 *Dendrophthoe falcata* (Linn.f.)
492 *Viscum articulatum* (Burm.f.)

Euphorbiaceae

493 *Acalypha indica* (Linn.)
494 *Acalypha lanceolata* (Willd.)
495 *Baliospermum montanum* (Willd.)
496 *Breynia retusa* (Dennst.)
497 *Breynia vitis-idea* (Burm.f.)
498 *Breynia airy-shawii* (P.T. Li.)
499 *Chrozophora prostrata* (Dalz.)
500 *Chrozophora rottleri* (Geisler.)
501 *Croton caudatus* (Geisel.)
502 *Croton bonplandianus* (Baill.)
503 *Euphorbia antiquorum* (Linn.)
504 *Euphorbia caducifolia* (Haines.)
505 *Euphorbia hirta* (Linn.)
506 *Euphorbia ligularia* (Roxb.)
507 *Euphorbia rosea* (Retz.)
508 *Euphorbia thymifolia* (Linn.)
509 *Euphorbia tirucalli* (Linn.)
510 *Euphorbia agallocha* (Linn.)
511 *Jatropha curcas* (Linn.)
512 *Jatropha gossypifolia* (Linn.)
513 *Macrococca mercurialis* (Linn.)
514 *Pedilanthus tithymaloides* (Linn.)
515 *Phyllanthus amarus* (Schum. & Thonn.)
516 *Phyllanthus fraternus* (Webster.)
517 *Phyllanthus reticulatus* (Poir.)
518 *Phyllanthus rotundifolius* (Klein.)
519 *Phyllanthus urinaria* (Linn.)
520 *Phyllanthus virgatus* (Linn.f.)
521 *Ricinus communis* (Linn.)
522 *Sauropus bacciformis* (Linn.)
523 *Sebastiania chamaelea* (Linn.)

524 *Securinega virosa* (Roxb.)
525 *Suregada multiflora* (A.Juss.)
526 *Tragia involucrata* (Linn.)

Urticaceae

527 *Laportea interrupta* (Linn.)
528 *Pilea microphylla* (Linn.)
529 *Pouzolzia auriculata* (Wight.)
530 *Pouzolzia zeylanica* (Linn.)

Ulmaceae

531 *Holoptelea integrifolia* (Roxb.)
532 *Trema orientalis* (Linn.)

Moraceae

533 *Artocarpus heterophyllus* (Lam.)
534 **Ficus arnottiana* (Miq.)
535 *Ficus auriculata* (Lour.)
536 *Ficus benghalensis* (Linn.)
537 *Ficus benjamina* (Linn.)
538 *Ficus benjamina* (Linn.) var. *nuda* (Miq.)
539 **Ficus geniculata* (Kurz.)
540 *Ficus hispida* (Linn.f.)
541 *Ficus microcarpa* (Linn.f.)
542 *Ficus religiosa* (Linn.)
543 *Ficus rumphii* (Bl.)
544 **Ficus tinctoria* (Forst.f.) spp. *parasitica* (Willd.)
545 **Ficus virens* (Ait.)
546 *Plecospermum spinosum* (Trecul.)
547 *Streblus asper* (Lour.)

Casuarinaceae

548 *Casuarina equisetifolia* (Linn.)

Monocotyledons

Ceratophyllaceae

549 *Ceratophyllum demersum* (Linn.)

Hydrocharitaceae

550 *Halophila beccarii* (Asch.)
551 *Halophila ovalis* (R.Br.)
552 *Halophila ovate* (Gaud.)
553 *Hydrilla verticillata* (Linn.f.)
554 *Nechamandra alternifolia* (Roxb.)
555 *Ottelia alismoides* (Linn.)
556 *Vallisneria natans* (Lour.)

Orchidaceae

557 *Acampe praemorsa* (Roxb.)
558 *Cymbidium aloifolium* (Linn.)
559 *Vanda tessellata* (Roxb.)

Zingiberaceae

560 *Globba racemosa* (Sm.)

Costaceae

561 *Costos speciosus* (Koenig.)

Amaryllidaceae

562 *Crinum defixum* (Ker.-Gawler.)

Agavaceae

563 *Agave sisalana* (Perrine.)
564 *Sansevieria roxburghiana* (Schult. & Schult.f.)

Hypoxidaceae

565 *Curculigo orchioides* (Gaertn.)

Dioscoreaceae

566 *Dioscorea bulbifera* (Linn.)
567 *Dioscorea hamiltonii* (Hook.f.)
568 *Dioscorea oppositifolia* (Linn.)
569 *Dioscorea pentaphylla* (Linn.)
570 *Dioscorea wallichii* (Hook.f.)

Liliaceae

571 *Asparagus racemosus* (Willd.)
572 *Gloriosa superba* (Linn.)

Smilacaceae

573 *Smilax zeylanica* (Linn.)

Pontederiaceae

574 *Eichhornia crassipes* (Mart.)
575 *Monochoria hastata* (Linn.)

Commelinaceae

576 *Commelina benghalensis* (Linn.)
577 *Commelina diffusa* (Burm. f.)
578 *Commelina erecta* (Linn.)
579 *Commelina longifolia* (Lamk.)
580 *Commelina paludosa* (Blume.)
581 *Cyanotis cristata* (Linn.)
582 *Murdannia nudiflora* (Linn.)
583 *Murdannia spirata* (Linn.)
584 *Tonningia axillaris* (Linn.)
585 *Amiscophacellus axillaris* (Linn.)

Arecaceae

586 *Borassus flabellifer* (Linn.)
587 *Calamus viminalis* (Willd.)
588 *Cocos nucifera* (Linn.)
589 *Phoenix sylvestris* (Linn.)

Pandanaceae

590 *Pandanus odoratissimus* (Linn.f.)

Typhaceae

591 *Typha angustata* (Bory. & Chaub.)

Araceae

592 *Pistia stratiotes* (Linn.)
593 *Scindapsus officinalis* (Roxb.)
594 *Typhonium trilobatum* (Linn.)

Lemnaceae

595 *Lemna perpusilla* (Torrey.)
596 *Spirodela polyrhiza* (Linn.)

Alismataceae

597 *Limnophytum obtusifolium* (Linn.)
598 *Sagittaria trifolia* (Linn.)
599 *Sagittaria guayanensis* (H.B.K.) ssp. *lappula* (D.Don)

Potamogetonaceae

600 *Halodule pinifilia* (Miki.)
601 *Halodule uninervis* (Forssk.)
602 *Potamogeton crispus* (Linn.)
603 *Potamogeton nodosus* (Poir.)
604 *Potamogeton octandrus* (Poir.)
605 *Potamogeton pectinatus* (Linn.)

Aponogetonaceae

606 *Aponogeton natans* (Linn.)

Ruppiceae

607 *Ruppia maritima* (Linn.)

Najadaceae

608 *Najas indica* (Willd.)
609 *Najas graminea* (Del.)
610 *Najas minor* (All.)

Eriocaulaceae

611 *Eriocaulon quinquangulare* (Linn.)

Cyperaceae

612 *Bulbostylis barbata* (Rottb.)
613 *Bulbostylis subspinescens* (Clarke.)
614 *Cyperus arenarius* (Retz.)
615 *Cyperus bifax* (Clarke.)
616 *Cyperus castaneus* (Willd.)
617 *Cyperus compressus* (Linn.)
618 *Cyperus cuspidatus* (Kunth.)
619 *Cyperus diffusus* (Vahl.)
620 *Cyperus distans* (Linn.f.)
621 *Cyperus iria* (Linn.)
622 *Cyperus malaccensis* (Lam.)
623 *Cyperus platystylis* (R.Br.)
624 *Cyperus rotundus* (Linn.)
625 *Eleocharis atropurpurea* (Retz.)
626 *Eleocharis dulcis* (Burm.f.)
627 *Eleocharis geniculata* (Linn.)
628 *Fimbristylis acuminata* (Vahl.)
629 *Fimbristylis aestivalis* (Retz.)
630 *Fimbristylis bisumbellata* (Forssk.)
631 *Fimbristylis cymosa* R.Br. ssp. *spathacea* (Roth.)
632 *Fimbristylis dichotoma* (Linn.)
633 *Fimbristylis dipsacea* (Rottlb.)
634 *Fimbristylis ferruginea* (Linn.)
635 *Fimbristylis miliacea* (Linn.)
636 *Fimbristylis ovata* (Burm.f.)
637 *Fimbristylis schoenoides* (Retz.)
638 *Fimbristylis umbellaris* (Lam.)
639 *Fuirena ciliaris* (Linn.)
640 *Fuirena umbellata* (Rottlb.)
641 *Kyllinga tenuifolia* (Steud.)
642 *Kyllinga triceps* (Rottb.)
643 **Lipocarpha chinensis* (Osbeck.)
644 *Mariscus dubius* (Rottlb.)
645 *Mariscus javanicus* (Houtt.)
646 *Pycreus flavidus* (Retz.)
647 *Pycreus polystachyos* (Rottb.)
648 *Pycreus pumilus* (Linn.)
649 *Rikliella squarrosa* (Linn.)
650 *Schoenoplectus articulates* (Linn.)
651 *Schoenoplectus littoralis* (Schard.)
652 *Schoenoplectus supinus* (Linn.)

Poaceae

653 *Alloteropsis cimicina* (Linn.)
654 *Aristida setacea* (Retz.)
655 *Bambusa vulgaris* (Schrad.)
656 *Bambusa arundinacea* (Retz.)
657 *Brachiaria distachya* (Linn.)
658 *Brachiaria ramosa* (Linn.)
659 *Brachiaria remota* (Retz.)
660 *Chloris barbata* (Sw.)
661 *Chloris dolichostachya* (Lagasca.)

662 *Chrysopogon articulatus* (Retz.)
663 *Cynodon barberi* (Rang. & Tad.)
664 *Cynodon dactylon* (Linn.)
665 *Cyrtococcum trigonum* (Retz.)
666 *Dactyloctenium aegyptium* (Linn.)
667 *Dichanthium bladhii* (Retz.)
668 *Dichanthium pertusum* (Linn.)
669 *Digitaria ciliaris* (Retz.)
670 *Digitaria longiflora* (Retz.)
671 *Dimeria ornithopoda* (Trin.)
672 *Dinebra retroflexa* (Vahl.)
673 *Diplachne fusca* (Linn.)
674 *Echinochloa cololna* (Linn.)
675 *Echinochloa stagnina* (Retz.)
676 *Eleusine coracana* (Linn.)
677 *Eleusine indica* (Linn.)
678 *Eragrostis ciliaris* (Linn.)
679 *Eragrostis coarctata* (Stapf.)
680 *Eragrostis japonica* (Thunb.)
681 *Eragrostis gangetica* (Roxb.)
682 *Eragrostis pilosa* (Linn.)
683 **Eragrostis tenella* (Linn.)
684 *Eragrostis tremula* (Lamk.)
685 *Eragrostis unioloides* (Retz.)
686 *Eriochloa procera* (Retz.)
687 *Hackelochloa granularis* (Linn.)
688 *Hemarthria compressa* (Linn.)
689 *Heteropogon contortus* (Linn.f.)
690 *Hygrorhyza aristata* (Retz.)
691 *Hymenachne acutigluma* (Steud.)
692 *Imperata cylindrical* (Linn.)
693 *Ischemum indicum* (Houtt.)
694 *Iseilema laxum* (Hack.)
695 *Iseilema prostratum* (Linn.)
696 *Leersia hexandra* (Sw.)
697 *Myriostachya wightiana* (Nees.)
698 *Oplismenus burmanii* (Retz.)
699 *Oplismenus compositus* (Linn.)
700 *Oryza rufipogon* (Griff.)
701 *Oryza sativa* (Linn.)
702 *Panicum brevifolium* (Linn.)
703 *Panicum notatum* (Retz.)
704 *Panicum paludosum* (Roxb.)
705 *Panicum psilopodium* (Trin.)
706 *Panicum repens* (Linn.)
707 *Panicum walense* (Mez.)
708 *Paspalidium flavidum* (Retz.)
709 *Paspalidium geminatum* (Forssk.)
710 *Paspalum distichum* (Linn.)
711 *Paspalum scrobiculatum* (Linn.)
712 *Paspalum vaginatum* (Sw.)
713 *Pennisetum pedicellatum* (Trin.)
714 *Perotis indica* (Linn.)
715 *Phragmites karka* (Retz.)
716 *Porteresia coarctata* (Roxb.)
717 *Pseudoraphis spinescens* (R.Br.)
718 *Rottboellia cochinchinensis* (Lour.)
719 *Saccharum spontaneum* (Linn.)
720 *Sacciolepis indica* (Linn.)
721 *Spinifex littoreus* (Burm.f.)
722 *Sporobolus coromandelianus* (Retz.)
723 *Sporobolus indicus* (Linn.) var. *diander* (Retz.)
724 *Setaria verticillata* (Linn.)
725 *Setaria pumila* (Poir.)
726 *Trachys muricata* (Linn.)
727 *Urochloa panicoides* (Beauva.)
728 *Vetiveria zizanioides* (Linn.)
729 *Zoysia matrella* (Linn.)

* Cultivated plants

Fisheries monitoring framework

(Source: CDA, 2004)

Sampling Sites

The total fish catch and composition is estimated by undertaking sampling at 18 fish landing stations, two daily fish markets of island villages of Maluda and Jadupur and 14 prawn collection centres/godowns. Kalupadaghat, Balugaon, Palur and Satpada are the survey headquarters for the respective sectors. Survey calendars are adopted which provided details of sampling schedule i.e. 6 days per month for each sampling site.

Formats

A total of eight formats capture the landing information for the different sampling sites. The formats capture data in relation to species composition of fish, prawn and crab in the sampling boats; estimated total landing at landing stations during sampling days; category wise total number of boats arriving at landing centre during forenoon and afternoon; total number of fishing days available at the centre during the month; percentage composition of catch; base price of each species of fish, prawn and crab, volume and species of juvenile catch; length-weight data for fish, prawn and mud crab and source of catch/ fishing area to estimate sectoral yield.

Sampling Method

All the identified landing centres, daily village fish markets and shrimp godowns are covered every month for collection and estimation of fish landing data. Each month is divided into three blocks of 10 days. Two consecutive days are selected for every 10 days for each centre i.e. 6 days of sampling per centre per month. Similar schedule is followed for fish markets and shrimp collection centres.

A sample size of 1/3rd population of the total boats arriving at the landing centre is taken into account. The first boat is randomly selected at the beginning of the boats arrival at landing centre and then the 4th boat is selected for observation (likewise the next boat is selected by adding 3 to the number i.e. 4+3=7th boat). Total numbers of boats under different categories are also recorded in forenoon and afternoon.

For individual fisher boats and small refugee boats the catch volume is assessed by eye estimation but for the commission boats, the actual weight of catch is recorded. Total quantity of shrimp is recorded in all the 14 shrimp collection centres. For daily island fish markets at Maluda and Jadupur the entire quantity along with species composition are recorded.

Landing Estimation

The fish landing for each sampling day is estimated in tonnes at each landing centre

E=(Total catch for all observed boats in kg/Total number of observed boats) × Total boats in the landing centre on the sampling day

Mean landing for each sampling day at the landing centre

Y= (E1 + E2+..........+E6)/6 Where, E1 to E6 are the estimated landing for 1st to 6th sampling day during the month.

Y= Mean landing for each sampling day in tonnes Total landing for each landing centre for each month is estimated in tonnes (MI)

MI=Y × Total number of fishing days availed at the landing centre

Total monthly landing is estimated in tonnes by adding the landings in all the 18 centres (TLC). Similarly the total monthly landings of the daily fish markets and prawn collection centres are estimated and all the three values are added up to get the total monthly landings of fish and prawn for the lake.

Species or group-wise estimation is done by multiplying the average catch composition with the total estimated landing for the sampling day at the landing centres and daily fish markets. Estimation of mud crabs is done by total enumeration of packed bamboo baskets containing 10 kg mud crab in each basket.

Productivity

The productivity of the lake is determined by dividing the total annual catch with the mean water spread area of the lagoon (923 km^2).

Catch Per-Unit Effort (CPUE)

Catch of Chilika fishery represents a multi-species and multi-gear fishing with different fishing methods and seasonal variation in fisheries. This makes the estimation of CPUE difficult for a specific net unit or a specific species. Hence, the CPUE is estimated by considering the number of boats actually engaged in fishing, average number of fishing days availed and total annual catch in MT.

CPUE=Total annual landing (MT)/(No. of fishing boats × No. of fishing days)

Biodiversity Assessment

Inventorisation of fin fish and shell fish diversity are done at the landing centres and the fishing grounds. Specimens are identified upto species level by taking digital images and preserved in 5% formalin for further studies.

Migration Studies

The migratory pattern of species was studied by conducting tagging experiments. Celluloid tags of 2mm x 6mm were inserted into fish body in between the dorsal fins in case of fish with two dorsal fins or in front of the dorsal fin for others. The tagged specimens are released into open lake. Prior to that the Fishermen Cooperative Societies are informed to get back the tagged specimen if found in their catch.

Finfish and Shellfish in lake Chilika
(Source: CDA)

Hemiscylliidae
1 **Chiloscyllium indicum* (Gmelin, 1789)

Carcharhininidae (Requiem sharks)
2 **Carcharhinus leucas* (Müller & Henle, 1839)
3 *Carcharhinus limbatus* (Müller & Henle, 1839)
4 *Carcharhinus melanopterus* (Quoy & Gaimard, 1824)
5 *Glyphis gangeticus* (Müller & Henle, 1839)
6 **Scoliodon laticaudus* (Müler & Henle, 1838)

Sphyrnidae
7 ***Eusphyra blochii* (Cuvier, 1816)
Previously recorded as Sphyrna blochii (Cuvier, 1817)
8 ***Sphyrna lewini* (Griffith & Smith, 1834)

Pristidae
9 *Pristis pectinata* (Latham, 1794)

Rhinobatidae (Guitar fishes)
10 ***Rhynchobatus djeddensis* (Forsskål, 1776)

Dasyatidae (Stingrays)
11 *Himantura imbricata* (Bloch & Schneider, 1801)
12 ***Himantura marginata* (Blyth, 1860)
Previously recorded as Dasyatis marginatus (Blyth, 1860)
13 **Himantura uarnak* (Forsskål, 1775)
14 **Himantura walga* (Müller & Henle, 1841)
15 **Pastinachus sephen* (Forsskål, 1775)
Previously recorded as Hypolophus sephen (Forsskål, 1775)

Myliobatidae (Eaglerays)
16 **Aetobatus flagellum* (Bloch & Schneider, 1801)
17 **Aetobatus narinari* (Euphrasen, 1790)
18 **Aetomylaeus nichofii* (Bloch & Schneider, 1801)

Notopteridae (Featherbacks)
19 **Notopterus chitala* (Hamilton & Buchanan, 1822)
Currently, Chitala chitala (Hamilton, 1822)
20 **Notopterus notopterus* (Pallas, 1769)

Elopidae
21 **Elops machnata* (Forsskål, 1775)

Megalopidae
22 **Megalops cyprinoides* (Broussonet, 1782)

Anguillidae (Freshwater eels)
23 **Anguilla bengalensis bengalensis* (Gray, 1831)
24 **Anguilla bicolor bicolor* (McClelland, 1844)

Muraenidae (Moray eels)
25 **Strophidon sathete* (Hamilton, 1822)
Previously recorded as Thyrosoidea macrura (Blecker, 1854)

Ophichthidae (Snake eels)
26 *Lamnostoma orientalis* (Mc Clelland, 1844)
27 **Pisodonophis boro* (Hamilton, 1822)
28 *Pisodonophis Cancrivorus* (Richardson, 1848)

Muraenesocidae (Pike congers)
29 **Congresox talabonoides* (Bleeker, 1853)
30 ***Muraenesox bagio* (Hamilton, 1822)
31 **Muraenesox cinereus* (Forsskål, 1775)

Clupeidae
32 ***Amblygaster leiogaster* (Valenciennes, 1847)
33 *Amblygaster sirm* (Walbaum, 1792)
Previously recorded as Sardinella sirm (Walbaum, 1792)
34 **Anodontostoma chacunda* (Hamilton, 1822)
35 **Corica soborna* (Hamilton, 1822)
36 *Dussumieria acuta* (Valenciennes, 1847)
37 ***Dussumieria elopsoides* (Bleeker, 1849)
38 ***Ehirava fluviatilis* (Deraniyagala, 1929)
39 **Escualosa thoracata* (Valenciennes, 1847)
40 **Gonialosa manmina* (Hamilton, 1822)
41 **Gudusia chapra* (Hamilton, 1822)
42 **Hilsa kelee* (Cuvier, 1829)
43 **Nematalosa nasus* (Bloch, 1795)
44 ***Sardinella fimbriata* (Valenciennes, 1847)
45 ***Sardinella longiceps* (Valenciennes, 1847)
46 *Sardinella melanura* (Cuvier, 1829)
47 **Tenualosa ilisha* (Hamilton, 1822)
Previously recorded as Hilsa ilisha (Ham, 1822)
48 ***Tenualosa toli* (Valenciennes, 1847)

Engraulidae (Anchovies)
49 *Setipinna phasa* (Hamilton, 1822)
50 **Stolephorus baganensis* (Hardenberg, 1933)
51 **Stolephorus commersonnii* (Lacepède, 1803)
52 **Stolephorus dubiosus* (Wongratana, 1883)
53 **Stolephorus indicus* (Van Hasselt, 1823)
54 ***Thryssa gautamiensis* (Babu Rao, 1971)
55 **Thryssa hamiltonii* (Gray, 1835)

56 *Thryssa kammalensoides* (Wongratana, 1883)
Previously recorded as Thryssa kammaleneis (Bleeker, 1849)
57 **Thryssa malabarica* (Bloch, 1795)
58 **Thryssa mystax* (Bloch & Schneider, 1801)
59 **Thryssa polybranchialis* (Wongratana, 1983)
60 **Thryssa purava* (Hamilton, 1822)
61 ***Thryssa setirostris* (Broussonet, 1782)
62 ***Thryssa vitrirostris* (Gilchrist & Thompson, 1908)

Chirocentridae (Wolf herrings)
63 *Chirocentrus dorab* (Forsskål, 1775)

Pristigasteridae (Pellonas)
64 ***Ilisha elongata* (Bennett, 1830)
65 **Ilisha megaloptera* (Swainson, 1839)
66 *Ilisha melastoma* (Bloch & Schneider, 1801)
67 ***Opisthopterus tardoore* (Cuvier, 1829)

Chanidae
68 **Chanos chanos* (Forsskål, 1775)

Cyprinidae (Carps & minnows)
69 **Amblypharyngodon mola* (Hamilton, 1822)
70 **Chela cachius* (Hamilton, 1822)
71 **Laubuca laubuca* (Hamilton, 1822)
Previous recorded as Chela laubuca (Hamilton, 1822)
72 **Cirrhinus mrigala* (Hamilton, 1822)
73 **Cirrhinus reba* (Hamilton, 1822)
74 *Crossocheilus latius* (Hamilton, 1822)
75 *Danio rerio* (Hamilton, 1822)
Previously recorded as Brachydanio rerio (Hamilton, 1822)
76 **Esomus danricus* (Hamilton, 1822)
77 **Catla catla* (Hamiltton, 1822)
78 ***Labeo boga* (Hamilton, 1822)
79 **Labeo calbasu* (Hamilton, 1822)
80 ***Labeo gonius* (Hamilton, 1822)
81 **Labeo rohita* (Hamilton, 1822)
82 ***Osteobrama cotio peninsularis* (Silas, 1952)
83 *Osteobrama vigorsii* (Sykes, 1839)
84 **Puntius chola* (Hamilton, 1822)
85 **Puntius sarana* (Hamilton, 1822)
86 **Puntius sophore* (Hamilton, 1822)
87 **Puntius ticto* (Hamilton, 1822)
88 *Puntius vittatus* (Day, 1865)
89 **Rasbora daniconius* (Hamilton, 1822)
Previously recorded as Parluciosoma daniconius (Hamilton, 1822)
90 **Rasbora rasbora* (Hamilton, 1822)
91 **Salmophasia bacaila* (Hamilton, 1822)

Cobitidae (Loaches)
92 *Lepidocephalichthys guntea* (Hamilton, 1822)
Previously recorded as Lepidocephalus guntea (Hamilton, 1822)

Bagridae (Bagrid catfishes)
93 **Mystus cavasius* (Hamilton, 1822)
94 **Mystus gulio* (Hamilton, 1822)
95 **Mystus vittatus* (Bloch, 1794)
96 **Sperata seenghala* (Sykes, 1839)
Previously recorded as Aorichthys seenghala (Sykes, 1839)

Siluridae (Eurasian catfishes)
97 **Ompok bimaculatus* (Bloch, 1794)
98 **Ompok pabda* (Hamilton, 1822)
99 **Wallago attu* (Bloch & Schneider, 1801)

Schilbeidae (Schilbid catfishes)
100 **Ailia coila* (Hamilton, 1822)
101 *Eutropiichthys vacha* (Hamilton, 1822)
102 *Silonia silondia* (Hamilton, 1822)

Pangasiida
103 **Pangasius pangasius* (Hamilton, 1822)

Sisoridae
104 **Bagarius bagarius* (Hamilton, 1822)
105 ***Bagarius yarrelli* (Sykes, 1839)

Clariidae
106 **Clarias magur* (Hamilton, 1822)
Previously recorded as Clarias batracacus (Linnaeus, 1758)

Heteropneustidae
107 **Heteropneustes fossilis* (Bloch, 1794)

Ariidae
108 **Arius arius* (Hamilton, 1822)
109 *Arius maculatus* (Thunberg, 1792)
110 **Nemapteryx caelata* (Valenciennes, 1840)
Previously recorded as Arius caelatus (Valenciennes, 1840)
111 **Osteogeneiosus militaris* (Linnaeus, 1758)
112 *Plicofollis argyropleuron* (Valenciennes, 1840)
Previously recorded as Arius satparanus (Chaudhuri, 1916)
113 *Plicofollis tenuispinis* (Day, 1877)

Plotosidae (Stinging catfishes)
114 **Plotosus canius* (Hamilton, 1822)
115 **Plotosus lineatus* (Thunberg, 1787)

Synodontidae
116 **Saurida tumbil* (Bloch, 1795)
117 **Trachinocephalus myops* (Forster, 1801)

Mugilidae (Mullets)
118 *Liza macrolepis* (Smith, 1846)
119 *Liza melinoptera* (Valenciennes, 1836)
120 *Liza parsia* (Hamilton, 1822)
121 *Liza subviridis* (Valenciennes, 1836)
122 *Liza tade* (Forsskål, 1775)
123 *Liza vaigiensis* (Quoy & Gaimard, 1825)
124 *Mugil cephalus* (Linnaeus, 1758)
125 *Rhinomugil corsula* (Hamilton, 1822)
126 *Valamugil cunnesius* (Valenciennes, 1836)
127 *Valamugil seheli* (Forsskål, 1775)
128 *Valamugil speigleri* (Bleeker, 1858-59)

Atherinidae
129 **Atherinomorus duodecimalis* (Valenciennes, 1835)
130 **Atherinomorus lacunosus* (Forster, 1801)

Belonidae
131 *Strongylura leiura* (Bleeker, 1850)
132 *Strongylura strongylura* (Van Hasselt, 1823)
133 *Xenentodon cancila* (Hamilton, 1822)

Hemiramphidae
134 **Hemiramphus far* (Forsskål, 1775)
135 *Hyporhamphus limbatus* (Valenciennes, 1847)

Adrianichthyidae
136 *Oryzias dancena* (Hamilon, 1822)

Aplocheilidae
137 *Aplocheilus panchax* (Hamilton, 1822)

Syngnathidae
138 *Hippocampus fuscus* (Rüppell, 1838)
Previously recorded as Hippocampas brachyrhynchus (Duncker, 1940)
139 *Ichthyocampus carce* (Hamilton, 1822)
140 **Hippichthys cyanospilos* (Bleeker, 1854)
Previously recorded as Syngnathus cyanospilos (Bleeker, 1854)

Synbranchidae
141 **Ophisternon bengalense* (Mc Clelland, 1844)

Mastacembelidae (Spiny eels)
142 *Macrognathus aral* (Bloch & Schneider, 1801)
143 *Macrognathus pancalus* (Hamilton, 1822)
144 *Mastacembelus armatus* (Lacepède, 1800)

Scorpaenidae
145 *Pterois radiata* (Cuvier, 1829)
Previously recorded as Pteropterus radiata (Cuvier, 1829)

Tetrarogidae
146 **Tetraroge niger* (Cuvier, 1829)

Platycephalidae
147 **Cociella crocodilus* (Cuvier, 1829)
148 **Kumococius rodericensis* (Cuvier, 1829)
Previously recorded as Suggrundus rodericensis (Cuvier, 1829)
149 *Platycephalus indicus* (Linnaeus, 1758)

Ambassidae (Perchlets, glass fishes)
150 *Ambassis ambassis* (Lacepede, 1802)
Previously recorded as Ambassis commersoni (Cuvier, 1828)
151 *Ambassis gymnocephalus* (Lacepède, 1802)
152 *Chanda nama* (Hamilton, 1822)
153 *Parambassis ranga* (Hamilton, 1822)
Previously recorded as Pseudoambassis ranga (Hamilton, 1822)

Latidae
154 *Lates calcarifer* (Bloch, 1790)

Serranidae (Groupers, Rock-cods)
155 **Epinephelus coioides* (Hamilton, 1822)
156 *Epinephelus lanceolatus* (Bloch, 1790)
Previously recorded as Promicrops lanceolatus (Bloch, 1790)
157 **Epinephelus malabaricus* (Bloch & Schneider, 1801)
158 *Epinephelus tauvina* (Forsskål, 1775)

Sillaginidae
159 *Sillaginopsis panijus* (Hamilton, 1822)
160 *Sillago sihama* (Forsskål, 1775)
161 **Sillago vincenti* (Mc Kay, 1880)

Lactariidae
162 **Lactarius lactarius* (Bloch & Schneider, 1801)

Rachycentridae
163 *Rachycentron canadum* (Linnaeus, 1766)

Echeneidae (Sharksuckers, Discfishes)
164 *Echeneis naucrates* (Linnaeus, 1758)

Carangidae (Jacks, Trevallies, Pompanos & Scads)
165 *Alectis indicus* (Rüppell, 1830)
166 *Alepes djedaba* (Forsskål, 1775)
167 *Atule mate* (Cuvier, 1833)
168 *Carangoides gymnostethus* (Cuvier, 1833)
169 *Carangoides praeustus* (Bennett, 1830)
170 *Caranx ignobilis* (Forsskål, 1775)
171 *Caranx melampygus* (Cuvier, 1833)
172 *Caranx sexfasciatus* (Quoy & Gaimard, 1825)
173 *Megalaspis cordyla* (Linnaeus, 1758)

174 *Parastromateus niger* (Bloch, 1795)
Previously recorded as Apolectus niger (Bloch, 1795)
175 ***Scomberoides commersonnianus* (Lacepède, 1801)
176 *Scomberoides lysan* (Forsskål, 1775)
177 **Scomberoides tala* (Cuvier, 1832)
178 ***Scomberoides tol* (Cuvier, 1832)
179 ***Selar boops* (Cuvier, 1833)
180 ***Selar crumenophthalmus* (Bloch, 1793)
181 **Selaroides leptolepis* (Cuvier, 1833)
182 *Trachinotus blochii* (Lacepède, 1801)
183 ***Trachinotus mookalee* (Cuvier, 1832)

Leiognathidae (Pony fishes)
184 *Eubleekeria splendens* (Cuvier, 1829)
Previously recorded as Leiognathus splendens (Cuvier, 1829)
185 **Gazza minuta* (Bloch, 1795)
186 *Leiognathus daura* (Cuvier, 1829)
187 **Leiognathus dussumieri* (Valenciennes, 1835)
188 **Leiognathus equulus* (Forsskål, 1775)
189 ***Leiognathus fasciatus* (Lacepède, 1803)
190 **Nuchequula blochii* (Valenciennes, 1835)
Previously recorded as Leiognathus blochii (Valenciennes, 1835)
191 ***Nuchequula gerreoides* (Bleeker, 1851)
192 ***Photopectoralis bindus* (Valenciennes, 1835)
Previously recorded as Leiognathus bindus (Valenciennes, 1835)
193 **Secutor insidiator* (Bloch, 1787)
194 ***Secutor ruconius* (Hamilton, 1822)

Lutjanidae (Snappers)
195 **Lutjanus argentimaculatus* (Forsskål, 1775)
196 **Lutjanus johnii* (Bloch, 1792)
197 **Lutjanus kasmira* (Forsskål, 1775)
198 **Lutjanus russellii* (Bleeker, 1849)

Datnioididae
199 **Datnioides polota* (Hamilton, 1822)
Previously recorded as Datnioides quadrifasciatus (Sevastianov, 1809)

Gerreidae (Silver biddies)
200 ***Gerres erythrourus* (Bloch, 1791)
Previously recorded as Gerres abbreviatus (Bleeker, 1850)
201 **Gerres filamentosus* (Cuvier, 1829)
202 **Gerres limbatus* (Cuvier, 1830)
203 *Gerres macracanthus* (Bleeker, 1854)
204 **Gerres oyena* (Forsskål, 1775)
205 *Gerres phaiya* (Iwatsuki & Hampstra, 2001)
Previously recorded as Gerres poieti (Cuvier, 1830)
206 **Gerres setifer* (Hamilton, 1822)
Previously recorded as Gerreomorpha setifer (Hamilton, 1822)

Haemulidae (Grunts & Rubberlips)
207 *Plectorhinchus nigrus* (Cuvier, 1830)
Previously recorded as Plectorhinchus nigers (Cuvier, 1830)
208 **Pomadasys argenteus* (Forsskål, 1775)
209 ***Pomadasys kaakan* (Cuvier, 1830)
210 ***Pomadasys multimaculatus* (Playfair, 1867)

Sparidae (Seabreams)
211 **Acanthopagrus berda* (Forsskål, 1775)
212 *Acanthopagrus latus* (Houttuyn, 1782)
213 *Argyrops spinifer* (Forsskål, 1775)
214 **Crenidens crenidens* (Forsskål, 1775)
215 **Rhabdosargus sarba* (Forsskål, 1775)

Nemipteridae
216 ***Nemipterus japonicus* (Bloch, 1791)

Sciaenidae (Croakers)
217 **Daysciaena albida* (Cuvier, 1830)
218 **Dendrophysa russelii* (Cuvier, 1829)
219 ***Johnius carruta* (Bloch, 1793)
220 *Johnius dussumieri* (Valenciennes, 1837)
221 **Johnius belangerii* (Cuvier, 1830)
222 *Johnius coitor* (Hamilton, 1822)
223 *Johnius macropterus* (Bleeker, 1853)
224 ***Nibea maculata* (Bloch & Schneider, 1801)
225 ***Otolithes ruber* (Bloch & Schneider, 1801)
226 *Otolithoides biauritus* (Cantor, 1849)
227 **Otolithoides pama* (Hamilton, 1822)
Previously recorded as Pama pama (Hamilton, 1822)
228 **Paranibea semiluctuosa* (Cuvier, 1830)
229 **Protonibea diacanthus* (Lacepède, 1802)

Polynemidae
230 **Eleutheronema tetradactylum* (Shaw, 1804)
231 **Leptomelanosoma indicum* (Shaw, 1804)
Previously recorded as Polydactylus indicus (Shaw, 1804)
& Polynemus indicus (Shaw, 1804)
232 ***Polydactylus plebeius* (Broussonet, 1782)
233 **Polydactylus sextarius* (Bloch & Schneider, 1801)

Mullidae
234 ***Upeneus sulphureus* (Cuvier, 1829)

Drepaneidae
235 **Drepane punctata* (Linnaeus, 1758)

Monodactylidae (Moonies)
236 **Monodactylus argenteus* (Linnaeus, 1758)

Nandidae (Leaf fishes)

237 **Nandus nandus* (Hamilton, 1822)

Terapontidae (Terapon perches)

238 *Pelates quadrilineatus* (Bloch, 1790)
239 **Terapon jarbua* (Forsskål, 1775)
240 **Terapon puta* (Cuvier, 1829)
241 **Terapon theraps* (Cuvier, 1829)

Cichlidae

242 **Etroplus suratensis* (Bloch, 1790)
243 ***Oreochromis mossambicus* (Peters, 1852)

Uranoscopidae (Stargazers)

244 **Ichthyoscopus lebeck* (Bloch & Schneider, 1801) *Previously recorded as Ichthyoscopus inermis* (Cuvier, 1829)

Blenniidae (Blennies & allies)

245 *Omobranchus zebra* (Bleeker, 1868)

Eleotridae (Gudgeons)

246 *Butis butis* (Hamilton, 1822)
247 *Eleotris fusca* (Forster, 1801)
248 ***Eleotris melanosoma* (Bleeker, 1852)

Gobiidae

249 **Acentrogobius cyanomos* (Bleeker, 1849)
250 *Acentrogobius griseus* (Day, 1876)
251 *Acentrogobius masoni* (Day, 1873)
252 *Acentrogobius viridipunctatus* (Valenciennes, 1837)
253 *Amoya madraspatensis* (Day, 1868) *Previously recorded as Acentrogobius madraspatensis* (Day, 1868)
254 *Bathygobius fuscus* (Ruppell, 1830)
255 *Bathygobius ostreicola* (Chaudhuri, 1916)
256 *Brachygobius nunus* (Hamilton, 1822)
257 **Drombus globiceps* (Hora, 1923)
258 **Glossogobius giuris* (Hamilton, 1822)
259 *Glossogobius mas* (Hora, 1923)
260 *Gobiopterus chuno* (Hamilton, 1822)
261 *Oligolepis acutipennis* (Valenciennes, 1837)
262 **Oligolepis cylindriceps* (Hora, 1923)
263 **Oxyurichthys microlepis* (Bleeker, 1849)
264 *Oxyurichthys tentacularis* (Vallenciennes, 1837)
265 *Parapocryptes rictuosus* (Valenciennes, 1837)
266 **Periophthalmus kalolo* Lesson, 1831 *Previously recorded as Periophthalmus koelreuteri* (Pallas, 1770)
267 **Psammogobius biocellatus* (Valenciennes, 1837) *Previously recorded as Glossogobius biocellatus* (Vallenciennes, 1837)
268 *Pseudapocryptes elongatus* (Cuvier,1816) *Previously recorded as Pseudapocryptes lanceolatus* (Bloch & Schneider, 1801)
269 *Pseudogobius javanicus* (Bleeker, 1856) *Previously recorded as Stigmatgobius javanicus* (Bleeker, 1856)
270 *Stigmatogobius minima* (Hora, 1923)
271 *Taenioides buchanani* (Day, 1873)
272 **Trypauchen vagina* (Bloch & Schneider, 1801)
273 ***Yongeichthys criniger* (Valenciennes, 1837)

Ephippidae

274 ***Ephippus orbis* (Bloch 1787)
275 ***Platax orbicularies* (Forsskål, 1775)

Scatophagidae (Scats)

276 **Scatophagus argus* (Linnaeus, 1766)

Siganidae (Spinsfoots, Rabbitfishes)

277 ***Siganus canaliculatus* (Park, 1797)
278 **Siganus javus* (Linnaeus, 1766)
279 **Siganus vermiculatus* (Valenciennes, 1835)

Acanthuridae (Surgeon fishes)

280 ***Acanthurus mata* (Cuvier, 1829)

Sphyraenidae (Barracudas)

281 ***Sphyraena jello* (Cuvier, 1829)
282 ***Sphyraena putnamae* (Jordan & Seale, 1905)

Trichiuridae (Hairtail fishes)

283 ***Eupleurogrammus glossodon* (Bleeker, 1860)
284 ***Trichiurus lepturus* (Linnaeus, 1758)
285 ***Lepturacanthus savala* (Cuvier, 1829)

Scombridae (Mackerels, Seerfishes, Tunas, Albacores)

286 ***Euthynnus affinis* (Cantor, 1849)
287 ***Rastrelliger kanagurta* (Cuvier, 1816)
288 **Scomberomorus lineolatus* (Cuvier, 1829)

Anabantidae (Climbing perches)

289 **Anabas cobojius* (Hamilton, 1822)
290 **Anabas testudineus* (Bloch, 1792)

Osphronemidae (Gouramies)

291 **Colisa fasciata* (Bloch & Schneider, 1801)
292 **Colisa lalia* (Hamilton, 1822)

Channidae (Snakeheads, Murrels)

293 ***Channa gachua* (Hamilton, 1822)
294 ***Channa marulia* (Hamilton, 1822)
295 **Channa punctata* (Bloch, 1793)
296 **Channa striata* (Bloch, 1793)

Paralichthyidae (Lefteye flounders)

297 **Pseudorhombus arsius* (Hamilton, 1822)
298 ***Pseudorhombus micrognathus* (Norman, 1927)
299 ***Pseudorhombus triocellatus* (Bloch & Schneider, 1801)

Soleidae (Soles)

300 **Brachirus orientalis* (Bloch & Schneider, 1801)
Previously recorded as Eyriglossa orientalis (Bloch & Schneider, 1801)

301 *Solea ovata* (Richardson, 1846)

Cynoglossidae (Tongue soles)

302 ***Cynoglossus lida* (Bleeker, 1851)

303 **Cynoglossus lingua* (Hamilton, 1822)

304 **Cynoglossus puncticeps* (Richardson, 1846)

Triacanthidae (Tripod fishes)

305 **Triacanthus biaculeatus* (Bloch, 1786)

Balistidae

306 ***Abalistes stellaris* (Bloch & Schneider, 1801)

Tetraodontidae (Puffers)

307 *Arothron reticularis* (Bloch & Schneider, 1801)

308 *Arothron stellatus* (Bloch & Schneider, 1801)

309 **Chelonodon patoca* (Hamilton, 1822)

310 *Lagocephalus lunaris* (Bloch & Schneider, 1801)

311 **Takifugu oblongus* (Bloch, 1786)

312 **Tetraodon cutcutia* (Hamilton, 1822)

313 **Tetraodon fluviatilis* (Hamilton, 1822)
Previously recorded as Chelonodon fluviailis (Hamilton, 1822)

Diodontidae

314 ***Diodon hystrix* (Linnaeus, 1758)

Shellfishes

Crab

Majidae

1 *Doclea hybrid* (H. Milne Edwards, 1834)

Calappidae

2 *Matuta planipes* (Fabricius, 1798)

3 *Matuta lunaris* (Forskal, 1775)

Leucosiidae

4 *Ebalia malefactrix* (Kemp, 1915)

5 *Philyra alcocki* (Kemp, 1915)

Hymenosomatidae

6 *Elamina* (Trigonoplax) cimex (Kemp, 1915)

Ocypodidae

7 *Ocypoda ceratophalma* (Pallas, 1772)

8 *Ocypoda macrocera* (H. Milne Edwards, 1852)

9 *Ocypoda platytarsis* (H. Milne Edwards, 1852)

10 *Uca annulipes* (H. Milne Edwards, 1837)

11 *Dotilla pertinax* (Kemp, 1915)

12 *Dotilla intermedia* (de man, 1888)

13 *Dotilla myctiroides* (H. Milnne Edwards, 1852)

14 *Macrophalmus gastrode* (Kemp, 1915)

15 *Camptandrium sexdentatum* (Stimpson, 1858)

16 *Leipocten sardidulum* (Kemp, 1915)

Grapsidae

17 *Pachygrapsus propinquus* (De Man, 1908)

18 *Varuna litterata* (Fabricius, 1798)

19 *Ptychognathus onyx* (Alock, 1900)

20 *Sesarma plicatum* (Latreille, 1806)

21 *Sesarma tetragonum* (Alcock, 1900)

22 *Sesarma batavicum* (Moreira, 1903)

23 *Sesarma quadrata* (De Haan, 1850)

24 *Plagusia depressa tuberculata* (Lamark, 1818)

25 *Metopograpsus messor* (Forskal, 1775)

Gecarcinidae

26 *Cardiosoma carnifex* (Herbst, 1796)

Xanthidae

27 *Heteropanope indica* (de Man, 1887)

Portunidae

28 *Portunus pelagicus* (Linnaeus, 1758)

29 *Scylla serrata* (Forskal, 1775)

30 *Thalamita crenata* (Ruppel, 1830)

31 *Charybdis cruciatai* (Herbst, 1794)

32 *Charybdis callianasa* (Herbst, 1801)

33 *Portunus sanguinolentus* (Herbst, 1783)

34 *Scylla tranquebarica* (Fabricius, 1798)

35 *Podophthalmus vigil* (Fabricius, 1798)

Shrimp and prawns

Penaeidae

1 *Penaeus monodon* (Fabricius, 1798)

2 *Penaeus indicus* (H. Milne Edwards, 1837)

3 *Penaeus canaliculatus* (Oliver, 1811)

4 *Penaeus semisulcatus* (De Haan, 1844)

5 *Metapenaeus monoceros* (Fabricius, 1798)

6 *Metapenaeus affinis* (H. Milne Edwards, 1837)

7 *Metapenaeus dobsoni* (Miers, 1878)

8 *Metapenaeus ensis* (De Haan, 1844)

Sergestidae

9 *Lucifer hanseni* (Nobili, 1905)

10 *Pontophilus hendersoni* (Kemp, 1915)

Palaemonidae

11 *Macrobrachium lamarrei lamarrei* (H. Milne Edwards, 1837)

12 *Macrobrachium malcolmsoni* (H. Milne Edwards, 1837)

13 *Macrobrachium rude* (Heller, 1862)

14 *Macrobrachium scabriculum* (Heller, 1862)
15 *Exopalaemon styliferus* (H. Milne Edwards, 1840)
16 *Periclimenes (Periclimenes) indicus* (Kemp, 1915)
17 *Periclimenes (Harpilius) demani* (Kemp, 1915)
18 *Macrobrachium rosenbergiii* (De Man, 1879)
19 *Macrobrachium equidens* (Dana, 1852)

Alpheidae

20 *Ogyrides striaticauda* (Kemp, 1915)
21 *Athanas polymorphus* (Kemp, 1915)
22 *Alpheus crassimanusi* (Heller, 1865)
23 *Alpheus malabaricusi* (Fabricius, 1775)
24 *Alpheus paludicola* (Kemp, 1915)

Atyidae

25 *Caridina nilotica* (P. Roux, 1833)
26 *Caridina propinqua* (De Man, 1908)

Pasiphaeidae

27 *Leptochela aculeocaudata* (Paulson, 1875)

Callianassidae

28 *Callianassa (Callichirus) maxima* (A. Milne Edwards, 1870)

Upogebidae

29 *Upogebia (Upogebia) heterocheir* (Kemp, 1915)

Lobsters

1 *Panulirus polyphagus* (Herbst, 1793)
2 *Panulirus ornatus* (Fabricius, 1798)

*Collection under Post-resetoration inventorial survey.
** New records during post-restoration period.

List of freshwater species in Lake Chilika

Sl No	Species	Common Name	Local Name
1	*Notopterus chitala* (Hamilton & Buchanan, 1822)	Humped featherback	Chithala
2	*Notopterus notopterus* (Pallas, 1769)	Bronze featherback	Fali
3	*Anguilla bengalensis bengalensis* (Gray, 1831)	Indian mottled eel	Bomi todi, Thumdi
4	*Anguilla bicolor bicolor* (McClelland, 1844)	Indonesian short fin eel	Bomi
5	*Gonialosa manmina* (Hamilton, 1822)	Ganges river, gizzard shad	Nadi makendi
6	*Gudusia chapra* (Hamilton, 1822)	Indian river shad	Mitha makundi
7	*Amblypharyngodon mola* (Hamilton, 1822)	Mola carplet	Mahurali
8	*Chela cachius* (Hamilton, 1822)	Silver hatchet chela	Bankuso
9	*Laubuca laubuca* (Hamilton, 1822)	Indian glass barb	Khakarkhai, Bankoe
10	*Cirrhinus mrigala* (Hamilton, 1822)	Mrigal	Mirikali, Midha
11	*Cirrhinus reba* (Hamilton, 1822)	Reba carp	Chhunchiapohada
12	*Crossocheilus latius* (Hamilton, 1822)	Gangetic Latia	Latia
13	*Danio rerio* (Hamilton, 1822)	Zebra danio	Dandakiri, Panch jeelardi
14	*Esomus danricus* (Hamilton, 1822)	Flying barb	Jhai, Dandikiri
15	*Catla catla* (Hamiltton, 1822)	Catla	Bhakura
16	*Labeo boga* (Hamilton, 1822)	Boga labeo	Chankora, Kalabattali
17	*Labeo calbasu* (Hamilton, 1822)	Orangefin labeo	Kalabainshi, Kalanchi
18	*Labeo gonius* (Hamilton, 1822)	Kuria labeo	Khursia
19	*Labeo rohita* (Hamilton, 1822)	Rohu	Rohi (Indian major carp)
20	*Osteobrama cotio peninsularis* (Silas, 1952)	Peninsular osteobrama	Nadi makerndi
21	*Osteobrama vigorsii* (Sykes, 1839)	Godavari osteobrama	Golund, Chalanta chilti
22	*Puntius chola* (Hamilton, 1822)	Swamp barb	Pitakerandi
23	*Puntius sarana* (Hamilton, 1822)	Olive barb	Serena, Chhena karandi
24	*Puntius sophore* (Hamilton, 1822)	Pool barb, swamp barb	Puntia kerandi
25	*Puntius ticto* (Hamilton, 1822)	Ticto barb, Firefin barb	Kuji kerandi
26	*Puntius vittatus* (Day, 1865)	Greenstripe barb	Chella karandi
27	*Rasbora daniconius* (Hamilton, 1822)	Slender rasbora	Jeello, Dandikari
28	*Rasbora rasbora* (Hamilton, 1822)	Gangetic scissortail	Jhimkadi, Dandikari
29	*Salmophasia bacaila* (Hamilton, 1822)	Large razorbelly minnow	Jallaha, Jillari, Jaradi
30	*Lepidocephalichthys guntea* (Hamilton, 1822)	Guntea loach	Kandatudi
31	*Sperata seenghala* (Sykes, 1839)	Giant river catfish	Addi kontia, Ali
32	*Ompok bimaculatus* (Bloch, 1794)	Butter catfish	Pabda
33	*Ompok pabda* (Hamilton, 1822)	Pabdah catfish	Pabda
34	*Wallago attu* (Bloch & Schneider, 1801)	Wallago	Balia
35	*Ailia coila* (Hamilton, 1822)	Gangetic ailia	Baunsapatri, Puttuli
36	*Eutropiichthys vacha* (Hamilton, 1822)	Batchwa vacha	Bachha, Nadi Batchua
37	*Silonia silondia* (Hamilton, 1822)	Silond catfish	Silond kantia, Adi

Sl No	Species	Common Name	Local Name
38	*Pangasius pangasius* (Hamilton, 1822)	Yellowtail catfish	Jalanga, Pangas, Jellum
39	*Bagarius bagarius* (Hamilton, 1822)	Dwarf goonch	Baghari, Salu
40	*Bagarius yarrelli* (Sykes, 1839)	Goonch	Baghari
41	*Clarias magur* (Hamilton, 1822)	Walking catfish, Magur	Magura
42	*Heteropneustes fossilis* (Bloch, 1794)	Stinging catfish	Singhee
43	*Rhinomugil corsula* (Hamilton, 1822)	Corsula mullet	Kekenda, Endula
44	*Xenentodon cancila* (Hamilton, 1822)	Freshwater garfish	Gangtudi
45	*Aplocheilus panchax* (Hamilton, 1822)	Blue panchax	Jhimkardi, Borgudi
46	*.Ichthyocampus carce* (Hamilton, 1822)	Freshwater pipefish	Balipoka
47	*Ophisternon bengalense* (Mc Clelland, 1844)	Bengal eel	Kuchia
48	*Macrognathus aral* (Bloch & Schneider, 1801)	One-stripe spiny eel	Todi
49	*Macrognathus pancalus* (Hamilton, 1822)	Barred spiny eel	Todi
50	*Mastacembelus armatus* (Lacepède, 1800)	Zig-zag eel	Bami todi
51	*Chanda nama* (Hamilton, 1822)	Elongate glass-perchlet	Guachopi
52	*Parambassis ranga* (Hamilton, 1822)	Indian glassy fish	Guachopi, Lal-Chandi
53	*Nandus nandus* (Hamilton, 1822)	Mottled nandus	Bodisee, Bhutsee
54	*Oreochromis mossambicus* (Peters, 1852)	Mozambique tilapia	Japani kou, Tilapia
55	*Glossogobius giuris* (Hamilton, 1822)	Tank goby	Balligirida
56	*Anabas cobojius* (Hamilton, 1822)	Gangetic koi	Kou
57	*Anabas testudineus* (Bloch, 1792)	Climbing perch	Kou
58	*Colisa fasciata* (Bloch & Schneider, 1801)	Banded gourami	Khasia
59	*Colisa lalia* (Hamilton, 1822)	Dwarf gourami	Khasikari
60	*Channa gachua* (Hamilton, 1822)	Pigmy snakehead	Chenga
61	*Channa marulia* (Hamilton, 1822)	Great snakehead	Saala
62	*Channa punctata* (Bloch, 1793)	Spotted snakehead	Gadisha
63	*Channa striata* (Bloch, 1793)	Snakehead murrel	Seula
64	*Tetraodon fluviatilis* (Hamilton, 1822)	Green pufferfish	Bengafula

List of marine species in Lake Chilika

Sl No	Species	Common Name	Local Name
1	*Eusphyra blochii* (Cuvier, 1816)	Winghead shark	Kamusora magar
2	*Sphyrna lewini* (Griffith & Smith, 1834)	Scalloped hammerhead	Hatudia magar
3	*Pristis pectinata* (Latham, 1794)	Smalltooth sawfish	Khanda magar
4	*Himantura walga* (Müller & Henle, 1841)	Dwarf whipray	Kati sankucha
5	*Muraenesox bagio* (Hamilton,1822)	Common pike conger	Danti
6	*Amblygaster leiogaster* (Valenciennes, 1847)	Smoothbelly sardinella	Kawla
7	*Amblygaster sirm* (Walbaum, 1792)	Spotted sardinella	Kawla kokili
8	*Anodontostoma chacunda* (Hamilton, 1822)	Chacunda gizzard shad	Baban Balangi
9	*Dussumieria acuta* (Valenciennes, 1847)	Rainbow sardine	Morooa kokali
10	*Dussumieria elopsoides* (Bleeker, 1849)	Slender rainbow sardine	Morwa
11	*Escualosa thoracata* (Valenciennes, 1847)	White sardine	Dudh kawla

Sl No	Species	Common Name	Local Name
12	*Sardinella fimbriata* (Valenciennes, 1847)	Fringescale sardinella	Kabla, Kokali
13	*Sardinella longiceps* (Valenciennes, 1847)	Indian oil sardine	Kokali
14	*Sardinella melanura* (Cuvier, 1829)	Blacktip sardinella	Kokali, Kabla
15	*Thryssa polybranchialis* (Wongratana, 1983)	Humphead thryssa	Patua
16	*Chirocentrus dorab* (Forsskål, 1775)	Dorab wolf-herring	Khandabalia
17	*Saurida tumbil* (Bloch, 1795)	Greater lizardfish	Enduli machha
18	*Trachinocephalus myops* (Forster, 1801)	Snake fish, Bluntnose	Mundha endua
19	*Pterois radiata* (Cuvier, 1829)	Radial firefish	Kanta chhatri
20	*Tetraroge niger* (Cuvier, 1829)	Wasp fish	Birudi machha
21	*Cociella crocodilus* (Cuvier, 1829)	Crocodile flathead	Takra
22	*Platycephalus indicus* (Linnaeus, 1758)	Bartail flathead	Takra
23	*Kumococius rodericensis* (Cuvier, 1829)	Spiny flathead	Takra
24	*Ambassis ambassis* (Lacepède, 1802)	Blad glassy	Phuluguna
25	*Epinephelus tauvina* (Forsskål, 1775)	Greasy grouper	Blola
26	*Lactarius lactarius* (Bloch & Schneider, 1801)	False trevelly	
27	*Rachycentron canadum* (Linnaeus, 1766)	Cobia, Black king fish	Samudra seula
28	*Alectis indicus* (Rüppell, 1830)	Indian threadfish	Jhanjar
29	*Alepes djedaba* (Forsskål, 1775)	Shrimp scad	Kanta marua, Kanta
30	*Atule mate* (Cuvier, 1833)	Yellowtail scad	Parei
31	*Carangoides gymnostethus* (Cuvier, 1833)	Bludger trevally	Konti parei
32	*Carangoides praeustus* (Bennett, 1830)	Brownback trevally	Tirana
33	*Caranx ignobilis* (Forsskål, 1775)	Giant trevally	Tiro parei, Toluparei
34	*Caranx melampygus* (Cuvier, 1833)	Bluefin trevally	Charko parei
35	*Caranx sexfasciatus* (Quoy & Gaimard, 1825)	Big eye trevally	Parei, Khokra kanto
36	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	Thumbda
37	*Parastromateus niger* (Bloch, 1795)	Black pomfret	Ghusura bahala
38	*Scomberoides commersonnianus* (Lacepède, 1801)	Talang queenfish	Telia parei, Koni
39	*Scomberoides lysan* (Forsskål, 1775)	Double spotted	Khadisa kanto, Koni
40	*Scomberoides tala* (Cuvier, 1832)	Barred queenfish	Kanto
41	*Scomberoides tol* (Cuvier, 1832)	Needlescaled queenfish	Kanto
42	*Selar boops* (Cuvier, 1833)	Oxeye scad	Kanta marua
43	*Selar crumenophthalmus* (Bloch, 1793)	Big eye scad	Konti
44	*Selaroides leptolepis* (Cuvier, 1833)	Yellowstripe scad	Koni, Konti
45	*Trachinotus blochii* (Lacepède, 1801)	Snubnose pompano	Chandi parei
46	*Trachinotus mookalee* (Cuvier, 1832)	Indian pompano	Chandi parei
47	*Eubleekeria splendens* (Cuvier, 1829)	Splendid ponyfish	Tanka chandi
48	*Gazza minuta* (Bloch, 1795)	Toothpony	Polanga, Tonki chandi
49	*.Leiognathus daura* (Cuvier, 1829)	Goldstripe ponyfish	Tonki chandi
50	*Leiognathus dussumieri* (Valenciennes, 1835)	Dussumier's pony fish	Chandee
51	*Leiognathus equulus* (Forsskål, 1775)	Common ponyfish	Chandee
52	*Leiognathus fasciatus* (Lacepède, 1803)	Striped ponyfish	Chandee
53	*Nuchequula blochii* (Valenciennes, 1835)	Twoblotch ponyfish	Tonki chandi

Sl No	Species	Common Name	Local Name
54	*Nuchequula gerreoides* (Bleeker, 1851)	Decorated ponyfish	Tonki chandi
55	*Photopectoralis bindus* (Valenciennes, 1835)	Orangefin ponyfish	Tonki chandi
56	*Secutor insidiator* (Bloch, 1787)	Pugnose ponyfish	Chandee
57	*Secutor ruconius* (Hamilton, 1822)	Deep pugnose ponyfish	Chandee
58	*Lutjanus kasmira* (Forsskål, 1775)	Common bluestripe	Angarua
59	*Gerres erythrourus* (Bloch, 1791)	Deep-bodied mojarra	Jagili
60	*Plectorhinchus nigrus* (Cuvier, 1830)	Black sweetlip	Paikili
61	*Argyrops spinifer* (Forsskål, 1775)	King soldierbream	Khuranti
62	*Crenidens crenidens* (Forsskål, 1775)	Karenteen seabream	Haribolia khuranti
63	*Nemipterus japonicus* (Bloch, 1791)	Japanese threadfin bream	
64	*Johnius macropterus* (Bleeker, 1853)	Largefin croaker	Kania, Patharamundi
65	*Nibea maculata* (Bloch & Schneider, 1801)	Blotched croaker	Patharamundi
66	*Otolithoides biauritus* (Cantor, 1849)	Bronze croaker	Patharamundi Sila
67	*Paranibea semiluctuosa* (Cuvier, 1830)	Half-mourning croaker	Pendi, Mundha boraga
68	*Protonibea diacanthus* (Lacepède, 1802)	Blackspotted croaker	Biradia sila
69	*Upeneus sulphureus* (Cuvier, 1829)	Sulphur goatfish	
70	*Drepane punctata* (Linnaeus, 1758)	Spotted sicklefish	Ghee chandi
71	*Ichthyoscopus lebeck* (Bloch & Schneider, 1801)	Longnosed Stargazer	Balighumura
72	*Omobranchus zebra* (Bleeker, 1868)	Zebra blenny	
73	*Oligolepis acutipennis* (Valenciennes, 1837)	Sharptail goby	
74	*Ephippus orbis* (Bloch 1787)	Orbfish	Chandi
75	*Siganus canaliculatus* (Park, 1797)	Whitespotted spinsfoot	Orah
76	*Siganus javus* (Linnaeus, 1766)	Streaked spinsfoot	Orah
77	*Siganus vermiculatus* (Valenciennes, 1835)	Vermiculated spinsfoot	Samodha
78	*Acanthurus mata* (Cuvier, 1829)	Elongate Surgeon fish	Moothia
79	*Sphyraena jello* (Cuvier, 1829)	Pickhandle barracuda	Gayala
80	*Sphyraena putnamae* (Jordan & Seale, 1905)	Sawtooth barracuda	Gayala
81	*Eupleurogrammus glossodon* (Bleeker, 1860)	Longtooth hairtail	Sapua, Rupapatia
82	*Trichiurus lepturus* (Linnaeus, 1758)	Largehead hairtail	Rupa patia
83	*Lepturacanthus savala* (Cuvier, 1829)	Savalani hairtail	Sapua, Rupapatia
84	*Euthynnus affinis* (Cantor, 1849)	Kawakawa	Kani
85	*Rastrelliger kanagurta* (Cuvier, 1816)	Indian mackerel	Morua, Kangurda
86	*Scomberomorus lineolatus* (Cuvier, 1829)	Streaked seerfish	Champa, Binjiram
87	*Pseudorhombus arsius* (Hamilton, 1822)	Largetooth flounder	Patta
88	*Pseudorhombus micrognathus* (Norman, 1927)	Flatfish	Patta
89	*Pseudorhombus triocellatus* (Bloch & Schneider, 1801)	Three spotted flounder	Patta
90	*Solea ovata* (Richardson, 1846)	Ovate sole	Patpatua
91	*Cynoglossus lida* (Bleeker, 1851)	Roughscale tonguesole	Patpatua
92	*Lagocephalus lunaris* (Bloch & Schneider, 1801)	Green rough-backed puffer	Bengafula
93	*Abalistes stellaris* (Bloch & Schneider, 1801)	Starry triggerfish	
94	*Diodon hystrix* (Linnaeus, 1758)	Spot-fin porcupinefish	Jhinka machha

List of brackish water species in Lake Chilika

Sl No	Species	Common Name	Local Name
1	*Chiloscyllium indicum* (Gmelin, 1789)	Slender bambooshark	Baunsia magar
2	*Carcharhinus leucas* (Müller & Henle, 1839)	Bull shark	Magar
3	*Carcharhinus limbatus* (Müller & Henle, 1839)	Blacktip shark	Kalapakha magar
4	*Carcharhinus melanopterus* (Quoy & Gaimard, 1824)	Blacktip reef shark	Icha magar
5	*Glyphis gangeticus* (Müller & Henle, 1839)	Ganges shark	Mundha magar
6	*Scoliodon laticaudus* (Müler & Henle, 1838)	Spadenose shark	Dudhia magar
7	*Rhynchobatus djeddensis* (Forsskål, 1776)	Giant guitarfish	Sisna magar
8	*Himantura imbricata* (Bloch & Schneider, 1801)	Scaly whipray	Kati sankucha
9	*Himantura marginata* (Blyth, 1860)	Blackedge whipray	Sankara sankucha
10	*Himantura uarnak* (Forsskål, 1775)	Honeycomb stingray	Mahuphenia sankucha
11	*Pastinachus sephen* (Forsskål, 1775)	Cowtail stingray	Gorulanjia sankucha
12	*Aetobatus flagellum* (Bloch & Schneider, 1801)	Longheaded eagleray	Chilla sankucha
13	*Aetobatus narinari* (Euphrasen, 1790)	Spotted eagleray	Dhalatipa pakhi
14	*Aetomylaeus nichofii* (Bloch & Schneider, 1801)	Banded eagleray	Garua pakhi chilli
15	*Elops machnata* (Forsskål, 1775)	Tenpounder, Lady fish	Nahama
16	*Megalops cyprinoides* (Broussonet, 1782)	Indo-Pacific tarpon	Paniakhia
17	*Strophidon sathete* (Hamilton, 1822)	Slender giant moray	Donti
18	*Lamnostoma orientalis* (Mc Clelland, 1844)	Oriental worm-eel	Samudra kuchia
19	*Pisodonophis boro* (Hamilton, 1822)	Rice-paddy eel	Dona, Dhanua
20	*Pisodonophis Cancrivorus* (Richardson, 1848)	Bengal's snake eel	Dona
21	*Congresox talabonoides* (Bleeker, 1853)	Indian pike conger	Donti
22	*Muraenesox cinereus* (Forsskål, 1775)	Daggertooth pike	Danti
23	*Corica soborna* (Hamilton, 1822)	Ganges river sprat	Ursi
24	*Ehirava fluviatilis* (Deraniyagala, 1929)	Malabar sprat	Saru kokali
25	*Hilsa kelee* (Cuvier, 1829)	Kelee shad	Kelipilla
26	*Nematalosa nasus* (Bloch, 1795)	Bloch's gizzard shad	Balangi, Luni makundi
27	*Tenualosa ilisha* (Hamilton, 1822)	Hilsa shad	Ilishi
28	*Tenualosa toli* (Valenciennes, 1847)	Toli shad	Kalapati ilishi
29	*Setipinna phasa* (Hamilton, 1822)	Gangetic hairfin anchovy	Phasi patua, Tamparia
30	*Stolephorus baganensis* (Hardenberg, 1933)	Bagan anchovy	Chauli
31	*Stolephorus commersonnii* (Lacepède, 1803)	Commerson's anchovy	Chauli patua
32	*Stolephorus dubiosus* (Wongratana, 1883)	Thai anchovy	Chauli patua
33	*Stolephorus indicus* (Van Hasselt, 1823)	Indian anchovy	Bali kokali
34	*Thryssa gautamiensis* (Babu Rao, 1971)	Gautama thryssa	Phasi patua
35	*Thryssa hamiltonii* (Gray, 1835)	Hamilton's thryssa	Kancha patua
36	*Thryssa kammalensoides* (Wongratana, 1883)	Godavari thryssa	Kona patua
37	*Thryssa malabarica* (Bloch, 1795)	Malabar thryssa	Tampla patua
38	*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa	Khanda patua, Phassa
39	*Thryssa purava* (Hamilton, 1822)	Oblique-jaw thryssa	Pusai patua
40	*Thryssa setirostris* (Broussonet, 1782)	Long-jaw thryssa	Badapati patua
41	*Thryssa vitrirostris* (Gilchrist & Thompson, 1908)	Orangemouth anchovy	Rangamukhi patua

Sl No	Species	Common Name	Local Name
42	*Ilisha elongata* (Bennett, 1830)	Elongate ilisha	Bada bajra
43	*Ilisha megaloptera* (Swainson, 1839)	Big eye ilisha	Badaakhia bajra
44	*Ilisha melastoma* (Bloch & Schneider, 1801)	Indian ilisha	Sana bajra
45	*Opisthopterus tardoore* (Cuvier, 1829)	Tardoore	Kharimakendi
46	*Chanos chanos* (Forsskål, 1775)	Milk fish	Seba khainga
47	*Mystus cavasius* (Hamilton, 1822)	Gangetic mystus	Tengra kontia
48	*Mystus gulio* (Hamilton, 1822)	Long whiskers catfish	Kontia
49	*Mystus vittatus* (Bloch, 1794)	Striped dwarf catfish	Gagar kontia
50	*Arius arius* (Hamilton, 1822)	Threadfin sea catfish	Singada, Gandia kontia
51	*Arius maculatus* (Thunberg, 1792)	Spotted catfish	Chita kontia
52	*Nemapteryx caelata* (Valenciennes, 1840)	Engraved catfish	Nishua kontia
53	*Osteogeneiosus militaris* (Linnaeus, 1758)	Soldier catfish	Sunga kontia
54	*Plicofollis argyropleuron* (Valenciennes, 1840)	Longsnouted catfish	Gandi kontia
55	*Plicofollis tenuispinis* (Day, 1877)	Thinspine Sea catfish	Gandia kontia
56	*Plotosus canius* (Hamilton, 1822)	Gray eel-catfish	Kaunda
57	*Plotosus lineatus* (Thunberg, 1787)	Striped eel-catfish	Kaunda
58	*Liza macrolepis* (Smith, 1846)	Largescale mullet	Dangala
59	*Liza melinoptera* (Valenciennes, 1836)	Otomebora mullet	Menjee
60	*Liza parsia* (Hamilton, 1822)	Goldspot mullet	Parsee
61	*Liza subviridis* (Valenciennes, 1836)	Greenback mullet	Menjee
62	*Liza tade* (Forsskål, 1775)	Tade mullet	Tuadi
63	*Liza vaigiensis* (Quoy & Gaimard, 1825)	Squaretail mullet	Mehadi manjee
64	*Mugil cephalus* (Linnaeus, 1758)	Flathead mullet	Khainga/Kabala
65	*Valamugil cunnesius* (Valenciennes, 1836)	Longarm mullet	Sorada/Soradi
66	*Valamugil seheli* (Forsskål, 1775)	Bluespot mullet	Chengakabala
67	*Valamugil speigleri* (Bleeker, 1858-59)	Speigler's mullet	Chanra
68	*Atherinomorus duodecimalis* (Valenciennes, 1835)	Tropical silverside	Kargil
69	*Atherinomorus lacunosus* (Forster, 1801)	Hardyhead silverside	Kargil
70	*Strongylura leiura* (Bleeker, 1850)	Banded needlefish	Sargara, Gania
71	*Strongylura strongylura* (Van Hasselt, 1823)	Spottail needlefish	Gania
72	*Hemiramphus far :* (Forsskål, 1775)	Black-barred halfbeak	Ekathanti
73	*Hyporhamphus limbatus* (Valenciennes, 1847)	Congaturi halfbeak	Ekdonti, gania, Sargara
74	*Oryzias dancena* (Hamilton, 1822)	Estuarine ricefish	Kauradia
75	*Hippocampus fuscus* (Rüppell, 1838)	Sea pony, Sea horse	Chilika ghoda
76	*Hippichthys cyanospilos* (Bleeker, 1854)	Blue spotted pipe fish	Balipoka
77	*Ambassis gymnocephalus* (Lacepède, 1802)	Bald glassy	Phuluguna
78	*Lates calcarifer* (Bloch, 1790)	Barramundi, Asian	Bhekti, Bhetki
79	*Epinephelus coioides* (Hamilton, 1822)	Orange-spotted grouper	Bhola
80	*Epinephelus lanceolatus* (Bloch, 1790)	Giant grouper	Bhola
81	*Epinephelus malabaricus* (Bloch & Schneider, 1801)	Malabar grouper	Bhola
82	*Sillaginopsis panijus* (Hamilton, 1822)	Flathead sillago	Jhudanga, Kadma
83	*Sillago sihama* (Forsskål, 1775)	Silver sillago	Jhudanga, Guji kadama
84	*Sillago vincenti* (Mc Kay, 1880)	Vincent's sillago	Jhudanga, Kadama

Sl No	Species	Common Name	Local Name
85	*Echeneis naucrates* (Linnaeus, 1758)	Live sharksucker	Magara joka
86	*Lutjanus argentimaculatus* (Forsskål, 1775)	Mangrove red snapper	Angarua
87	*Lutjanus johnii* (Bloch, 1792)	John's snapper	Rangua, Soosta
88	*Lutjanus russellii* (Bleeker, 1849)	Russell's snapper	Angarua
89	*Datnioides polota* (Hamilton, 1822)	Four-banded tigerfish	Verenda, Bhandari khura
90	*Gerres filamentosus* (Cuvier, 1829)	Whipfin silverbiddy	Odan Jagili
91	*Gerres limbatus* (Cuvier, 1830)	Saddleback silverbiddy	Jagili
92	*Gerres macracanthus* (Bleeker, 1854)	Longspine silverbiddy	Jagili
93	*Gerres oyena* (Forsskål, 1775)	Common silverbiddy	Jagili
94	*Gerres phaiya* (Iwatsuki & Hampstra, 2001)	Longtail silverbiddy	Jagili
95	*Gerres setifer* (Hamilton, 1822)	Small Bengal	Jagili
96	*Pomadasys argenteus* (Forsskål, 1775)	Silver grunt	Kokaraba
97	*Pomadasys kaakan* (Cuvier, 1830)	Javelin grunter	Kokaraba
98	*Pomadasys multimaculatus* (Playfair, 1867)	Cock grunter	Kokaraba
99	*Acanthopagrus berda* (Forsskål, 1775)	Picnic seabream	Kala khuranta
100	*Acanthopagrus latus* (Houttuyn, 1782)	Yellowfin seabream	Khuranti
101	*Rhabdosargus sarba* (Forsskål, 1775)	Goldlined seabream	Dhala Khuranta
102	*Daysciaena albida* (Cuvier, 1830)	Bengal corvina	Boraga
103	*Dendrophysa russelii* (Cuvier, 1829)	Goatee croaker	Borei, Golora
104	*Johnius carruta* (Bloch, 1793)	Karut croaker	Patharamundi
105	*Johnius dussumieri* (Valenciennes, 1837)	Bearded croaker	Golora, Borei
106	*Johnius belangerii* (Cuvier, 1830)	Belanger's croaker	Kania
107	*Johnius coitor* (Hamilton, 1822)	Coitor croaker	Kania, Pendi
108	*Otolithes ruber* (Bloch & Schneider, 1801)	Tigertooth croaker	Patharamundi shila
109	*Otolithoides pama* (Hamilton, 1822)	Pama croaker	Sila mundi
110	*Eleutheronema tetradactylum* (Shaw, 1804)	Fourfinger threadfin	Sahala, Kora
111	*Leptomelanosoma indicum* (Shaw, 1804)	Indian threadfin	Bhusa sahala
112	*Polydactylus plebeius* (Broussonet, 1782)	Striped threadfin	Ghusura sahala
113	*Polydactylus sextarius* (Bloch & Schneider, 1801)	Blackspot threadfin	Seengali
114	*Monodactylus argenteus* (Linnaeus, 1758)	Silver moony	Chandee
115	*Pelates quadrilineatus* (Bloch, 1790)	Fourlined terapon	Charigaria gahana
116	*Terapon jarbua* (Forsskål, 1775)	Jarbua terapon	Gahani, Gahana
117	*Terapon puta* (Cuvier, 1829)	Small-scaled terapon	Tadikiri gahana
118	*Terapon theraps* (Cuvier, 1829)	Large-scaled terapon	Badakati gahana
119	*Etroplus suratensis* (Bloch, 1790)	Green chromide	Kundala
120	*Butis butis* (Hamilton, 1822)	Duckbill sleeper	Gagibalakhera
121	*Eleotris fusca* (Forster, 1801)	Dusky sleeper,	Balakhera
122	*Eleotris melanosoma* (Bleeker, 1852)	Broadhead sleeper	Kala balakhera
123	*Acentrogobius cyanomos* (Bleeker, 1849)		Luna gulah
124	*Acentrogobius griseus* (Day, 1876)	Grey goby	
125	*Acentrogobius masoni* (Day, 1873)	Mason's goby	
126	*Acentrogobius viridipunctatus* (Valenciennes, 1837)	Spotted green goby	Luna baila

Sl No	Species	Common Name	Local Name
127	*Amoya madraspatensis* (Day, 1868)		Chariakhia baila
128	*Bathygobius fuscus* (Ruppell, 1830)	Dusky frillgoby	Matia gidda
129	*Bathygobius ostreicola* (Chaudhuri, 1916)		
130	*Brachygobius nunus* (Hamilton, 1822)	Bumblebee goby	
131	*Drombus globiceps* (Hora, 1923)	Bighead goby	Gagibalakhara
132	*Glossogobius mas* (Hora, 1923)		Baligullah
133	*Gobiopterus chuno* (Hamilton, 1822)		Nalia gida
134	*Oligolepis cylindriceps* (Hora, 1923)		
135	*Oxyurichthys microlepis* (Bleeker, 1849)	Maned goby	Gallah
136	*Oxyurichthys tentacularis* (Vallenciennes, 1837)	Tentacled goby	
137	*Parapocryptes rictuosus* (Valenciennes, 1837)		Rutta
138	*Periophthalmus kalolo* (Lesson, 1831)	Atlantic mudskipper	Chedhuan
139	*Psammogobius biocellatus* (Valenciennes, 1837)	Sleepy goby	Neuli
140	*Pseudapocryptes elongatus* (Cuvier, 1816)		Ruttapitallu
141	*Pseudogobius javanicus* (Bleeker, 1856)	Javaness goby	
142	*Stigmatogobius minima* (Hora, 1923)	Minima goby	
143	*Taenioides buchanani* (Day, 1873)	Burmese gobyeel	
144	*Trypauchen vagina* (Bloch & Schneider, 1801)	Burrowing goby	Pania, Gatua chedhuan
145	*Yongeichthys criniger* (Valenciennes, 1837)	Poisonous goby	
146	*Platax orbicularies* (Forsskål, 1775)	Orbicular batfish	Pati chandi
147	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat	Kara chandi
148	*Brachirus orientalis* (Bloch & Schneider, 1801)	Oriental sole	Dudhpatua
149	*Cynoglossus lingua* (Hamilton, 1822)	Long tongue sole	Dudhpatua
150	*Cynoglossus puncticeps* (Richardson, 1846)	Speckled tongue sole	Aswa
151	*Triacanthus biaculeatus* (Bloch, 1786)	Shortnosed triapodfish	Sukura
152	*Arothron reticularis* (Bloch & Schneider, 1801)	Reticulated pufferfish	Samudra benga
153	*Arothron stellatus* (Bloch & Schneider, 1801)	Starry toadfish	Bengta
154	*Chelonodon patoca* (Hamilton, 1822)	Milkspotted puffer	Bengafula
155	*Takifugu oblongus* (Bloch, 1786)	Lattice blassop	Bengti
156	*Tetraodon cutcutia* (Hamilton, 1822)	Ocellated pufferfish	Bengafula

Commercially important finfish and shellfish in Lake Chilika

Fin Fish

1	*Notopterus notopterus*
2	*Anodontosoma chacunda*
3	*Tenualosa ilisha*
4	*Nematalosa nasus*
5	*Stolephorus bagenensis*
6	*Stolephorus commersonii*
7	*Stolephorus dubiosus*
8	*Thryssa hamiltonii*
9	*Thryssa purava*
10	*Cirrhinus mrigala*
11	*Labeo rohita*
12	*Mystus gulio*
13	*Mystus cavasius*
14	*Osteogenenious militaris*
15	*Arius arius*
16	*Nemapteryx caelata*
17	*Wallagu attu*
18	*Plotosus canius*
19	*Plotosus lineatus*
20	*Hyporhamphus limbatus*
21	*Strongylura strongylura*
22	*Strongylura liura*
23	*Xenentodon cancila*
24	*Lates calcarifer*
25	*Terapon jarbua*
26	*Terapon puta*
27	*Sillago sihama*
28	*Datnioides polata*
29	*Gerres setifer*
30	*Gerres oyena*
31	*Gerres filamentosus*
32	*Pomadasys argenteus*
33	*Crenidens crenidens*
34	*Rhabdosargus sarba*
35	*Daysciaena albida*
36	*Dendrophysa russeli*
37	*Scatophagus argus*
38	*Etroplus suratensis*
39	*Liza macrolepis*
40	*Liza parsia*
41	*Liza subviridis*
42	*Mugil cephalus*
43	*Rhinomugil corsula*
44	*Valamugil cunnesius*
45	*Valamugil speigleri*
46	*Eleutheronema tetradactylum*
47	*Channa striata*
48	*Channa marulia*
49	*Macrognathus pancalus*
50	*Mastacembelus armatus*
51	*Triacanthus biaculeatus*

Shell Fish

1	*Metapenaeus dobsoni*
2	*Metapenaeus monoceros*
3	*Penaeus indicus*
4	*Penaeus monodon*
5	*Penaeus semisulcatus*
6	*Macrobrachium malcomsonii*
7	*Macrobrachium rosenbergii*
8	*Macrobrachium rude*
9	*Portunus pelagicus*
10	*Scylla serrata*
11	*Scylla tranquebarica*

Migration pattern of finfish in Lake Chilika

Catadromous

1 *Anguilla bengalensis bengalensis*
2 *Anguilla bicolor bicolor*
3 *Lates calcarifer*
4 *Terapon jarbua*
5 *Liza macrolepis*
6 *Liza melinoptera*
7 *Liza parsia*
8 *Liza subviridis*
9 *Liza tade*
10 *Liza vaigiensis*
11 *Mugil cephalus*
12 *Valamugil cunnesius*
13 *Valamugil seheli*
14 *Valamugil speigleri*
15 *Chanos chanos*

Anadromous

1 *Pisodonophis boro*
2 *Pisodonophis cancrivorus*
3 *Anodontosoma chacunda*
4 *Tenualosa ilisha*
5 *Hilsa toli*
6 *Hilsa kelee*
7 *Nematalosa nasus*
8 *Ilisha megaloptera*
9 *Stolephorus commersonii*
10 *Rhinomugil corsula*
11 *Euryglossa orientalis*
12 *Chelonodon patoca*
13 *Mystus gulio*

Amphidromous

1 *Carcharhinus leucas*
2 *Carcharhinus limbatus*
3 *Carcharhinus melanopterus*
4 *Glyphis gangeticus*
5 *Scoliodon laticaudus*
6 *Sphyrna blochii*
7 *Pristis pectinata*
8 *Himantura uarnak*
9 *Himantura imbricata*
10 *Pastinachus sephen*
11 *Himantura marginatus*
12 *Aetobatus flagellum*
13 *Aetobatus narinari*
14 *Aetomylaeus nichofii*
15 *Megalops cyprinoides*
16 *Strophidon sathete*
17 *Congresox talabonoides*
18 *Saurida tumbil*
19 *Tetraroge niger*
20 *Escualosa thoracata*
21 *Gonialosa manmina*
22 *Sardinella melanura*
23 *Ehirava fluviatilis*
24 *Ilisha melanstoma*
25 *Opisthopterus tardoore*
26 *Stolephorus bagenensis*
27 *Stolephorus dubiosus*
28 *Thryssa hamiltonii*
29 *Thryssa malabarica*
30 *Thryssa gautamiensis*
31 *Puntius sophore*
32 *Mystus cavasius*
33 *Silonia silondia*
34 *Arius arius*
35 *Nemapteryx caelata*
36 *Plicofolis tennuispinis*
37 *Plotosus canius*
38 *Plotosus lineatus*
39 *Xenentodon cancila*
40 *Hippocampus fuscus*
41 *Ichthyocampus carce*
42 *Hippichthys cynospilos*
43 *Ambassis gymnocephalus*
44 *Epinephelus malabaricus*
45 *Sillaginopsis panijus*
46 *Sillago sihama*
47 *Sillago vincenti*
48 *Scomberoides commersonianus*
49 *Alepes djedaba*
50 *Caranx sexfasciatus*
51 *Selaroides leptolepis*
52 *Lepturacanthus savala*
53 *Trichiurus lepturus*
54 *Nuchequula gerreoides*
55 *Eubleekeria splendens*
56 *Eubleekeria blochii*
57 *Leiognathus equulus*
58 *Secutor insidiator*
59 *Photopectoralis bindus*
60 *Gerres setifer*
61 *Gerres filamentosus*
62 *Gerres limbatus*
63 *Gerres phaiya*
64 *Dayscieaena albida*
65 *Dendrophysa russelli*
66 *Johnius belangerii*
67 *Johnius carutta*
68 *Otolithoides ruber*
69 *Otolithoides biauritus*
70 *Otolithoides pama*
71 *Ephippus orbis*
72 *Drepane punctatus*
73 *Scatophagus argus*
74 *Oreochromis mossambicus*
75 *Eleutheronema tetradactylus*
76 *Leptomelanosoma indicum*
77 *Polydactylus sextarius*
78 *Acentrogobius cyanomos*
79 *Drombus globiceps*
80 *Acentrogobius griseus*
81 *Acentrogobius madraspatensis*
82 *Acentrogobius masoni*
83 *Acentrogobius viridipunctatus*
84 *Bathygobius fuscus*
85 *Bathygobius ostreicola*
86 *Brachygobius nunus*
87 *Psammogobius biocellatus*
88 *Glossogobius giuris*
89 *Gobiopterus chuno*
90 *Oligolepis acutipennis*
91 *Oxyurichthys microlepis*
92 *Oxyurichthys tentacularis*
93 *Parapocryptes rictuosus*
94 *Periophthalmus kalolo*
95 *Pseudapocryptes elongatus*
96 *Pseudogobius javanicus*
97 *Stigmatogobius minima*
98 *Butis butis*
99 *Eleotris fusca*
100 *Eleotris melanosoma*

101 *Taenioides buchanani*
102 *Trypauchen vagina*
103 *Cynoglossus lingua*
104 *Parastromateus niger*
105 *Johinus coitor*
106 *Terapon puta*
107 *Abalistis stellaris*
108 *Plicofollis argyropleuron*
109 *Chirocentrus dorab*
110 *Setipinna phasa*

Potamodromous

1 *Notopterus notopterus*
2 *Catla catla*
3 *Salmophasia bacaila*
4 *Cirrhinus mrigala*
5 *Crossocheilus latius*
6 *Esomus danricus*
7 *Cirrhinus reba*
8 *Labeo calbasu*
9 *Labeo rohita*
10 *Rasbora daniconius*
11 *Puntius sarana*
12 *Puntius ticto*
13 *Labeo boga*
14 *Labeo gonius*
15 *Puntius chola*
16 *Lepidocephalichthys guntea*
17 *Sperata seenghala*
18 *Ompok bimaculatus*
19 *Wallago attu*
20 *Eutropiichthys vacha*
21 *Pangasius pangasius*
22 *Bagarius bagarius*
23 *Clarias batrachus*
24 *Osteogeneiosus militaris*
25 *Hyporhamphus limbatus*
26 *Chanda nama*
27 *Parambassis ranga*
28 *Anabas testudineus*
29 *Channa punctatus*
30 *Channa striatus*
31 *Channa marulius*
32 *Mastacembelus armatus*
33 *Tetraodon fluviatilis*
34 *Tetradon cutcutia*
35 *Bagarius yarreli*
36 *Gudusia chapra*

Oceanodromous

1 *Chiloscyllium indicum*
2 *Sphyrna lewini*
3 *Elops machnata*
4 *Muraenesox cinereus*
5 *Muraenesox bagio*
6 *Atherinomorus duodecimalis*
7 *Platycephalus indicus*
8 *Sardinella longiceps*
9 *Stolephorus indicus*
10 *Thryssa mystax*
11 *Thryssa purava*
12 *Strongylura lieura*
13 *Ambassis ambassia*
14 *Epinephelus tauvina*
15 *Rachycentron canadus*
16 *Carangoides praeustus*
17 *Caranx ignobilis*
18 *Lutjanus argentimaculatus*
19 *Lutjanus johni*
20 *Gerres erythrourus*
21 *Plectorhychus hasta*
22 *Pomadasys multimaculatus*
23 *Rhabdosargus sarba*
24 *Acanthopagrus berda*
25 *Upeneus sulphureus*
26 *Sphyraena jello*
27 *Siganus canaliculatus*
28 *Siganus javus*
29 *Scomberomorus lineolatus*
30 *Rastrelliger kanagurta*
31 *Euthynnus affinis*
32 *Pseudorhombus arsius*
33 *Lagocephalus lunaris*

Spawning, migration and juvenile recruitment of commercially important finfish and shellfish

Pre-JICA-CDA Project				JICA, 2009a
Species & Authors	**Migration**	**Size (mm)**	**Month**	
Mugil cephalus (Jhingran, 1958 & 1959, Patnaik, 1966, Jhingran & Natarajan, 1969, Mohanty, 1975)	Brood-fish from lake to sea, mainly through Outer channel and lake mouth	403-587 (female) 284-430 (male)	Sep-Jan; Peak: Nov	Migrate through Palur canal and outer channel, breeding season August to December
	Fry/Juveniles from sea to Lake	22-24mm (fry) move Upto lake mouth in the outer channel	Nov-Feb	
		Juvenile recruitment at modal size:112mm	Apr-Jul	
Liza macrolepis (Jhingran & Natarajan, 1969, Mohanty, 1975, Patnaik, 1970)	Brood-fish from lake to sea	310-450mm	Nov-Jan; Peak: Jan	
	Fry/juveniles from sea to Lake	10-12mm (fry) immigrate into outer channel not to the main lake	Dec-Feb	
		Juvenile recruitment at modal size:100mm	Jul-Aug	
Eleutheronema tetradactylum (Kowtal, 1965 & 1972, Mohanty, 1975, Patnaik, 1970)	Brood-fish perform inter sea lake movements Breeds both in Northern sector and sea	263-570mm	Dec-Jul; Peak: Mar & June	Prolonged breeding from December to July. Major spawning in sea in high saline waters
	From sea to lake and juveniles within the lake	62-112mm	Available almost throughout the year	
Tenualosa ilisha (Jones & Sujansingani, 1951, Ramakrishnaiah, 1972, Jhingran & Natarajan, 1969, Mohanty, 1975)	Brood-fish from sea to middle and lower reaches of Daya river	350-375 (male) 375-400mm (female)	Jul-Aug (monsoon) for breeding Winter: for feeding	Breeding season from July to September
	Juveniles from river Daya to Lake	50-149mm	Aug-Nov	
Nematalosa nasus (Jhingran & Natarajan, 1969, Kowtal, 1970, Mohanty, 1975).	Brood-fish migrates from sea to southern sector of Lake	135-260mm	Feb-Jul; Peak: June Jan-June	
Daysciaena albida (Jhingran & Natarajan, 1979, Mohanty, 1975)	Breeds in northern sector and sea as well	324-524mm	Apr-Jul; Peak: June	
	Juveniles within the lake and from the sea	Recruitment at modal size: 87-112mm	Feb	

Pre-JICA-CDA Project				JICA, 2009a
Species & Authors	**Migration**	**Size (mm)**	**Month**	
Arius arius (Jones & Sujansingani, 1954)	Brood-fish from sea to lake in northern and central sectors		Jan, Feb and July	
Lates calcarifer (Jhingran & Natarajan, 1966 & 1969, Mohanty, 1975)	Brood-fish from Lake to sea	425-600mm & above	Apr-July; Peak: Jun-Jul	Breeding season from April to July
	Advanced fry from sea to lake	112-162mm (modal size)	July-Aug & Jan-Mar	
Gerres setifer (Jhingran & Natarajan, 1966 & 1969, Patnaik, 1971, Mohanty, 1975)	Brood-fish from sea to southern sector of lake	110-175mm	May-Aug (extended breeding)	
	Juvenile recruitment within the lake	52mm (modal size)	Mar, May, Aug, Nov-Dec	
Sparus sarba (Jhingran & Natarajan, 1966)	Brood-fish from lake to sea near lake mouth	175-250mm	Nov-Jan	
	Fry and fingerlings from sea to lake	90mm	Jan-May	
Crenidens crenidens	Brood-fish from lake to sea		Winter months	
Penaeus indicus (Jhingran & Natarajan, 1966 & 1969, Pravakar Rao, 1967)	Primary adult moves from lake to sea	65-95mm	July-Aug	
	Secondary adult from lake to sea	105-120 mm	Dec	
	Post-larvae from sea to lake		Throughout the year with three peaks during Jan-Mar (Peak: Feb), April-Jul (Peak:May), Oct-Nov (minor)	
Penaeus monodon (Jhingran & Natarajan, 1966 & 1969, Pravakar Rao, 1967)	Primary adult moves from lake to sea	135mm	June-Oct	
	Secondary adult from lake to sea	175mm	Jan-April	
	Post-larvae from sea to lake		Throughout the year with two peaks during Oct-Jan & April-May	
Metapenaeus monoceros (Jhingran & Natarajan, 1966)	Adult prawn from lake to sea	65-105mm	Jul-Sep	
Metapenaeus dobsoni (Jhingran & Natarajan, 1966)	Adult prawn from lake to sea	60mm	Jan-April	
Scylla serrata (Mohanty *et al.*, 2006)	Adult crab from lake to sea	79mm onwards	Throughout the year; Peak: Aug-Nov	
Scylla tranquebarica (Mohanty *et al.*, 2006)	Adult crab from lake to sea	121mm onwards	Mar-Jun	

Avifauna of Lake Chilika

(Source: Balachandran *et al.*, 2009)

Waterbird species

Podicipedidae

1 *Tachybaptus ruficollis* (Pallas, 1764)
2 *Podiceps cristatus* (Linnaeus, 1758)

Pelecanidae

3 *Pelecanus onocrotalus* (Linnaeus, 1758)
4 *Pelecanus philippensis* (Gmelin, 1789)
5 *Pelecanus crispus* (Bruch, 1832)

Phalacrocoracidae

6 *Phalacrocorax niger* (Vieillot, 1817)
7 *Phalacrocorax fuscicollis* (Stephens, 1826)
8 *Phalacrocorax carbo* (Linnaeus, 1758)

Anhingidae

9 *Anhinga melanogaster* (Pennant, 1769)

Ardeidae

10 *Egretta garzetta* (Linnaeus, 1766)
11 *Egretta gularis* (Bosc, 1792)
12 *Ardea cinerea* (Linnaeus, 1758)
13 *Ardea purpurea* (Linnaeus, 1766)
14 *Casmerodius albus* (Linnaeus, 1758)
15 *Mesophoyx intermedia* (Wagler, 1829)
16 *Bubulcus ibis* (Linnaeus, 1758)
17 *Ardeola grayii* (Sykes, 1832)
18 *Butorides striatus* (Linnaeus, 1758)
19 *Nycticorax nycticorax* (Linnaeus, 1758)
20 *Ixobrychus sinensis* (Gmelin, 1789)
21 *Ixobrychus cinnamomeus* (Gmelin, 1789)
22 *Dupetor flavicollis* (Latham, 1790)

Ciconiidae

23 *Mycteria leucocephala* (Pennant, 1769)
24 *Anastomus oscitans* (Boddaert, 1783)
25 *Ciconia episcopus* (Boddaert, 1783)
26 *Ephippiorhynchus asiaticus* (Latham, 1790)

Threskiornithidae

27 *Threskiornis melanocephalus* (Latham, 1790)
28 *Pseudibis papillosa* (Temminck, 1824)
29 *Platalea leucorodia* (Linnaeus, 1758)

Phoenicopteridae

30 *Phoenicopterus ruber* (Linnaeus, 1758)
31 *Phoenicopterus minor* (Geoffroy Saint-Hilaire, 1798)

Anatidae

32 *Dendrocygna bicolor* (Vieillot, 1816)
33 *Dendrocygna javanica* (Horsfield, 1821)
34 *Anser anser* (Linnaeus, 1758)
35 *Anser indicus* (Latham, 1790)
36 *Anser erythropus* (Linnaeus, 1758)
37 *Tadorna ferruginea* (Pallas, 1764)
38 *Tadorna tadorna* (Linnaeus, 1758)
39 *Sarkidiornis melanotos* (Pennant, 1769)
40 *Nettapus coromandelianus* (Gmelin, 1789)
41 *Anas strepera* (Linnaeus, 1758)
42 *Anas penelope* (Linnaeus, 1758)
43 *Anas poecilorhyncha* (Forster, 1781)
44 *Anas acuta* (Linnaeus, 1758)
45 *Anas clypeata* (Linnaeus, 1758)
46 *Anas querquedula* (Linnaeus, 1758)
47 *Anas crecca* (Linnaeus, 1758)
48 *Rhodonessa rufina* (Pallas, 1773)
49 *Aythya ferina* (Linnaeus, 1758)
50 *Aythya nyroca* (Guldenstadt, 1770)
51 *Aythya fuligula* (Linnaeus, 1758)

Rallidae

52 *Rallina fasciata* (Raffles, 1822)
53 *Gallirallus striatus* (Linnaeus, 1766)
54 *Rallus aquaticus* (Linnaeus, 1758)
55 *Amaurornis akool* (Sykes, 1832)
56 *Amaurornis phoenicurus* (Pennant, 1769)
57 *Porzana pusilla* (Pallas, 1776)
58 *Porzana fusca* (Linnaeus, 1766)
59 *Gallicrex cinerea* (Gmelin, 1789)
60 *Porphyrio porphyrio* (Linnaeus, 1758)
61 *Gallinula chloropus* (Linnaeus, 1758)
62 *Fulica atra* (Linnaeus, 1758)

Jacanidae

63 *Hydrophasianus chirurgus* (Scopoli, 1786)
64 *Metopidius indicus* (Latham, 1790)

Haematopodidae

65 *Haematopus ostralegus* (Linnaeus, 1758)

Rostratulidae

66 *Rostratula benghalensis* (Linnaeus, 1758)

Charadriidae

67 *Pluvialis fulva* (Gmelin, 1789)
68 *Pluvialis squatarola* (Linnaeus, 1758)
69 *Charadrius hiaticula* (Linnaeus, 1758)
70 *Charadrius dubius* (Scopoli, 1786)
71 *Charadrius alexandrines* (Linnaeus, 1758)
72 *Charadrius mongolus* (Pallas, 1776)
73 *Charadrius leschenaultii* (Lesson, 1826)
74 *Vanellus malabaricus* (Boddaert, 1783)
75 *Vanellus cinereus* (Blyth, 1842)
76 *Vanellus indicus* (Boddaert, 1783)

Scolopacidae

77 *Gallinago stenura* (Bonaparte, 1830)
78 *Gallinago gallinago* (Linnaeus, 1758)
79 *Lymnocryptes minimus* (Brunnich, 1764)
80 *Limosa limosa* (Brunnich, 1764)
81 *Limosa lapponica* (Linnaeus, 1758)
82 *Numenius phaeopus* (Linnaeus, 1758)
83 *Numenius arquata* (Linnaeus, 1758)
84 *Tringa erythropus* (Pallas, 1764)
85 *Tringa totanus* (Linnaeus, 1758)
86 *Tringa stagnatilis* (Bechstein, 1803)
87 *Tringa nebularia* (Gunnerus, 1767)
88 *Tringa ochropus* (Linnaeus, 1758)
89 *Tringa glareola* (Linnaeus, 1758)
90 *Xenus cinereus* (Guldenstadt, 1775)
91 *Actitis hypoleucos* (Linnaeus, 1758)
92 *Arenaria interpres* (Linnaeus, 1758)
93 *Limnodromus semipalmatus* (Blyth, 1848)
94 *Calidris tenuirostris* (Horsfield, 1821)
95 *Calidris canutus* (Linnaeus, 1758)
96 *Calidris alba* (Pallas, 1764)
97 *Eurynorhynchus pygmeus* (Linnaeus, 1758)
98 *Calidris minuta* (Leisler, 1812)
99 *Calidris ruficollis* (Pallas, 1776)
100 *Calidris temminckii* (Leisler, 1812)
101 *Calidris subminuta* (Middendorff, 1853)
102 *Calidris alpina* (Linnaeus, 1758)
103 *Calidris ferruginea* (Pontoppidan 1763)
104 *Limicola falcinellus* (Pontoppidan, 1763)
105 *Philomachus pugnax* (Linnaeus, 1758)

Recurvirostridae

106 *Himantopus himantopus* (Linnaeus, 1758)
107 *Recurvirostra avosetta* (Linnaeus, 1758)

Burhinidae

108 *Esacus recurvirostris* (Cuvier, 1829)

Glareolidae

109 *Glareola pratincola* (Linnaeus, 1766)
110 *Glareola maldivarum* (Forster, 1795)
111 *Glareola lacteal* (Temminck, 1820)

Laridae

112 *Larus heuglini* (Bree, 1876)
113 *Larus ichthyaetus* (Pallas, 1773)
114 *Larus brunnicephalus* (Jerdon, 1840)
115 *Larus ridibundus* (Linnaeus, 1766)
116 *Gelochelidon nilotica* (J.E. Gmelin, 1789)
117 *Sterna caspia* (Pallas, 1770)
118 *Sterna aurantia* (Gray, 1831)
119 *Sterna bengalensis* (Lesson, 1831)
120 *Sterna bergii* (Lichtenstein, 1823)
121 *Sterna hirundo* (Linnaeus, 1758)
122 *Sterna albifrons* (Pallas, 1764)
123 *Sterna saundersi* (Hume, 1877)
124 *Sterna acuticauda* (Gray, 1832)
125 *Chlidonias hybridus* (Pallas, 1811)
126 *Chlidonias leucopterus* (Temminck, 1815)
127 *Chlidonias niger* (Linnaeus, 1758)

Rynchopidae

128 *Rynchops albicollis* (Swainson, 1838)

Gruidae

129 *Grus virgo* (Linnaeus, 1758)

Other bird species

Accipitridae

130 *Elanus caeruleus* (Desfontaines, 1789)
131 *Milvus migrans* (Boddaert, 1783)
132 *Haliastur indus* (Boddaert, 1783)
133 *Haliaeetus leucogaster* (Gmelin, 1788)
134 *Haliaeetus leucoryphus* (Pallas, 1771)
135 *Circaetus gallicus* (Gmelin, 1788)
136 *Circus aeruginosus* Linnaeus, 1758)
137 *Circus macrourus* (Gmelin, 1770)
138 *Circus melanoleucos* (Pennant, 1769)
139 *Accipiter badius* (Gmelin, 1788)
140 *Accipiter nisus* (Linnaeus, 1758)

Pandionidae

141 *Pandion haliaetus* (Linnaeus, 1758)

Falconidae

142 *Falco tinnunculus* (Linnaeus, 1758)
143 *Falco chicquera* (Daudin, 1800)
144 *Falco subbuteo* (Linnaeus, 1758)
145 *Falco peregrinus* (Tunstall, 1771)

Phasianidae

146 *Francolinus pondicerianus* (Gmelin, 1789)
147 *Perdicula asiatica* (Latham, 1790)

Columbidae

148 *Columba livia* (Gmelin, 1789)
149 *Streptopelia orientalis* (Latham, 1790)
150 *Streptopelia senegalensis* (Linnaeus, 1766)
151 *Streptopelia chinensis* (Scopoli, 1786)
152 *Streptopelia tranquebarica* (Hermann, 1804)
153 *Streptopelia decaocto* (Frivaldszky, 1838)
154 *Psittacula krameri* (Scopoli, 1769)

Cuculidae

155 *Clamator jacobinus* (Boddaert, 1783)
156 *Hierococcyx varius* (Vahl, 1797)
157 *Eudynamys scolopacea* (Linnaeus, 1758)
157 *Centropus sinensis* (Stephens, 1815)

Strigidae

159 *Otus bakkamoena* (Pennant, 1769)
160 *Athene brama* (Temminck, 1821)
161 *Asio flammeus* (Pontoppidan, 1763)

Apodidae

162 *Cypsiurus balasiensis* (Gray, 1829)
163 *Apus affinis* (Gray, 1830)

Alcedinidae

164 *Alcedo atthis* (Linnaeus, 1758)
165 *Halcyon smyrnensis* (Linnaeus, 1758)
166 *Halcyon pileata* (Boddaert, 1783)
167 *Ceryle rudis* (Linnaeus, 1758)

Meropidae

168 *Merops orientalis* (Latham, 1802)
169 *Merops philippinus* (Linnaeus, 1766)

Coraciidae

170 *Coracias benghalensis* (Linnaeus, 1758)

Upupidae

171 *Upupa epops* (Linnaeus, 1758)

Capitonidae

172 *Megalaima zeylanica* (Gmelin, 1788)
173 *Megalaima haemacephala* (Muller, 1776)

Alaudidae

174 *Mirafra cantillans* (Blyth, 1844)
175 *Mirafra erythroptera* (Blyth, 1845)
176 *Eremopterix grisea* (Scopoli, 1786)
177 *Calandrella cheleensis* (Swinhoe, 1871)
178 *Galerida cristata* (Linnaeus, 1758)
179 *Alauda gulgula* (Franklin, 1831)

Hirundinidae

180 *Hirundo rustica* (Linnaeus, 1758)
181 *Hirundo daurica* (Linnaeus, 1771)

Motacillidae

182 *Motacilla maderaspatensis* (Gmelin,1789
183 *Motacilla citreola* (Pallas, 1776)
184 *Motacilla flava* (Linnaeus, 1758)
185 *Motacilla cinerea* (Tunstall, 1771)
186 *Anthus richardi* (Vieillot, 1818)
187 *Anthus rufulus* (Vieillot, 1818)
188 *Anthus campestris* (Linnaeus, 1758)

Pycnonotidae

189 *Pycnonotus jocosus* (Linnaeus, 1758)
190 *Pycnonotus cafer* (Linnaeus, 1766)
191 *Pycnonotus luteolus* (Lesson, 1841)

Laniidae

192 *Lanius cristatus* (Linnaeus, 1758)

Turdinae

193 *Monticola solitarius* (Linnaeus, 1758)
194 *Luscinia svecica* (Linnaeus, 1758)
195 *Copsychus saularis* (Linnaeus, 1758)
196 *Saxicoloides fulicata* (Linnaeus, 1766)
197 *Phoenicurus ochruros* (Gmelin, 1774)
198 *Saxicola caprata* (Linnaeus, 1766)
199 *Cercomela fusca* (Blyth, 1851)

Timaliinae

200 *Chrysomma sinense* (Gmelin, 1789)
201 *Turdoides malcolmi* (Sykes, 1832)
202 *Turdoides striatus* (Dumont, 1823)

Sylviinae

203 *Cisticola juncidis* (Rafinesque, 1810)
204 *Prinia inornata* (Sykes, 1832)
205 *Acrocephalus dumetorum* (Blyth, 1849)
206 *Acrocephalus stentoreus* (Ehrenberg, 1833)
207 *Phylloscopus trochiloides* (Sundevall, 1837)
208 *Sylvia curruca* (Linnaeus, 1758)

Nectariniidae

209 *Nectarinia zeylonica* (Linnaeus, 1766)

Eastrildidae

210 *Lonchura malacca* (Linnaeus, 1766)

Passerinae

211 *Passer domesticus* (Linnaeus, 1758)

Ploceinae

212 *Ploceus manyar* (Horsfield, 1821)
213 *Ploceus philippinus* (Linnaeus, 1766)

Sturnidae

214 *Sturnus roseus* (Linnaeus, 1758)
215 *Sturnus vulgaris* (Linnaeus, 1758)
216 *Sturnus contra* (Linnaeus, 1758)
217 *Acridotheres tristis* (Linnaeus, 1766)
218 *Acridotheres ginginianus* (Latham, 1790)
219 *Acridotheres fuscus* (Wagler, 1827)

Oriolidae

220 *Oriolus oriolus* (Linnaeus, 1758)

Dicruridae

221 *Dicrurus macrocercus* (Vieillot, 1817)

Corvidae

222 *Dendrocitta vagabunda* (Latham, 1790)
223 *Corvus splendens* (Vieillot, 1817)
224 *Corvus macrorhynchos* (Wagler, 1827)

Villages around Lake Chilika

Northern Sector

1	Badabenakudi
2	Karimpur
3	Mudiratha
4	Khajuria
5	Kapileswarpur
6	Nisibhanr
7	Jagannathpur
8	Jaripada
9	Matiapada
10	Totapada
11	Balinasi
12	Panchupatia
13	Bhagabatipur
14	Mansinghpur
15	Sorana
16	Karamala
17	Janghar
18	Barora
19	Dochian
20	Chupring
21	Gadakharada
22	Balipatana
23	Dokanda
24	Balabhadrapur
25	Jankia
26	Gopinathpur
27	Jagueipadar
28	Gadisagoda
29	Nuagaon
30	Kaudikhuni
31	Kanas
32	Balipatapur
33	Bhusandpur
34	Urumukhi
35	Jhatinuagaon
36	Nizagharkuhudi
37	Ratanpur
38	Tangi
39	Jhanscipatana
40	Gedapatana
41	Tentulipada
42	Gobardhanpur
43	Abhimanpur
44	Katuliagothapatana
45	Katuliagothapatana colony
46	Gobardhanpur colony
47	Jhatinuagaon colony
48	Kantalabai colony
49	Jatcapatna
50	Naligadia (Chilikasahi)
51	Baunsumulu
52	Barunpada
53	Kaaratisahi
54	Mangarajodi

Central Sector

55	Banpur
56	Galua
57	Bhimpur
58	Bidharpur
59	Balugaon
60	Baulabandha
61	Balia
62	Hatabaradi
63	Kumaandal patana
64	Bheleri
65	Chandraput
66	Chheda padar
67	Gabapadar
68	Injanpur
69	Sananairi
70	Bhagabati patana
71	Dhuanl
72	Mathapur
73	Singheswar
74	Alanda
75	Khatiakudi
76	Berhampur
77	Khirisahi
78	Mainsha
79	Kamalasinghi
80	Krushna Pradesh
81	Chilika nuapada
82	Khatia sahi
83	Nuagaon
84	Siandi
85	Nairi

Southern Sector

86	G.Kainchapur
87	Pallibandha
88	Bhanrkudi
89	Haripur Buridi
90	Palurgarh
91	Rambha NAC
92	Madhurchuan
93	Jagannath Patana
94	Samalnasi
95	Keshpur
96	Langaleswar
97	Pathara
98	Sabulia
99	Khola Muhan
100	Rasakudi
101	Sahabajpur
102	Maleswari
103	Naba
104	Kumarpur
105	Patanasi
106	Ramalenka
107	Chilikanuapada (Pradhan Sahi)
108	Anlakuda
109	Gurubai
110	Krushnaprasad San anlo
111	Dalabehera Sahi
112	Khatiakudi
113	Jagiri Kuda
114	Prayagiri
115	Malud
116	Bramandio
117	Paikaraiper
118	Samantaraiper
119	Rasategaon
120	Patharaganja
121	Anua

122 Jamuna
123 Alanda
124 Tichhana
125 Chadheia
126 Tubuka
127 Sipiya
128 Bauripalli

Outer Channel

129 Arakhakuda
130 Gopinathpur
131 Jadupur
132 Keutakudi
133 Manikapatana
134 Parbatipur
135 Mirjapur
136 Padanpur
137 Siara
138 Gangadhar Pur
139 Gorapur
140 Sipakuda
141 Alupatana
142 Satapadagada
143 Satapada Banki Jala
144 Naubadi
145 Baulapatana
146 Nuagaon
147 Gambhari
148 Tua
149 Podadhia
150 Panasapada
151 Baghamunda
152 Chandikhol Bhoisahi

Wetlands International - South Asia
A-25, 2nd Floor, Defence Colony
New Delhi - 110 024, INDIA
Tele.:+91 11 32937908
TeleFax.:+91 11 24338906
Email: wi.southasia@wi-sa.org
URL. http://south-asia.wetlands.org/

Chilika Development Authority
Plot .No- C/11, BJB Nagar,
Bhubaneswar, Odisha, India
Phone: 91-674-2434044/2436654
Fax: 91-674-2434485
Email: ajitpattnaik13@gmail.com
chilika@chilika.com