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Draft Report

Economics of Ecosystem Services and Biodiversity for Conservation and Sustainable Management of Inland Wetlands

04

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

WETLANDS



Ministry of Environment, Forest and Climate Change
Government of India



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THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

Indo-German Biodiversity Programme

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- The Economics of Ecosystems and Biodiversity - India Initiative (TII)
- India Business and Biodiversity Initiative (IBBI)
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Economics of Ecosystem Services and Biodiversity for Conservation and Sustainable Management of Inland Wetlands

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THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

The Economics of Ecosystems and Biodiversity – India Initiative (TII) aims at making the values of biodiversity and linked ecosystem services explicit for consideration and mainstreaming into developmental planning. TII targets action at the policy making levels, the business decision level and awareness of citizens. TII has prioritized its focus on three ecosystems - forests, inland wetlands, and coastal and marine ecosystems - to ensure that tangible outcomes can be integrated into policy and planning for these ecosystems based on recommendations emerging from TII.

In addition to the existing knowledge, TII envisions establishing new policy-relevant evidences for ecosystems values and their relation to human well-being through field-based primary case studies in each of the three ecosystems. In response to an open call for proposals for conducting field-based case studies in the context of relevant policy or management challenges for conservation and the sustainable use of biodiversity and ecosystem services, over 200 proposals were received. A Scientific and Technical Advisory Group (STAG), comprising eminent ecologists and economists, appraised the proposals and recommended 14 case studies for commissioning under TII.

These studies in forests deal with issues such as hidden ecosystem services of forests, conflicts between humans and wildlife, and the economic consequences of species decline. In wetlands, the studies draw lessons on water resources management, community stewardship and equity, and the economics of hydrological regime changes. In coastal and marine ecosystems, the studies explore the opportunities and economic efficiency of interventions such as eco-labelling, seasonal fishing bans, mangrove regeneration, and the challenge of bycatch in marine fisheries.

The reports of these 12 case studies have been published in this TII series.

THE SERIES:

FOREST

- 01 Valuation of Forest Ecosystem Services and Biodiversity in The Western Ghats: Case Study in Uttara Kannada
- 02 The Economics and Efficacy of Elephant-Human Conflict Mitigation Measures in Southern India
- 03 An Economic Assessment of Economic Services Provided by Vultures: A Case Study from the Kanha-Pench Corridor

WETLANDS

- 04 Economics of Ecosystem Services and Biodiversity for Conservation and Sustainable Management of Inland Wetlands
- 05 Economics of Biodiversity and Ecosystem Services of Rivers for Sustainable Management of Water Resources
- 06 Economic Valuation of Ecosystem Services: A Case Study of Ousteri Wetland, Puducherry
- 07 Economic Valuation of Landscape Level Wetland Ecosystem and its Services in Little Rann of Kachchh, Gujarat
- 08 Economic Feasibility of Willow Removal from Wular Lake, Jammu & Kashmir

COASTAL AND MARINE ECOSYSTEMS

- 09 Valuation of Planted Mangroves
- 10 Assessment of Eco-labelling as Tool for Conservation and Sustainable Use of Biodiversity in Ashtamudi Lake, Kerala
- 11 Economic Valuation of Seasonal Fishing Ban on Marine Fisheries Services in Selected Maritime States of India
- 12 Economic Valuation of Biodiversity Loss: A Study of By-Catch from Marine Fisheries in Andhra Pradesh

KEY MESSAGES (LOKTAK LAKE)

Loktak wetlands complex are the lifeline of the north-eastern state of Manipur. Spanning over 469 sq km, these wetlands are source of fish, edible plants and freshwater, and are the only known natural habitat of globally endangered Manipur Brow Antlered Deer (*Rucervus eldi eldi*). Regulating the wetlands for hydropower generation has led to an alteration in the ecology of the lake ecosystem.

FINDINGS

- The natural capital asset worth of Loktak is estimated at **₹63.8 billion (US\$ 1.06 billion)**, considering its value in terms of fisheries, aquatic plants, freshwater, nutrient retention, and biodiversity-linked non-use values.
- Phumdi, floating mats of vegetation which are a characteristic feature of these wetlands, help maintain water quality by trapping nutrients. Replacing this function through artificial techniques may impose an annual cost of **₹113.3 million (US\$ 1.9m)**.
- The worth of water provided from Loktak for hydropower generation is **₹183.30 million (US\$ 3m)**. This value is not adequately accounted for in hydropower pricing. The ecological costs of lake water regime regulation are not appropriately factored in, which may lead to inefficient water management decisions.
- In order to maintain biodiversity and ecosystem services of Loktak, regulation of water regimes will need to consider multiple objectives rather than just maximisation of hydropower production. By lowering water allocation for hydropower during the lean season, critical ecosystem processes can be maintained.



RECOMMENDATIONS

- Sustainable management of Loktak water regimes should be based on a full range of biodiversity and ecosystems service values.
- Alternate sources for power are to be used during winter to ensure that ecosystem processes and services are maintained.
- Integrated wetland management should be pursued to ensure that ecosystem services and biodiversity can be maintained on a long-term basis.

KEY MESSAGES (KANWAR JHEEL)

Kanwar Jheel is the largest floodplain wetland of Gandak-Kosi Basin of North Bihar. Spanning 67 sq km, the wetland buffers floods, recharges groundwater, sustains the livelihoods of farmers and fishers and is an important waterbird habitat. Land-use changes triggering the transformation of this multi-functional resource towards permanent agriculture have created a trade-off between provisioning and regulating ecosystem services.

FINDINGS

- The ecosystem services bundle of Kanwar Jheel operates at maximum value if the wetland is managed as it was in the 1970s. At that time, the entire wetland was inundated and a diverse land-use system was in place. This land-use system could have annually provided ₹87 million (US\$ 1.45m) worth of fisheries, ₹18.42 million (US\$ 307,000) worth of wetland agriculture and ₹9.07 million (US\$ 15,117) worth of fuelwood.
- If the current trend of conversion of the wetland to permanent agriculture continues, there will be a significant opportunity cost in the form of lost ecosystem services. It is estimated that the annual loss for fisheries would be up to ₹74.19 million (US\$ 1.2m), for aquatic plants up to ₹7.9 million (US\$ 131,667) and for groundwater recharge up to ₹9.66 million (US\$ 160,000). The gain from increased area under permanent agriculture would only be worth ₹12.67 million (US\$ 211,168). Therefore, by changing Kanwar Jheel from a wetland to permanent agriculture, the value of lost ecosystem services are not matched by the gains from agriculture.
- In terms of wetland management, perhaps the restoration of Kanwar

Jheel (towards the 1970s scenario) would be desirable for its diverse ecosystem benefits, especially for fishers. However, this would be unpopular among farmers due to loss of area available for agriculture. Therefore, ideal management would be to try and maintain a moderate hydrological regime (like the 1980s scenario), where benefits to farmers and fishers were possibly more equitable.



RECOMMENDATIONS

- Management of Kanwar Jheel should aim to restore hydrological regime as in the 1980s, wherein nearly 67% of the wetland was inundated for at least 6 months.
- Wetland zoning principles should be used to maximise ecosystem services and biodiversity benefits. The core of the wetland should be maintained for biodiversity, whereas a mix of fisheries and subsistence level wetland agriculture should be permitted in the rest of the wetland to address livelihood needs.
- A management authority may be constituted for Kanwar restoration with representation of all stakeholders and sectors.

KEY MESSAGES (CHILIKA LAKE)

Ecological restoration has brought life back in Chilika Lagoon, the livelihood base of 200,000 fishers and 400,000 farmers. It has also improved habitat quality of this Ramsar Site, including a million wintering migratory waterbirds and a healthy population of Irrawaddy Dolphins.

FINDINGS

- Ecological restoration of Chilika sustains an annual benefit flow of **₹3.38 billion (US\$ 56m)** worth tourism, **₹1.46 billion (US\$ 24m)** worth fisheries, **₹34 million (US\$.57m)** worth aquatic vegetation and **₹14 million (US\$.24m)** worth inland navigation. In addition, significant benefits are received from the wetland ecosystem's ability to buffer extreme events and provide bioprospecting potential.
- Sustaining these benefits has required a programmatic expense of **₹1.6 billion (US\$ 27m)** since 1991 for an integrated lake basin management programme addressing various degradation drivers.
- Every rupee invested in Chilika has transformed into **₹4.9** worth of benefits through sustained flow of ecosystem services.
- Interventions aimed at improving the distribution of benefits from Chilika fisheries by strengthening Primary Fishermen Cooperative Societies have resulted in **21%** increase in gross value realisation by fisher households and **13%** savings in interest outgo on household debt.
- Fisher communities of Mangalajodi have stopped waterbird hunting and shifted to ecotourism, so as to benefit from improved habitat quality of Chilika. This transition has increased their income over **2.5 times** in the last two decades. Besides income gains, awards and recognitions have brought considerable incentives to these communities for stewardship of Chilika.



RECOMMENDATIONS

- Implementation of lake basin management should be continued to ensure that biodiversity and ecosystem services are maintained on a long-term basis.
- Capacity building and finance for Fisher Cooperative Societies are required to ensure that Chilika fishers are incentivised for sustainable fisheries.
- Models of community managed ecotourism should be incorporated in wetland management so that communities gain livelihood benefits from ecological restoration.
- This experience may be used as a motivation for other coastal wetlands (e.g. Pulicat, Ashtamudi and Vembanad-Kol) waiting to go the Chilika way.



Photo: Ritesh Sharma

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1. Introduction

1.1. TEEB India Initiative

The Economics of Ecosystems and Biodiversity – India Initiative (TII) was launched in 2010 by the Ministry of Environment, Forests and Climate Change, Government of India (MoEFCC, GoI) to highlight the economic consequences of loss of biological diversity and the associated decline in ecosystem services. The initiative envisions mainstreaming of ecosystem services and biodiversity values in developmental programming using an evidence building approach for three ecosystem types, namely inland wetlands, forests and coastal and marine ecosystems. Twelve demonstration projects have been supported under the initiative to identify pathways for applying economics-based approaches for improved management of ecosystem services and biodiversity.

Inclusion of wetlands (as inland wetlands and as components of coastal and marine ecosystems) as priority within TII is a significant opportunity for increasing visibility of the value of their ecosystem services and biodiversity in policy and decision-making processes. Wetlands underpin societal well-being in a number of ways, yet are under threat from a range of anthropogenic and non-anthropogenic drivers and pressures. The resultant losses in ecosystem services and biodiversity have direct economic repercussions, which are unfortunately underestimated. Making the value of wetlands visible to economies and society creates an evidence base to pave the way for more targeted and cost-effective solutions.

1.2. Wetland Wise Use and Valuation of Ecosystem Services

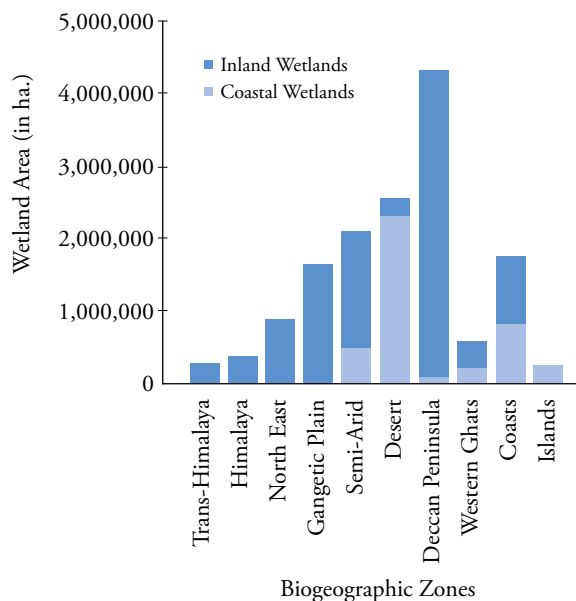
Wetlands are ecosystems located at the interface of land and water. Combining attributes of both terrestrial and purely aquatic ecosystems, wetlands are often characterised by the presence of permanent or seasonal inundation, hydric soils and hydrophytic vegetation. The Ramsar Convention adopts a broad definition of wetlands. As per Article 1.1 of the Convention, wetlands are ‘areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters. Article 2.1 states that wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands. The definition thus covers a large number of inland wetlands (such as swamps, marshes,

lakes and peatlands); coastal and near-shore marine wetlands (such as coral reefs, mangroves, seagrass beds and estuaries) and human made wetlands (such as rice paddy fields, dams, reservoirs and fish ponds).

The extremes of climatic, geological and topographic diversity in India create conducive conditions for sustaining a rich diversity of wetlands. These range from high altitude lakes in the Himalayas, floodplains and marshes in the Gangetic

Brahmaputra alluvial plains, saline flats in the Great Indian Desert, tanks and reservoirs in the Deccan region and extensive mangrove marshes and coral reef areas straddling the country’s 8000 km coastline on the east and west. As per the National Wetland Atlas, the total extent of wetlands is 15.26 million ha, which is equivalent to nearly 4.63% of the geographical area of the country. Inland wetlands account for nearly 69% (10.56 million ha) of the total area. Rivers and riverine wetlands constitute 35% of the total wetland area in the country, and are the predominant wetland type in several bio-geographic regions: the Gangetic plains (56%), Himalayas (74%), Trans-Himalayas (59%), North-east (79%), Semi-arid (34%) and the Western Ghats (30%). (Figure 1). Within the Deccan, reservoirs and barrages form 33% of its wetland area. Within the Desert, inter-tidal mudflats account for 81% of the total area.

Figure 1: Distribution of wetlands in biogeographic zones of India



Wetlands are managed for wise use. The approach recognises that stemming wetland loss and degradation requires incorporation of linkages between people and wetlands, and thereby emphasises that human use of these ecosystems on a sustainable basis is compatible with conservation (Finlayson et al., 2011). The Ramsar Convention on Wetlands defines wise use as “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development”. Ecological character is the combination of ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. An ecosystem approach calls for considering the complex relationship between various ecosystem elements and integrated management of land, water and living resources. Through emphasis on sustainable development, wise use calls for resource use patterns which can ensure that human dependence on wetlands can be maintained not only in the present, but also in the future. Seen in totality, wise use calls for maintaining wetland values and functions in order to ensure flow of benefits from wetlands (their ecosystem services) in the present as well as the future.

Value is ‘the contribution of an action or object to user specified goals, objectives or conditions’ (Farber et al., 2002). Valuation is “the process of expressing a value for a particular good or service...in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology and so on)” (ibid). Valuation involves assigning relative weights to the various aspects of individual and social decision-making problems, with the weights being reflections of the goals and worldwide views of the community, society and culture of individuals (Costanza, 1991; North, 1994). Economic valuation is an expression of these weights in monetary terms, making them comparable with alternate uses, which often have benefits and costs flows defined in similar units. It is essentially an anthropocentric way of looking at nature, wherein values are assigned to the extent

that these fulfill and directly or indirectly contribute to human well-being (positive change in well-being hereinafter termed as benefit after TEEB 2012).

Achieving wise use requires addressing tradeoffs between values people hold for wetlands. Functioning wetlands produce multiple provisioning, regulating and cultural services. Since they are interlinked, they are affected either positively or adversely in response to wetland use in the context of wider developmental programming. Some services co-vary positively (for example, improving flood buffering capacity of wetlands can support increased groundwater recharge and help maintain productive fisheries), whereas in several circumstances ecosystem services may co-vary negatively (use of wetlands for permanent agriculture may reduce capability of wetlands to moderate water regimes).

As public goods, a large category of wetland ecosystem services are not considered and incorporated in public policy. Economic values make explicit the impact of public policy or private decisions on ecosystem service values, and enable expression of these value changes in units that allow for their inclusion in public decision making (Mooney et al., 2005). It is a means of communicating the value of wetland ecosystem services to different groups of people using a language that speaks to dominant economic and political viewpoints across the world. Economic valuation improves the possibility of achieving sound decisions on wetland use and management, by acting as a feedback mechanism alerting society on the consequences of consumption choices and behavior (Zavetoski, 2004).

1.3. Report Purpose and Scope

TII uses an evidence building approach to demonstrate application of ecosystem services economics to wetland management contexts. The current report presents a synthesis of economic assessments of wetland ecosystem services at following three sites:

Site I: Lake Chilika, a coastal lagoon in Odisha State; the case study provides insights into economic

As public goods, a large category of wetland ecosystem services are not considered in public policy. Economic valuation seeks to effectively communicate the value of these services, enabling sound decisions on wetland use

efficiency of ecological restoration and mechanisms through which enhanced flow of ecosystem services transform into tangible livelihood outcomes

Site II: Loktak Lake, a floodplain lake in Manipur; the case study uses economic assessments to inform water management options for maintaining biodiversity and ecosystem services values

Site III: Kanwar Jheel, a floodplain wetland complex of Gandak Kosi basin in North Bihar; the case study uses economic assessment to demonstrate the implications of changing land use, and options for hydrological restoration

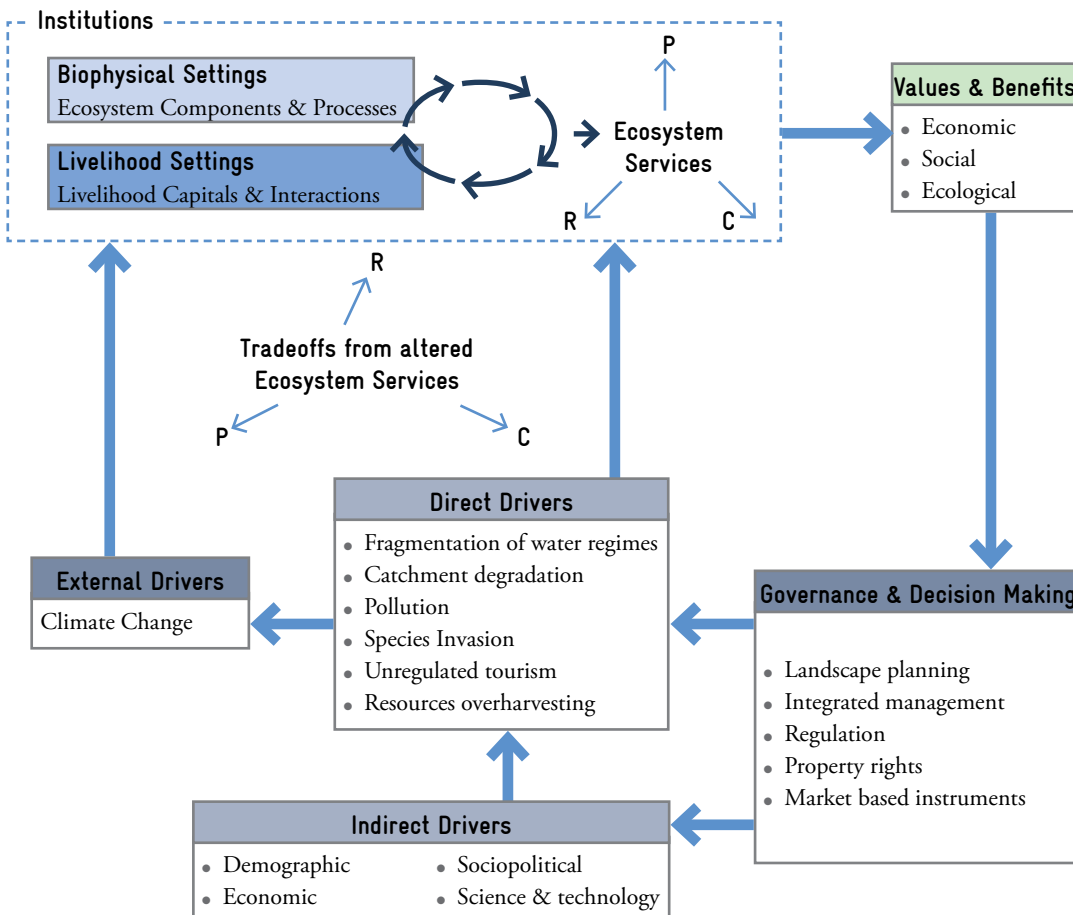
The three case studies, along with 4 others implemented by TII partnership, will be collated into a sectoral synthesis report for wetlands. The synthesis aims to provide recommendations for mainstreaming values of wetland ecosystem services into developmental programming.

1.4. Approach and Methodology

A conceptual approach linking ecosystem services, benefits and values, governance and direct and indirect drivers used in the analysis of case studies is presented in Figure 2. It also shows ecosystem components and processes, as well as livelihood capitals condition delivery of ecosystem services, which operate in an institutional space. The values and benefits are considered to be derived from these ecosystem services, as transformed by prevailing formal and informal institutions. The values influence decision making, which lead to a range of direct and indirect drivers, subsequently modifying ecosystem components, processes, livelihood capitals and ultimately ecosystem services. Transformations also lead to ecosystem services tradeoffs, leading to differential impacts on stakeholders.

The analytical methodology is set in four steps and is aimed at uncovering various reasons for

Figure 2: Conceptual framework for economic assessment of ecosystem services



which stakeholders value ecosystem services. It also identifies which tradeoffs need to be addressed while making decisions regarding wetland management. The framework enables comparison of alternate management regimes through their consequences on ecosystem services.

The first step of the framework involves defining the policy context. Ecosystem services are identified based on analysis of biophysical and livelihood settings. An analysis of sectoral developmental planning encapsulates institutional arrangements that influence ecosystem services. These lead to key policy questions that need to be answered through the ecosystem services assessment.

The second step involves construction of scenarios

and linked ecosystem services bundles, which can help make a comparison between various management options.

The third step is aimed at evaluating scenarios. This includes determining the various ecosystem services bundles that are associated with each scenario, as well as analysing the socio-political context associated with each scenario. Evaluation involves a range of economic and non-economic metrics, which can capture the implications of change in ecosystem provision.

The fourth and final step involves creating the basis for decision-making. It is aimed at deriving specific management recommendations, enabling integration of wetland ecosystem services in developmental programming.



2. Lake Chilika, Odisha

2.1. Context

Chilika, a brackish water coastal lagoon situated in Odisha, forms the base of livelihood security for more than 0.2 million fishers and 0.4 million farmers living in and around the wetland and its adjoining catchments. The lagoon spans an area of 1,165 km² and is flanked by ephemeral floodplains extending to over 400 km². Over one million migratory birds commonly winter here. Chilika is one of only two lagoons in the world that supports Irrawaddy Dolphin (*Orcaella*

brevirostris) populations. *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. Chilika was designated as a Wetland of International Importance (Ramsar Site under the Convention on Wetlands) by the Government of India in 1981.

Channelisation of floodplains, increased agriculture and decreasing forest cover in the direct catchments mobilised soil transport and increased the overall sedimentation of the lake (Das and Jena, 2008). Coupled with the northward littoral sediment

drift, these changes led to the choking of the channel entrance from the Bay of Bengal. Average salinity within the lake reduced from 13.2 ppt (parts per thousand) in 1960-61 (Jhingran and Natrajan, 1966) to 1.4–6.3 ppt in 1995 (Banerjee *et al.*, 1998). This concomitantly led to a decline in fisheries, with the annual average landing declining from 8600 kg to 1702 kg between 1985-86 and 1998-99 (Mohapatra *et al.*, 2007). The area under weeds increased from 20 km² in 1972 to 523 km² in October, 2000 (WISA, 2004). Introduction of shrimp culture, as well as overall decline in fisheries, led to a gradual breakdown of traditional resource management systems. There was an occupational displacement due to loss of fishing grounds of the traditional fishing communities, and resentment between traditional fishers and the immigrants (Dujovny, 2009). Chilika fisheries gradually converted from a “community-managed fishery” to “contested-common”, wherein non-fishers gradually exerted pressure for more fishing rights. The decline in ecosystem components and processes led to inclusion of Chilika in the Ramsar Convention’s Montreux Record in 1993.

Concerned over the rapid decline of Chilika, the Government of Odisha created the Chilika Development Authority (CDA) in 1991 under the aegis of Department of Forests and Environment, as the nodal agency to undertake measures for ecological restoration. The institutional design of the authority has the Chief Minister of the Government of Odisha as the chairperson. The governing body is constituted by secretaries of all concerned departments; political representatives as well as representatives of fisher communities. With financial support from the state government and the Ministry of Environment, several programmes were initiated, including treatment of degraded catchments, hydro-biological monitoring, sustainable development of fisheries, wildlife conservation, community participation, development and capacity building at various levels. In 2000, a major hydrological intervention in the form of opening of a new mouth to the sea was undertaken based on modeling, and stakeholder consultations.

The hydrological intervention, followed by an intensive programme of participatory watershed management, aimed to reduce the overall silt loading from the direct catchments. A series of awareness campaigns on values and functions of the wetland system, particularly amongst the villages and school children, were undertaken in participation with civil society. A visitor centre at Satapada was constructed as

a hub of these activities. Specific initiatives were also undertaken to manage tourism by building capacity of the boatmen association. To improve connectivity in island villages, a ferry services for people and vehicles was launched between Satpada and Jahnikuda, benefitting more than 70,000 people and drastically reducing travel time between Berhampur and Puri. CDA has also strengthened fishing infrastructure through the construction of landing centers and jetties. Woman SHG (Self-Help Groups) were organised and trained to undertake enterprises on manufacture of dry fish and crab fattening.

The restoration initiatives had several positive impacts for the wetland ecosystem. Restoration of marine flow by opening a new mouth to the Bay of Bengal in 2000 restored the hydrological regimes and re-established salinity regimes. Recovery of the fisheries and biodiversity was rapid. The average fish landing during 2001-14 was nearly 13,000 MT. The annual census by CDA reported an increase in the number of Irrawaddy Dolphins within Chilika from 89 to 158 individuals between 2003 and 2014, and an increase in habitat use, improved breeding, dispersal and decline in mortality rates. The sea grass meadows expanded from 20 km² in 2000 to 80 km² at present. An improvement of the Chilika habitat, in particular the increase in dolphins, has led to a resurgence of wetland tourism, which had dwindled due to degradation. The annual number of tourists visiting the wetland from 2000-2014 averaged 0.3 million — an increase of over 60% as compared to 1994-1999.

Based on the positive changes noticed in the ecological character, the Ministry of Environment and Forests requested the Ramsar Convention to remove the site from the Montreux Record. Following an advisory mission in December 2001, the site was de-listed and the intervention was recognised with the Ramsar Wetland Conservation Award and the Evian Special Prize for “wetland conservation and management initiatives”. Building on the knowledge-base developed and interventions so far, an integrated management planning framework has been developed to guide wetland management.

Restoration of Lake Chilika stands out as a unique effort benefitting biodiversity and ecosystem processes, as well as the livelihoods of dependent communities. Economic assessment of ecosystem services of Chilika was therefore included as one of the three case studies to:

- Assess economic benefits resulting from ecological restoration

- Determine cost-effectiveness of ecological restoration
- Identify models of community-based incentive mechanisms, based on improved ecosystem services and biodiversity values.

2.2. Biophysical Setting

Chilika is an assemblage of shallow to very shallow marine, brackish and freshwater ecosystems. The lagoon’s origin is attributed to a complex geologic process involving deposition of beach ridges and spits enclosing a body of sea water within the Bay of Bengal. Chilika formed a part of the Bay about 6,000 years ago, and served to be its gulf during Pleistocene. The current form of Chilika is attributed to successive recession of the coastline, aided by marine and fluvial dynamics over 6 –7,000 years (Phlegar, 1969).

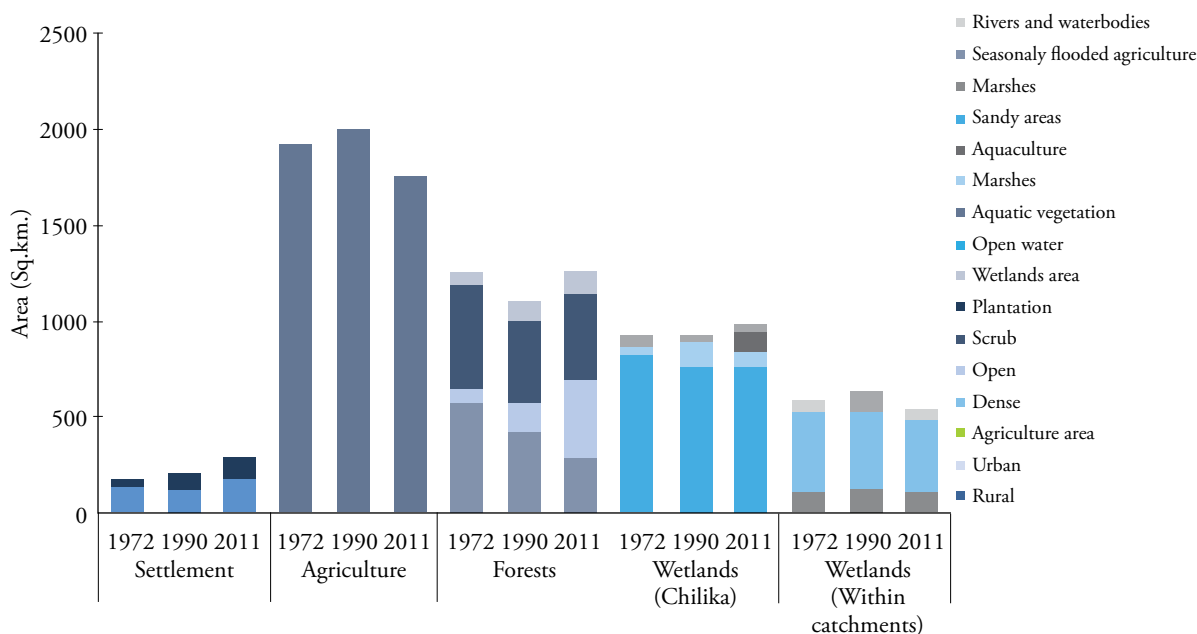
Lake Chilika forms a part of the deltaic segment of the River Mahanadi drainage basin. The total area of the direct basin, including the wetland, its islands and coastal strip is 5,020 km². Inflows into the wetland are received from Mahanadi River tributaries (Daya, Bhargabi, Luna and Makara), streams from the western catchments (1560 km²), runoff and irrigation drainage from the delta region (2250 km²).

The western catchments comprise rolling plains, mostly 30-150m above msl in the north; higher hills up to 600m in the northern and western parts (with laterite soils, and deep gullies and ravines interspersed

with alluvium-filled depressions); and a portion of the Eastern Ghats in the west and southwest at over 600m (Ghosh and Pattnaik, 2005). The delta fraction of the Chilika Basin is low-lying (less than 30m above msl) alluvial land dissected by the Daya, Bhargavi and Nuna distributary channels of the Mahanadi River, as well as rivers carrying only local runoff, in particular the Malaguni that drains into the Daya River.

Agriculture is the predominant land use, comprising 35% of Chilika’s catchment. Dense and open deciduous forests follow next, accounting for 33% of the land use. The area under forests is majorly confined to the hills of the Eastern Ghats, located on the crown of the western catchment. Lower elevations and alluvial plains are almost exclusively used for intensive agriculture. Rice and cashew are respectively the primary food and cash crops cultivated in the wetland catchments. The land use and land cover of the lake basin indicate a gradual intensification of developmental activities. Within the Mahanadi Delta, the overall dense forest cover has declined from 1,161 km² in 1975 to 920 km² in 2010, with an increase in open forest area from 2,127 km² to 2,442 km². Similarly, within lake basin, dense forests have been replaced by open forests, and agricultural land has turned into settlements and aquaculture in the last four decades (1972-2011) (Figure 3). The lake basin is inhabited by 2.58 million

Figure 3: Land use and land cover change in lake Chilika basin (1972-2011)



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 km² during 1971-2011, as compared to 140-236 persons per km² for the State of Odisha

The water regimes of Chilika can be broadly classified into three sub-systems. The freshwater flows are received through the tributaries of River Mahanadi and the streams of the western catchment. Flows from the Bay of Bengal form the third sub system, which connects to Chilika through the lake mouths (at Magarmukh and Gabakund) and the Palur Canal in the extreme south. River Mahanadi is the principal source of freshwater for Chilika. It creates a complex arc-like delta beginning at Naraj (near Cuttack), dividing into three distributaries, namely Kuakhai, Kathjodi and Birupa. Daya and Bhargabi, which are distributaries of Kuakhai, bring the Mahanadi flows to Chilika. The highly ravenous and gullied western catchment is drained by 47 streams, of which eight, namely Badaghati, Badanai, Badasankha, Kansari, Kusumi, Mangalajodi, Salia and Tarimi are the major ones. The flow in these streams is mainly during monsoons.

Lake Chilika, as indicated by hydrological monitoring data collected since 1999, annually receives 5,178 million cubic metres of freshwater from the river systems, of which 75% is contributed by the Mahanadi Delta river system. The flows received from Mahanadi delta system form around 6% of the undivided flows upstream of Naraj. The lake is also subject to sedimentation from its extensive catchments as well from the sea. The average annual sediment loading into the lake is 0.8 million metric tonnes, of which the Mahanadi system contributed 76%. The lake is filling with sediment 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.

The longshore sediment transport continues northwards throughout the year. Along the east coast, high annual littoral sediment drift (of the order of 1.2 million cubic meters) causes the sea inlet to continually shift northwards, leading to the 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.

Assessment of water quality parameters indicate that Lake Chilika is a shallow, well-mixed, nutrient-rich water body that is generally turbid and remains alkaline throughout the year. The lake is well oxygenated throughout the year due to its large size,

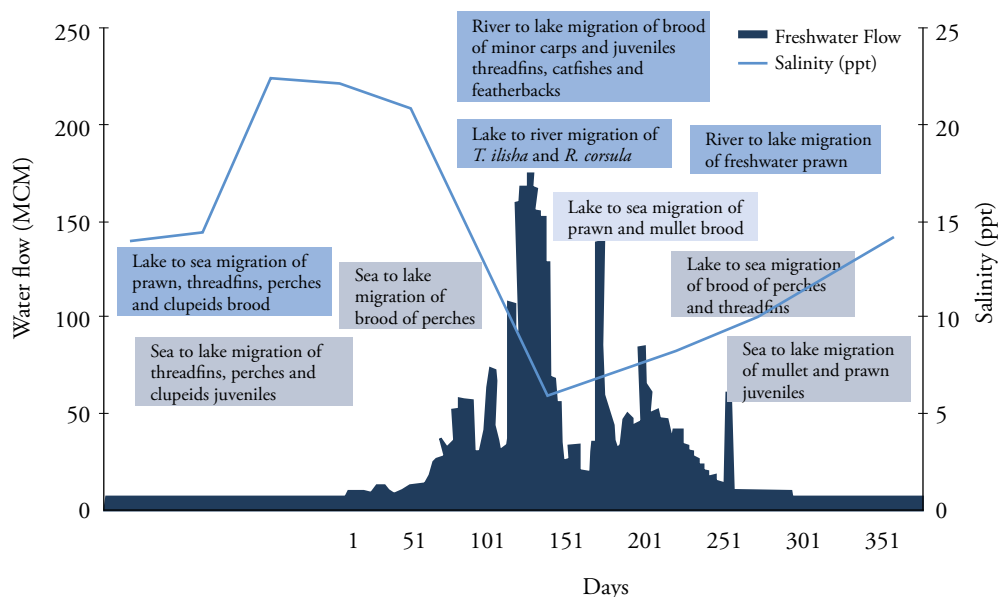
high photosynthetic activity and wind churning effects. A unique salinity gradient from the northern sector to the southern sector during monsoon and post-monsoon, and towards the outer channel in the pre-monsoon period is maintained in the lake. Notably, this gradient has been re-established after the hydrological intervention of September 2000, and has maintained since then.

Chilika and its fringe areas, along with the islands, are a habitat for 399 phytoplankton, 14 algae, 726 plants, 37 zooplankton, 61 protozoa, 6 porifera, 7 coelentrates, 29 platyhelminthes, 36 nematodes, 31 annelids, 136 mollusca, 31 crustacea, 31 decapoda, 5 echinoderms, 1 protochordata, 318 fish, 7 amphibia, 30 reptilia, 225 birds and 19 mammals. The lake is also a habitat for some rare and endangered species.

During 1990, reduced salinity and increased nutrient load from the catchment greatly favoured luxuriant growth of a large variety of macrophytes in Chilika. As a result of reduction in salinity and depth in the northern sector, *Paspalidium Germinatum*, *Ceratophyllum Demersum*, and *Panicum Repens* were restricted to areas with higher depth and salinity, in the southern sector (Mohapatra, 1998). Post hydrological intervention, within the northern sector, the salinity remains within 5 ppt during monsoon and winter, but increases during summer to about 15 ppt. With the revival of the salinity regime of the lake, the area under *Eicchornia Crassipes* rapidly declined, which increased the weed-free area from 333 km² to 505 km². However, there was a rapid increase in the area under *Phragmites* (which is known to tolerate salinity upto 18 ppt).

Lake Chilika provides a suitable habitat for a range of catadromous, anadromous and endemic finfish and shellfish species. As per assessments by CDA, Chilika harbours 318 fish species belonging to 83 families and 20 orders. Of this, 59 are true freshwater, 76 are marine and 182 are euryhaline species. In addition to this, 29 species of prawn and 35 species of crab are found in the lake (Satpathy and Panda, 2009). Overall, 73 species contribute to the commercial landing (species contributing more than 1% to the total landing) (Mohapatra *et al.*, 2007). 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 patterns of catadromous and anadromous species are triggered by salinity changes (Figure 4).

The annual total fish, prawn and crab catch from Chilika ranged between 9,955 and 14,050 MT during 2001-2015. There was a sharp fall in yield during

Figure 4: Relationship between flow pulses, salinity changes and fish migration in Chilika

1985-1999 (from an annual total landing of 8,669 MT to 1,745 MT). The hydrological intervention has played a distinct positive role in restoring the catch. 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 indicated that the system could sustain a catch of 1,053-1,158 MT/month, i.e. 12,636-13,896 MT/year (CIFRI, 2006). The current production levels almost match up to the potential yields.

Orcaella Brevisrostris (Irrawaddy dolphin) is the flagship cetacean inhabiting Lake Chilika. Chilika is one of only two lagoons in the world that supports Irrawaddy Dolphin populations, the other being Lake Songkhla in Cambodia. The species is found confined within Asia, between Chilika and Indonesia. Irrawaddy dolphins are globally threatened, but have an increasing population in Chilika. In 2014, the total population was estimated to be 158.

Chilika is known for harbouring a range of bird species, which apart from being a key component of its biodiversity, are also a tourist delight. Assessment of diversity and the number of birds in Chilika has been systematically carried out by Bombay Natural History Society (BNHS) since 2000. Lake Chilika provides habitat to 224 bird species belonging to 50 families (ibid), including 129 waterbird species belonging to

19 families. 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 Srepera*) 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 Leucorhphus*), Indian Skimmer (*Rynchops Albicollis*), Spoonbill Sandpiper (*Calidris Pygmeus*), Lesser White-fronted Goose (*Anser Erythropus*) and Great Knot (*Calidris Tenuirostris*).

Congregation of birds helps in recycling the nutrients back into the system through guano droppings. 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 fact that Chilika has established into a new ecological regime post hydrological restoration was tested when the region was hit by a severe tropical cyclone on October 12, 2013. Strong gales, torrential downpour, and floods churned the entire wetland and shifted it once again towards predominantly freshwater conditions, prevailing for over three months. The sea grass beds were heavily damaged, and so were the ecological habitats. A third inlet was opened between the existing Dhalabala and Gabakunda

inlets. However, ecological monitoring during the last year has indicated maintenance of fish catch levels, reestablishment of sea grass beds, and restoration of salinity dynamics.

2.3. Socio-economic Settings

The shorelines of Chilika are densely populated, especially on the southern, central and northern sector margins. There are 424 villages within 2 km of the wetland boundary (including all island villages on the seaward side), falling within eight blocks of three districts (namely, Puri, Khurda and Ganjam). Livelihood systems prevailing in and around Lake Chilika are mainly related to fisheries, agriculture, petty business or the government sector. Fishery-based livelihoods include fishers, small time fish traders (who procure fish from the fishers/local markets and sell in areas adjoining Chilika), 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 livelihoods of 64% of the working population (Table 1). Agriculture follows next, being the primary occupation of 27% of the population. The rest draws sustenance through employment in the private or government sector and/or undertaking petty business. The northern and central sectors, fed by Mahanadi Delta Rivers and western catchment tributaries have relatively higher proportion of the population dependent 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. Fisher settlements are dispersed over 152 revenue villages. Their overall population in 2009 was 403,356, of which the fisher households formed 36%. 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 was around 2,900.

Organised fishing in Chilika dates back to the 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. The fishers established a unique system of governance 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 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 organisation called 'desh', responsible for settling disputes, administering common property resources and organising collective fishing for communal purposes (Samal and Meher, 2003). Presently, Primary Fishermen Cooperative Societies (PFCS) are the key community institutions that influence fishers' efforts and local management within the wetland. These institutions were nearly decimated due to onset of highly commercial and capital-intensive shrimp farming by non-fishers, but have reemerged due to strategic efforts made by CDA and the Department of Fisheries.

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

Table 1: Occupational profile of community living around Chilika Lake

	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%a

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 the opening of a new mouth. The communities initially engaged in protests, but were soon to invest in tourism, building on the fact 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. Mostly called the tourist motorboat associations, these community institutions have taken up the task of assigning tourists to the member boats, liaising with the taxi drivers to ensure a steady inflow of tourists to the association and in certain cases, maintaining infrastructure such as boat jetties, fast food joints, toilets and other amenities. The members of the association are mostly caste fishers (90% of the membership). 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.

The average annual household income was assessed to be ₹26,403, or a per capita annual income of ₹4,632. 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 the jobs that 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).

Incomes are strongly correlated to asset ownership. Fishing within the lake is a collective activity. A typical fishing expedition involves 4-6 fishers per boat, each getting an equal share of the catch value. Agricultural land provides an important means of asset diversification to households. Presently, 30% of the households own land, with the average landholding being 1.5 acres per household. Fish agents have the maximum proportion of households owning land (92%), followed by agriculture farmers (40%). On an average, 69% of the households are indebted. Indebtedness is particularly high amongst

the agriculture farmers (83%) and fishers (74%). Most of the loans are sourced from informal credit sources, i.e local money lenders (74%) and friends and relatives (24%). Formal credit institutions such as banks, are used for the purpose of taking credit by only 26% of the respondent households. The average amount of loan taken per indebted household was estimated to be ₹24,232, which is almost comparable to the annual household income from fisheries (₹24,006). Of this, an average of 83% was provided by informal sources (majority being local money lenders (68%), followed by relatives and friends).

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 schools, the proportion of villages with middle and high schools was 81% and 73% respectively. There were 17 institutions imparting technical/vocational courses.

In general, the coastal areas of Odisha have very low sanitation. Within the survey, this was reflected in low proportions of households having separate toilets (22%), a 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 the service sector) had better sanitary 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, 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 water-borne diseases such 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 within these villages is very low. Nearly half (49%) of the houses have electricity, 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 a socio-economic survey by JICA, drawing drinking water for household use and fuelwood collection were rated the highest among all sectors.

There has been rapid development of infrastructure related to fisheries. 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.

The trend of change in livelihood assets that emerges from the data indicates that the period up until 2000 was one of declining natural resource productivity and diminishing social and financial capital. The hydrological restoration led to increase in fisheries and thereby improved natural resource productivity compared to the conditions in 2000.

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 debt. Trends in human capital are positive. Similarly, there has been betterment of several components of physical capital; however, aspects of water, sanitation and hygiene remain a cause for concern.

2.4. Ecosystem Services

The dynamic ecological components and processes of Lake Chilika underpin its wide range of ecosystem services. The key provisioning services include commercial fisheries, aquatic vegetation for economic use and a means for inland navigation. The ability to

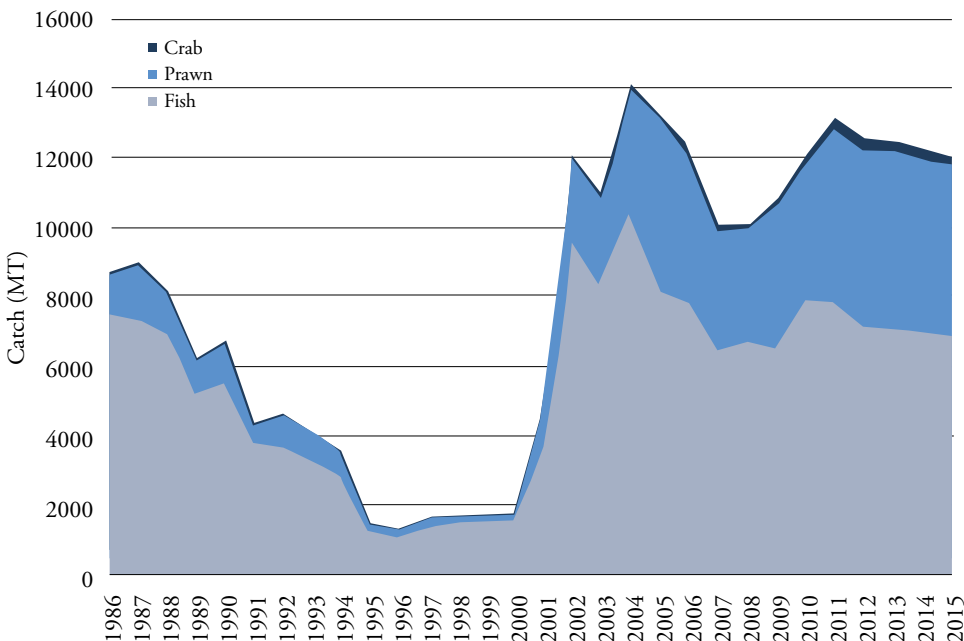
regulate hydrological regimes is an important regulating service provided by Chilika. Cultural services in the form of religious as well as the value of tourism are key sources of sustenance.

2.4.1. Fisheries

Lake Chilika harbours 73 fish, prawn and crab species of commercial value. The annual average harvest of 11,958 MT (average for 2001-15) supports livelihoods of 0.14 million fishers living in 152 villages spread around Chilika (Figure 5). There are 34,700 active fishers that fish for over 220 days in the wetland. Of the total landing, 24% is sold in and around Chilika, 21% in Odisha State, 47% exported to states outside Odisha and the balance 8% is exported to international markets. Fishing is organised along a complex market chain, involving middlemen and commission agents. The annual catch is also close to maximum sustainable yield, underlining the need for management.

Chilika also contributes to off-shore fisheries, as several estuarine fish and prawn species use the wetland as spawning and breeding habitats, and finally migrate towards the sea. The existing body of research on species-specific recruitment is limited, and thereby quantification of the contribution of Chilika towards fisheries has not been attempted.

Figure 5: Trend in Chilika fish catch (1986-2015)



2.4.2. Aquatic vegetation

Chilika Lake harbors 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. *Schoenoplectus Littoralis* (Sipala) is used by fisher communities located near Bhushundpur village, to make mats, *Phragmites Karka* (Nala Dala) is used as fuel by villagers on the northern shores, *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*, a agar producing algae, is another species of economic importance. Three seaweed derivatives viz. agar, alginates and carrageen, are currently utilised for economic purposes. Besides, they have great ecological value as a natural habitat for crabs and other related species. As per an assessment in 2007, over 58,000 MT of vegetation are harvested for the above mentioned uses.

2.4.3. Inland Navigation

Chilika is used as mode of inland navigation, especially by the island villages. For several of them, this is the only mode of communication. This is a source of revenue generation for the government, as well as for the private boat operators who ferry the passengers from one sector of the lake to the other. During 2003-14, over 35,000 passengers used this mode of transport on an average annually.

2.4.4. 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 for buffering floods and impacts of extreme events. This was evident during Phailin, wherein the wetland absorbed a significant proportion of cyclonic impact, thereby reducing impact on neighboring villages. Regulation of the salinity gradient also underpins productive fisheries and maintenance of the habitat for a range of species. For example, extensive sea grass beds inside Chilika need appropriate salinity levels to exist.

2.4.5. Cultural Services

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 into the state. Balugaon, Satpada and Rambha are the 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 the local boatmen. Babakundaleswar Temple is located near Manikapatna and Narayani, Bhagbati and Dakshya Prajapti Temples are located near Barakul, also important religious sites located in and around Chilika. Bird Island, a rocky island in the southern sector of the lake has huge hanging rocks covered with herbs, shrubs and creepers that are inhabited by numerous resident and migratory bird species. Somolo and Dumkudi, located within the central and southern sectors of lake and the inundated remnants of the 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, entrenched with sand dunes, are ideal spots for nature lovers. Irrawaddy Dolphin sightings near Satpada are an important component for visitors to the lake.

The trend of tourist arrival at Chilika for the period 1994-2013 is indicated in Figure 6. As is evident, the average number of annual tourist arrivals since the hydrological restoration of 2000 is 85% more than the 1994-99 period. Ecological restoration and habitat management measures have also resulted in the maintenance of a healthy population of Irrawaddy Dolphins in the wetlands (Figure 7).

2.5. Economic Valuation of Ecosystem Services

In the current section, the economic value of fisheries, aquatic vegetation, inland navigation, tourism and non-use benefits are presented. The value of regulatory

Chilika Lake harbors a rich diversity of aquatic vegetation and is used for inland navigation, buffering flood and the impacts of extreme events, a variety of cultural services, and, increasingly, tourism

Figure 4: Trends in tourist arrivals in Chilika (1994-2013)

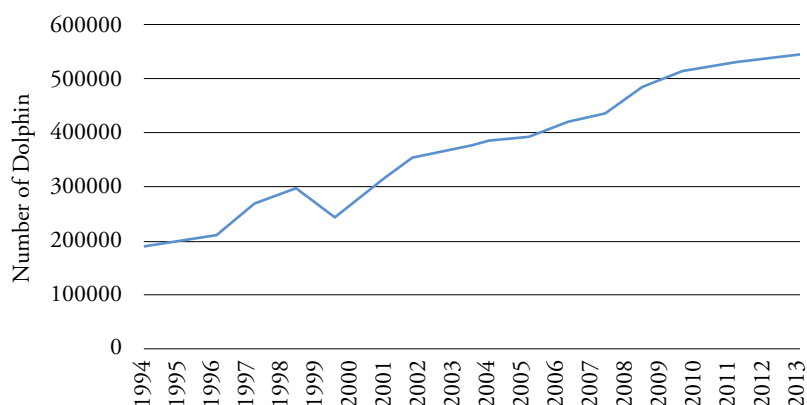
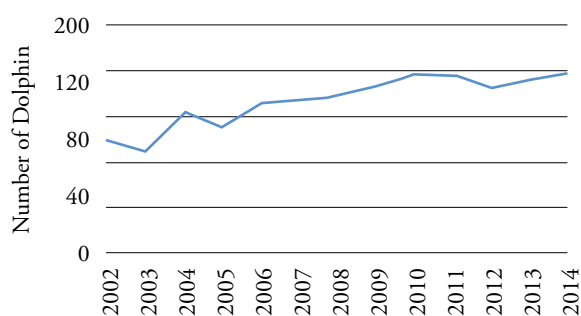


Figure 5: Trends in Irrawaddy Dolphin population in Chilika (2002-2014)



ecosystem services has not been attempted due to absence of quantifiable indicators.

2.5.1. Fisheries

Fish being a marketed commodity, can be valued using the market price method. The average annual catch in the last five years represents a reasonable picture of state of wetland fisheries. During 2011-2015, the total annual catch was estimated to be 12,465 MT, of which fish, prawn and crab species constituted 57%, 40% and 3% respectively.

Prawns are the most valued component of Chilika fisheries. Of the total catch, 43% is exported to international markets, with the trade almost restricted to three species, i.e. *Penaeus Monodon*, *Fenneropenaeus Indicus*, *Metapenaeus Monoceros* and a very limited proportion of scampi. It may be noted that the current landing data excludes harvest from illegal prawn farms located on the southern and outer channel of Chilika. Around 26% of total prawn landing is exported to

states outside Odisha, whereas 23% is consumed in and around Chilika. A small proportion of the total landing (8%) is traded in the western and southern districts of Odisha.

Chilika fish is traded in three forms, i.e. fresh fish (98.14%), live fish (1.03%) and dry fish (0.83%). The fresh fish component includes the landing in two island villages, Maluda and Jadupur. They receive fresh fish directly from the fishers and therefore do not form part of the catch landed at any of the 18 landing centers. 47% of the total catch is exported to atleast 8 states, i.e. West Bengal, Jharkhand, Delhi, Madhya Pradesh, Tamil Nadu, Gujarat, Kerala and Andhra Pradesh. Local consumption, which includes through markets around Chilika and consumption by the fishers, forms the next major category (40%). 14% of the total fish catch is also traded within the western and southern districts of Odisha State.

Local consumption mostly comprises cat-fishes and lower values fish, whereas the ones exported out of state are of relatively higher value. The live fish trade is almost exclusively focused on markets outside the state, with around 95% sent to West Bengal and the rest to Andhra Pradesh. This form of trade constitutes 22% and 30% of total murrel and featherback catch from Chilika. On similar lines, dried fish is largely traded within the states (but outside markets around Chilika).

The opening of a new mouth and subsequent shortening of the distance between the sea and the main lake has led to distinct creation of crab fisheries in Chilika. Of the total catch, 52% is exported to states other than Odisha, whereas 48% is consumed within the state (including within Chilika).

Estimation of gross economic value is based on

the value realisation to fishers through sale to retailers, fish cooperatives and commission agents. Data on trade location and quantity sold in each market segment has been compiled from primary records of CDA. Quantity weighted prices have been estimated for each market segment. As per the assessment, the gross annual value of fish catch is estimated to be ₹1463 million. The gross annual value of the catch, which is incremental over the pre-restoration period (average for 1996-2000) is estimated to be ₹1,275.19 million. (Table 2)

2.5.2. Vegetation

Valuation of benefits emanating through the use of aquatic vegetation is based on the assessment of extent of resource harvest and use patterns. The extent of harvest

been valued at the cost paid for transportation of the material to the shoreline. Valuation of economically important plant species derived from Chilika is presented in Table 4.

2.5.3. Inland Navigation

Inland navigation within Chilika can be broadly divided into two segments. The first segment caters to transport needs of the island villages, which have limited road connectivity and have to primarily depend on water transport. The other segment caters to tourists. The tourist boats operate from four locations, i.e. Barkul, Balugaon, Satpara and Sipakuda. There are nearly 1,400 boats presently catering to this segment. Valuation of inland navigation benefits related to the tourist segment

Table 2: Estimation of gross economic value of Chilika fisheries

	Fish	Prawn	Crab	Total
Trade location (in MT)				
Within Chilika	2,610.36	995.07	-	3,605.43
Within Orissa State	859.40	326.27	185.18	1,370.85
Exported Outside Orissa State	3,677.76	1,341.75	154.02	5,173.53
Exported to international markets	-	2,315.75	-	2,315.75
	7,147.52	4,978.84	339.21	12,465.57
Quantity sold to (in MT)				
Retailers	765.08	536.08		1,301.16
PFCS	5,079.73	3,529.99		8,609.72
Commission Agents	1,302.70	912.78	339.21	2,554.69
Quantity weighted prices (per kg)				
Retailers	₹94.12	₹214.28	₹165.60	
PFCS	₹78.43	₹178.57		
Commission Agents	₹62.13	₹131.58	₹138.00	
Gross Value (in ₹ Million)	551.35	865.33	46.81	1,463.48

of the four species based on the survey is depicted in table 3.

Valuation of the use of *Schoenplectus Littoralis* for mat making is based on the price of the final produce, i.e. the mat. Trade mainly takes place within major towns and cities. Trading of mats takes place through a series of middlemen, the largest market being Bhubaneswar. Therefore, average prices at Bhubaneswar have been used for the present purpose. Valuation of the use of *Phragmites* is based on the opportunity cost of time valued at the prevailing wage rate. Use of plant species as packing material has

Table 3: Economically important plant species harvested from Chilika

Species	Use	Annual harvest (MT)
<i>Schoenplectus littoralis</i>	Mat making	3,836.00
<i>Phragmites karka</i>	Fuel / Roofing	54,878.04
<i>Potamogeton pectinatus and Naja sp. (Chari dala)</i>	Packing material for fisheries	1,985.76

Table 4: Value of economically important plant species harvested from Chilika

Species	Valuation Method	Economic Value (₹ Millions)
<i>Schoenplectus littoralis</i>	Value of finished produce	9.59
<i>Phragmites karka</i>	Opportunity cost of time in collection	20.75
<i>Potamogeton pectinatus and Naja sp. (Chari dala)</i>	Opportunity cost of time in collection	3.97

is included within the assessment of consumer surplus derived from tourism. Hence, the valuation aims at capturing the surplus gained from the domestic transport segment only.

Presently, 35,600 persons use Chilika as a mode of inland navigation, which leads to an average time cost saving of 4.5 hrs. CDA operates a passenger ferry between islands on a no-profit-no-loss basis. Since data on age and occupation profile of the passengers is not available, it is assumed that the proportion of working population within the passengers is similar to that of the regional average (42%). The value of opportunity cost of time, using wage rate accrued to the fisher (₹182/day), is estimated to be ₹13.6 million, which is almost comparable to the revenue generated (₹12.46 million).

2.5.4. Tourism

The Individual Travel Cost Method (ITCM) has been used to estimate tourism and recreational benefits from Chilika. Demand curves relating the annual site visitation rate to the visit costs, income, and other socio-economic characteristics have been developed separately for domestic and foreign tourists. Individual consumer surplus has been aggregated to the total site arrival for estimation of the overall consumer surplus for the site.

A survey of tourists to elicit the overall economic value attributed to wetland-based tourism was carried

out in and around Chilika. Overall, 433 tourists responded to the survey, of which 36 respondents were of foreign origin and the rest were Indian nationals. The assessment of consumer surplus is provided separately for the two categories.

2.5.5. Estimation of Consumer Surplus for Domestic Tourists

The following double log demand function was found to be the best fit, with annual visitation rate, derived from the number of visits made in the last 10 years, being the dependent variable: (Table 5)

An assessment of the model indicates that the predictors do a fairly good job of predicting the dependent variable as indicated by high R square values. The ANOVA test with a high value of Fisher’s Statistic and low p value indicates that the independent variables do a good job in predicting the dependant variable. Based on the signs of the independent variable coefficients and their significance, the visitation rate has been observed to be negatively related to distance, group size and per person trip cost. The demand curve estimated from the regression is presented in Figure 2.6.

The individual consumer surplus is given by:

$$CS = (e^c * \overline{trip_dur}^{\beta1} * \overline{dist}^{\beta2} * \overline{jour_pur}^{\beta3} * \overline{gsize}^{\beta4} * \overline{income}^{\beta5} * \overline{age}^{\beta6} * \int_{tc\ min}^{tc\ max} \frac{d(tc)}{tc^{\beta7}})$$

$$= (e^c * \overline{trip_dur}^{\beta1} * \overline{dist}^{\beta2} * \overline{jour_pur}^{\beta3} * \overline{gsize}^{\beta4} * \overline{income}^{\beta5} * \overline{age}^{\beta6} * \left[\frac{(tc)^{\beta7+1}}{\beta7+1} \right]_{tc\ min}^{tc\ max})$$

From the dataset, the tc max (maximum travel cost per person) and tc min (minimum travel cost per person) are estimated to be 3,750 and 75 respectively. Substituting the values in the equation above, we can rewrite the equation as follows:

$$\overline{CS} = 5.86 * \left[\frac{3750^{.819} - 75^{.819}}{.819} \right] = 5806.82$$

35,600 people currently use Chilika as a mode of inland navigation, with an average time cost saving of 4.5 hrs, thus generating a time-opportunity cost of ₹13.6 million

Table 5: Regression coefficients (Domestic Tourists)

Parameter	Coefficients	t (Significance)
(Constant)	4.303	7.995 (.000)
Ln (Trip Duration)	-.108	-1.426 (.156)
Ln (Distance)	-.420	-9.963 (.000)
Ln (Journey Purpose)	.147	1.728 (.086)
Ln(Group Size)	-.173	-3.760 (.000)
Ln (Income)	0.016	.397 (.682)
Ln (age)	.102	1.059 (.291)
Ln (Trip cost / person)	-.181	-4.616 (.000)
Adjusted R ²	.540	
DW Statistic	1.948	
N	179	
F Statistic and significance	28.674 (.000)	

The annual average consumer surplus based on the demand curve has been estimated to be ₹5,806.82

2.5.6. Estimation of Consumer Surplus for Foreign Tourists

The overall sample size for the foreign tourists was not large; only 32 responses were received, of which 31 were further analysed for development of demand function. The double log function, of which the estimation parameters are presented in table 6 below, was found to be best fit for the data:

The regression model has low levels of predictability. Of the various parameters, only trip cost per person influences the visitation rate negatively. The demand curve estimated from regression is presented in Figure 9.

From the dataset, the tc max (maximum travel cost per person) and tc min (minimum travel cost per person) are estimated to be US \$20,000 and US \$250 respectively. Substituting the values, the equation can be rewritten as follows:

$$\overline{CS} = 1.6015 * \left[\frac{2000^{.775} - 250^{.775}}{.775} \right] = 2686.56$$

Table 6: Regression coefficients – International tourists

Parameter	Coefficients	t (Significance)
(Constant)	0.718	0.211 (.835)
Ln (Group Size)	-0.0064	-0.41 (.685)
Ln (Income)	-0.126	-0.579 (.568)
Ln (Age)	0.273	0.652 (.521)
Ln (Trip cost per person)	-0.225	-3.136 (.005)
Ln (Journey Purpose)	-0.008	-0.256 (.800)
Ln (Trip Duration)	-0.004	-0.385 (.704)
Adjusted R ²	.455	
DW Statistic	2.240	
N	31	
F Statistic and significance	32.05 (.020)	

The annual average consumer surplus based on the demand curve has been estimated to be US 2,686.56, which is ₹170,597 at the current exchange rate.

2.5.7. Aggregate Consumer Surplus

The aggregate consumer surplus has been estimated based on average arrivals during 2010-2013. (Table 7)

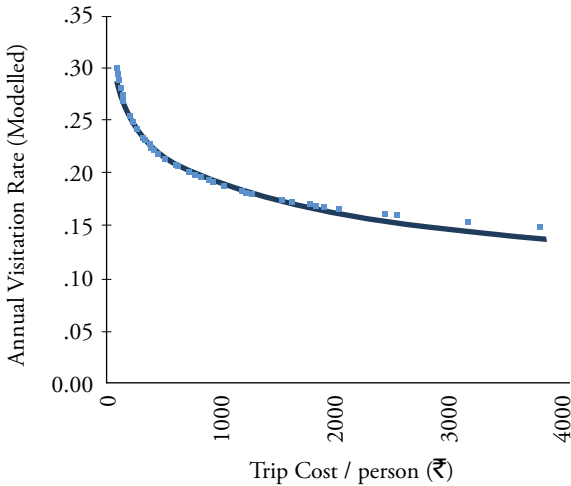
2.5.8. Non-Use Benefits

Estimation of consumer surplus derived from non-use benefits of the lagoon ecosystem is based on analysis of the closed-ended data, used to generate the mean willingness to pay for biodiversity. The WTP was assessed using a logit model to identify the determinants of the responses to the question: “Yes, I am willing to pay ₹ X” or “No, I am not willing to pay ₹ X”, where X

Table 7: Economic value of Chilika tourism

	Average WTP	Arrivals	Total Surplus (₹ Millions)
Domestic	5,806.82	521,326	3,027.34
Foreign	170,597	2,062	351.77
Total	176,403.82	523,388	3,379.11

Figure 8: Recreation demand curve for domestic tourists



refers to the amount of closed bid in each case.

The model relates the 1 (yes) and 0 (no) response variable to the bid levels faced by each respondent. The model generates coefficients to describe a curve that fits through the line in Figure 8 below, using the maximum likelihood model to describe the data.

The general form of the model is expressed by the following equation:

$$P_i = E(Y = 1 | X_i) = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_1)}}$$

Wherein, P_i is the probability of an individual i willing to pay the stated bid amount X . Using a logit regression to relate individual responses to the bid values results in estimates of coefficients β_1 and β_2 , which can be used to derive the mean WTP. The model output is presented below:

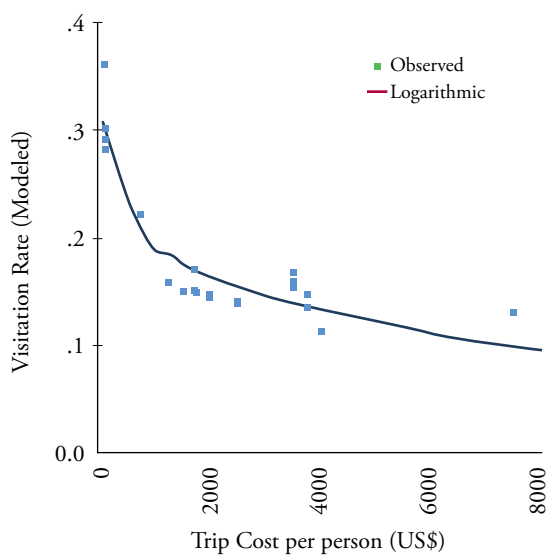
Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step	WTPLOG	-.005	.000	278.255	1	.000	.995
1 ^a	Constant	3.829	.244	247.022	1	.000	46.022

a. Variable(s) entered on step 1: WTPLOG.

The Hosmer and Lemeshow Test yields a significance value of .005, based on which we reject the null hypothesis that there is no significant difference between the observed and predicted values of the WTP. The Cox and Snell R Square and Nagelkerke R Square values have been estimated to be .382 and .509. The classification table indicates that the model estimates “No” and “Yes” values at 89.1% and 70.9%

Figure 9: Recreation demand curve for foreign tourists



correctly, with an overall percentage of correctness at 80.1 %. The model output indicates that the coefficient for WTPLOG (β_1 and β_2) is negative and significant, therefore the probability of accepting a particular bid level decreases with an increase in the bid amount. This is consistent with the theory. The estimated mean willingness to pay for the sample is ₹257.63. The predicted bid function from the sample is presented in Figure 11.

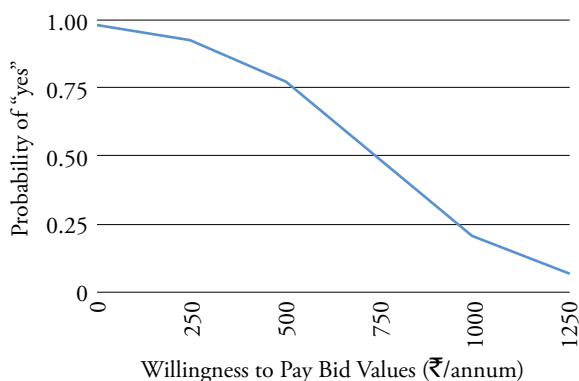
The aggregate non-use value, calculated by extrapolating willingness to pay, among the population of Bhubaneswar City, has been assessed at ₹166.952 million. An overall picture of use and non-use values of Lake Chilika, as assessed during the study, is reflected in Figure 9.

2.6. Management Costs

CDA is the designated agency instituted and mandated by the Government of Odisha for conservation and sustainable management of Chilika. Much of the investment for wetland management is funded by the state and national government at present and routed through CDA. Thereby the programmatic expenses of CDA present a realistic picture of costs to maintain Chilika’s biodiversity and ecosystem services values.

As per data on programmatic expenses of CDA from its inception in 1991 till 2012-13, the authority has invested cumulatively 1545.55 million towards watershed management, maintenance of hydrological

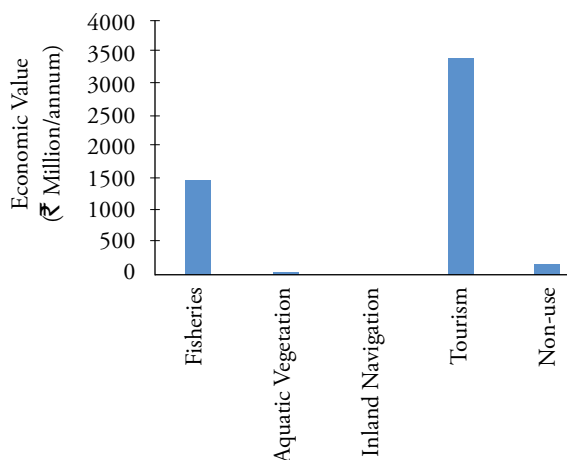
Figure 10: Bid function for non use values of Chilika



regimes, habitat conservation, community livelihoods, monitoring and evaluation, and communication and outreach. Figures 12 and 13 present the trends in programme expenditure (including cumulative expenses adjusted at a nominal rate of 5%) and programmatic components.

A majority of the funding (76%) has been received in the form of Grant-in-aid by the Finance Commission (tenth, eleventh, twelfth and thirteenth). The MoEFCC and the Government of Odisha have provided 5% and 7% respectively of the total programme funds so far. Of the total, nearly half (46%) is invested on maintenance of hydrological regimes (connectivity with the sea). One-fifth of the investment (19%) has been made on wetland monitoring and evaluation and another

Figure 11: Economic value of select ecosystem services of Chilika



one-fifth on fisheries development and livelihood improvement. As can be seen, the total costs are much lower than the annual flow of ecosystem services assessed in the previous section. In annual terms, the ratio of programmatic costs to ecosystem benefits is a minimum of 1:15.88.

2.7. Transforming ecosystem services benefits into livelihood outcomes

The impact of ecosystems services on livelihoods is mediated by the pre-existing institutional environment,

Figure 12: Trends in programmatic expenses of Lake Chilika (1991-2013)

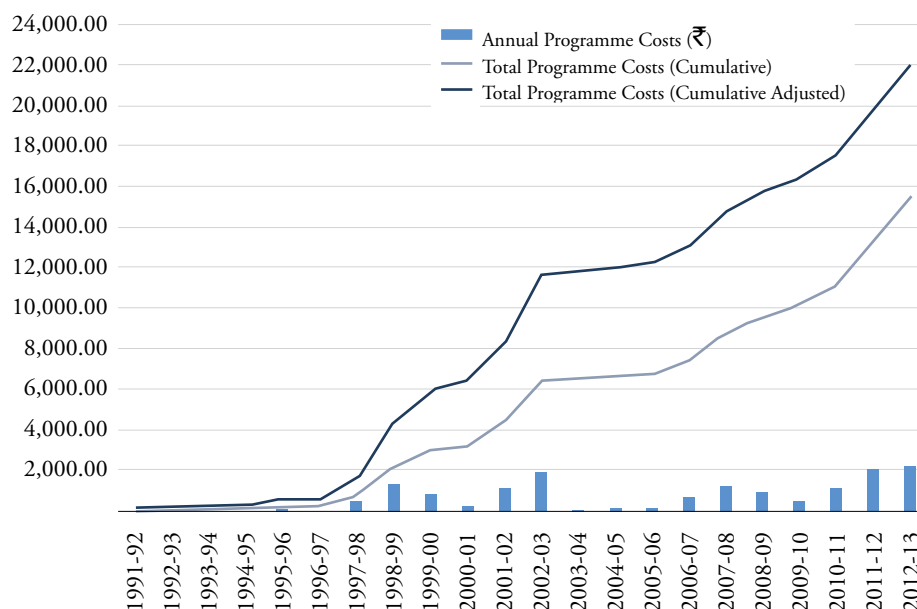
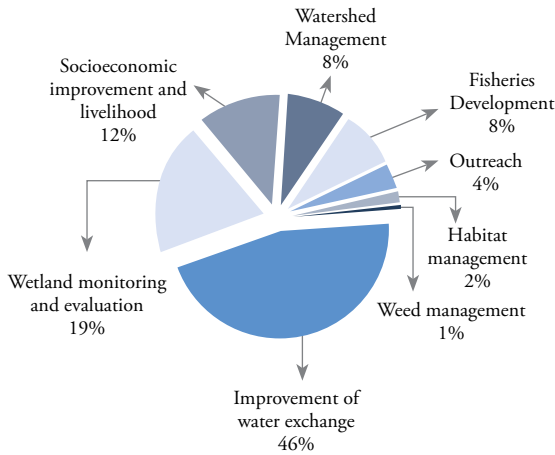


Figure 13: Component-wise programmatic expenses for Lake Chilika



which influence access and benefit sharing within communities. In Chilika, such interlinkages are particularly relevant in the case of fisheries and tourism related recreational benefits. CDA, within the larger ambit of integrated management planning, has undertaken measures to strengthen the role of community institutions so as to ensure that communities are incentivised for natural resource stewardship. In this section, the impact of interventions related to the strengthening of primary fisher cooperatives and community-managed ecotourism have been assessed.

2.7.1. Primary Fisher Cooperative Societies

Fisheries institutions influence the overall distributional equity related to Chilika fisheries. Ensuring effectiveness of Primary Fishermen Cooperative Societies (PFCS) is an important management goal for Chilika in the overall efforts towards promoting responsible fisheries.

2.7.2. History of Organised Fishing in Chilika

The rulers and administrators promoted 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

erstwhile administrators into over 300 fishing grounds, which were leased out to fishers on payment of revenue.

The emergence of Bengal as an important trade center in the early 19th century ushered in the role of traders in fisheries leasing. This prompted the government to ensure systems for organising collective fisheries, primarily with an objective of 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 until the later part of the 1950s. The fishery cooperative society in Chilika was established in 1942, with an objective of improving livelihoods of fishers and preventing exploitation in the hands of middlemen. By 1959, 25 Primary Fishers Cooperative Societies (PFCS) emerged around Chilika as the grassroots level of fishery institutions. 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.

2.7.3. Decline of Community-Managed Fisheries

The community-managed fisheries, since establishment, were under pressure due to entry of non-fishers, largely lured into the occupation in the interest of short-term monetary gains. Fisheries of Chilika gained the interest of Kolkata merchants in the early 19th century, who used to take leases from the fishing source owners and sub-lease to fishers at higher rates. After the abolition of estate, the non-fishers were allotted a small share of dian and jano fisheries. Das Committee 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.

The impact of ecosystems services on livelihoods is influenced by the pre-existing institutional environment, which shapes access and benefit sharing within communities

The introduction of shrimp culture, as well as overall decline in fisheries, brought change to institutions and freedoms of the fisher communities. With the introduction of new fishing gear and increased profitability from prawn farming, traditional caste–occupation relationships broke down

The introduction of shrimp culture, however, changed the whole market structure of Chilika fisheries. A steady increase in global demand of fish provided significant impetus to aquaculture development since the 1970s globally. Prawns, which had very little commercial value till the 1970s, came to be recognised as ‘pink gold’ (Kurien, 1992). Chilika, which had *P. Monodon* naturally occurring in the wetland system, caught attention of the aquaculture farmers in the 1980s. 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 profitability of shrimp farming included a devaluation of the Indian Rupee (Costanza, 1991) and the development of export markets. Trade liberalisation 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 because of high capital investment and dependence on trade chains for value realisation. The non-fishers gradually encroached upon the capture fishing area, deploying economic and political methods. The government also provided impetus to prawn aquaculture, and as a first major indicator, sanctioned a project for the establishment of a shrimp farm in 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 a joint venture between 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.

The 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 gear and increased profitability through prawn farming. Introduction of nylon nets and mechanised boats in the 1970s posed a major challenge to the traditional crafts and gear 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 fishers and non-fishers in a ratio of 60:40 (Ghosh et al., 2006). This decision was challenged by traditional fishers, who demanded a review of the judgement. The fact-finding committee established in response by the government, recognised the prevalence of a coercive culture fishing structure that 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 continues along more than 60% of the shoreline (2009 satellite images), especially in the southern sector and on the islands.

The CAFL also witnessed an unprecedented resistance from traditional fishers, non-fishers and others concerned about the environmental conditions of the wetland. The *Chilika Bachao Andolan* is 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 rallies, sit-ins and 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 seeking profit. The PFCS were crowded out by the merchants and shrimp farmers through subletting 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 Uthapani were merged into the prawn category and the rest into the latter. The lease term was once again reduced to one year, and a single value fixed irrespective of the productivity and area (₹9,300 for non-prawn sources, and ₹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

a 10% increase in the annual lease value. During 2001-2004, although 127 fishery sources were leased out by FISHFED, 15 were surrendered, since many PFCS were not interested in sub-leases due to unproductive nature and disputes on the source. Again, from the remaining 112 sources, nearly 30% were forcibly encroached upon by non-fishers and outsiders for illegal ghera operation. 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 a decline in marketing activities and financial support to the member PFCS.

The impact of middlemen on distribution of benefits from Chilika fisheries is elucidated in Table 8 below, constructed from Kumar et al (2011). It can be seen that despite a nearly five-fold increase in fish catch, the incomes of fishers increased marginally, and there was no discernible change in indebtedness.

2.7.4. Fisheries Resource Management and Impacts

In 2010, CDA in technical collaboration with Japan International Cooperation Agency (JICA), formulated a Fisheries Resource Management plan (FRMP) based on over 3 years of resource survey, assessment of the biology and ecology of eight commercially important high value fish, prawn and mud crab species; modeling for various conservation and management options; wide-range stakeholder consultations and ratification by an expert committee. The plan entails convergence in fisheries governance to ensure sustainable fish production through wise use of fisheries resources, as well secure livelihoods of fishers. Rejuvenating PFCS

Table 8: Changes in select socioeconomic indicators of Chilika fishers

Survey year	1999	2007
Number of fisher households	12,363	16,710
Number of active fishers	27,200	32,200
Average annual fish catch per active fisher (kg.)	64.2	309.2
Average annual income per capita in US\$ at 2011 prices	84	113
% households having outstanding loan	86%	88%
% loan sources from informal sector	71%	70%
Average amount of debt per fisher household (US\$ at 2011 prices)	398	738

Table 9: Details of PFCSs surveyed

Number Surveyed	8
Average number of members/Society	485
Average annual operational expenses (₹)	524,100
Proportion of total fish catch traded by society	71%
% members availing loans from the society	22%
Average loan amount per debtor	17312
Rate of interest charged by the society / annum	4.14%
Term of elected member	5 Yrs.
Average seed capital received per society from Government (₹)	914,000
% seed capital paid back	77%

Table 10: Quantity weighted prices (₹/kg)

	PFCS	Middlemen	% hike
Prawn	178.57	131.58	35%
Fish	78.43	62.13	26%
Crab	*	138	

* not traded by surveyed PFCS

has been identified as one of the major intervention areas in the FRMP.

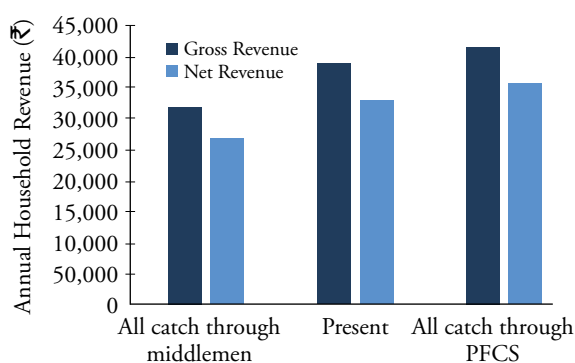
In July 2010, the state government established a Central Fishermen Cooperative Society (Chilika Fishermen Central Cooperative Society Limited or CFCCS) as an apex agency for managing Chilika fisheries. Under a pilot initiative, CDA, through the Fisheries and Animal Resources Department, is providing revolving funds, PFCSs and ice-boxes to its members, to revive the institution and ensure credit at fairer rates and terms. The cooperatives are being trained in bookkeeping and accounting. They are also being sensitised towards Code of Conduct for Responsible Fisheries.

In order to assess the impacts of measures undertaken on economic returns to the fishers, 8 PFCSs (3 from the Central Sector, 4 from the Northern Sector and 1 in the Outer Channel) was assessed (Table 9). Data on the society's operational costs, total fish handled, prices paid to fishers, cost of fishing equipment, and working capital were collected and analysed. To arrive at net values, the depreciated cost of fishing equipment, fuel and society expenses were reduced from the gross revenue accrued by the fisheries. The gross revenue generated by the fishers was estimated based on total catch sold by the members to society and a quantity

weighted price (estimates for fish, prawn and crab are presented in Table 9).

The society incurs costs towards maintenance of infrastructure, transportation, payment of loan installments, and conducting mandatory annual audits. These expenses are recovered by levying a nominal charge per kilogram of catch (₹7 for a kg of prawn and ₹5 for fish). Figure 14 presents the gross and net revenue realised per member fisher, for three scenarios. The present scenario corresponds to 71% the catch being traded through the PFCS and the rest through existing channels. These have been compared with gross and net revenues when the entire catch is traded through middlemen and PFCS respectively. It is assumed that the members are price takers, can sell the entire catch to middlemen or the PFCS, and face similar operational costs under the three scenarios. As can be seen, in terms of gross value, the current situation is at least 21% higher than the situation if the entire catch is sold to the middlemen, and is likely to be 30% if the entire catch is traded through the PFCS. In terms of net value, the current situation is at least a 21% improvement compared to the situation in which all catch was sold to middlemen, and a 32% improvement if all catch was traded through fisher cooperatives.

A substantial benefit is also accrued in terms of reduced interest for loan. The interest charged by middlemen, works out to be in excess of 24% per annum. The average debt per fisher household based on a 2009 household survey was estimated to be ₹24,159, which works out to be ₹32,375 in 2015 (adjusted for a 5% per annum increase). The cost savings in terms of lower annual interest outgo in percentages over the baseline situation (assuming of the total loan was to be sourced from middlemen), to the present situation (wherein of the 74% households needing debt, only 22% are able to source loans from the cooperative, and the amount availed is only 53% of the requirement)

Figure 14: Gross and net revenue per fisher household under three scenarios**Table 11: Average loan interest payment made per household**

	Annual Interest payment (₹)	% reduction over middlemen
Present	6,740	13.2%
If the entire loan is sourced from middlemen	7,771	
If the entire loan is sourced from PFCS	1,295	83.3%

has been estimated to be 13% (Table 11). If the entire loan were to be made available through the fisher cooperative, the cost savings would be 83% against the per household interest outgo of ₹7,771.

Data from the sampled PFCS indicates that the investments made in strengthening their operations have led to enhanced value realization to fishers (21% in net terms) and reduced loan servicing costs (13% over baseline). Making cooperatives financially viable is likely to bring in further reductions in debt servicing costs. However, for increased value realisation for catch, there is a need to improve prices paid to the fishers through improvement in value chain, and transferring market chain surplus towards these institutions.

2.7.5. Community-Managed Ecotourism at Manglajodi

The case of ecotourism at Manglajodi stands out as a community initiative for creating win-win opportunities for wetland conservation, as well as securing livelihoods of dependent communities.

Located along the northern shorelines of Chilika, Mangalajodi village fringes the marshy environment of the wetland's northern sector. Shallow depth, plentiful food and varied vegetation makes this area an ideal habitat for migrating waterbirds. The fishers of Manglajodi, once deriving livelihood from illegal waterbird hunting, presently sustain themselves on

community-managed wetland ecotourism, a venture under the aegis of their society, 'Sri Sri Mahavir Pakshi Surakshya Samiti (SSMPSS)'.

Waterbird hunting in Manglajodi flourished in the 1980s and 1990s. Manglajodi was specially known as an established source of illegally hunted Red-crested Pochards, transported to markets as far as Kolkata. The 25 members of the group earned significantly high income during the winter migration season, supplementing their meager income from fisheries. The efforts of Mr. Nand Kishore Bhujabal, an avid bird poacher from the region, who later transformed into a strong advocate for bird protection, played a catalytic role in waning fishers away from illegal hunting to ecotourism as a livelihood option.

Controlling illegal hunting of waterbirds was identified as a major issue within the restoration efforts of Chilika. CDA, with support of the local NGO Wild Odisha initiated a community based ecotourism programme in 1999 to curtail instances of illegal hunting and promote ecotourism as an alternate livelihood option. The establishment of SSMPSS was facilitated in 1999. CDA provided support for the construction of an office space, provided three boats to cater to the tourists, a watchtower, training for identification of birds, bird watching equipment and guides.

As the number of tourists visiting Chilika soared after the hydrological restoration, the number of footfalls to Manglajodi (which consistently supports large waterbird congregation numbers, next only to Nalabana) also increased. The community has since been making steady income from tourists interested in bird watching, much better than the income levels and risks associated with illegal waterbird hunting.

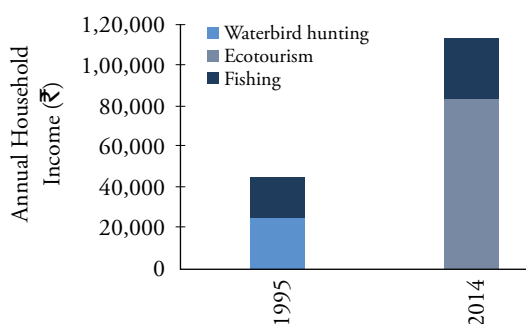
Presently, the area is visited by 5,000 tourists each year and stands out as one of the popular destinations for watching migratory waterbirds in a serene environment.

Apart from direct economic benefits, the initiative has resulted in improved habitat quality for migrating waterbirds. Over 50 species of waterbirds have been recorded in this area, of which over 30 are migratory. Community members provide protection to nests and eggs, and promptly report any damage to the society members.

There is a self-imposed regulation on use of motorised boats; only manual paddle boats are used for showing tourists around. Similarly, use of plastic is prohibited. The community also maintains regular watch and ward on the area through its three watchtowers. With the construction of Godwit Eco-Cottages, a private venture, serious bird watchers can

Table 12: Estimated household income (1995)

	Leader	Members
Numbers	2	23
Probability of being caught and prosecuted	0.6	0.17
Income per member from illegal hunting if not caught	₹80,000	₹25,000
Grease money paid when caught	₹10,000	₹5,000
Value of reduced catch if member caught and prosecuted	₹21,000	₹15,750
Probability weighted income from illegal waterbird hunting/ household	₹61,400	₹21,391
Income from fisheries	₹20,000	₹20,000
Average annual household income	₹81,240	₹41,391
Average annual household income (for entire group)	₹44,592	

Figure 15: Annual income patterns within communities of Mangalajodi**Table 13: Estimated household income (2014)**

	Peak Season	Remaining year
Tourists inflow (no.)	3500	1500
Boat rent		
Per trip	₹750	₹750
Of which to Guide	₹200	₹200
To Boatman	₹400	₹400
Towards Boat rent	₹100	₹100
Towards Society charges	₹50	₹50
Number of society boats	7	7
Number of external boats hired	13	10
Rent paid per externally hired boat	₹400	₹400
Number of daily trips per boat	2	1
Gross revenue to society members	₹2,700,000	₹11,47,500
Pay out to Society	₹369,000	₹171,000
Pay out to hired boat	₹936,000	₹360,000
Net Total revenue from ecotourism to members	₹1,395,000	₹616,500
Income / member	₹55,800	₹24,660
Total annual income / member from tourism	₹80,460	
Income from fisheries	₹32,000	
Total annual income/ member	₹ 112,460	

also stay overnight and enjoy local hospitality.

Efforts of SSMPSS are now widely recognised. Awards such as Pakshi Bandhu Puraskar (2001) and Biju Patnaik Pakshi Mitra (2007) have instilled confidence in the society to pursue and strengthen conservation efforts. CDA, in collaboration with BNHS, is implementing a long-term waterbird monitoring programme, to continuously assess the ecological health of the marshes as waterbird habitats.

Analysis of income patterns validates the direct benefits accrued to the communities due to livelihood transformation. Figure 15 captures the annual household income in two scenarios, one pertaining to 1995, wherein illegal hunting was rampant, and the second scenario pertaining to present situation. As indicated in Table 12, each household, on an average, earned ₹24,952 from illegal waterbird hunting. The income varied with their level of proficiency in trapping birds, with the 2 leaders earning a significantly higher income during season than the rest of the group. The risk of the leaders being caught and the consequent impact on the season's earning was also high. Adding ₹20,000 from fisheries, each of the 25 member households earned ₹44,952. The present income from ecotourism and fisheries based livelihoods translates to ₹112,460 per annum (Table 13), which is 2.5 times higher in absolute terms than the previous situation.

The ecotourism at Mangalajodi is presently low-key and environment friendly. However, to ensure that the communities continue to benefit from an improved environment, and to prevent their incremental gains being crowded out due to adverse anthropogenic impacts, it is important to integrate this model into a wider tourism master plan being developed for Chilika. It is also pertinent to ensure that the number of tourists visiting this ecologically fragile area is regulated so that waterbird habitats are not unduly disturbed. There is lot of scope for adding value to the existing tourism experience, such as enhancing bird watching infrastructure like hides and walkways, and building the capacity of fishers in interpretation skills. There is presently no direct engagement of communities in the operation of the accommodation infrastructure. Creating avenues for homestays would serve to enhance the overall experience, and allow tourists to engage in local culture and tradition.

¹ Heterogeneous masses of over 70 species of plants, soil and organic matter at various stages of decomposition.



3. Loktak Lake, Manipur

3.1. Context

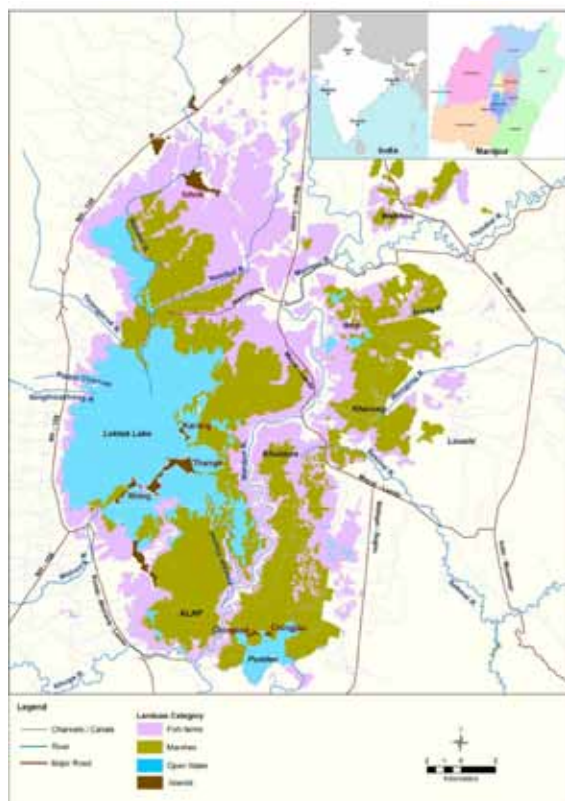
The floodplain wetlands of Manipur River, known as the Loktak Lake complex (encompassing Loktak, Pumlun, Ikop, Kharung, Khoidum and other satellite wetlands), are the lifeline of the northeastern state of Manipur. Spanning over 469 km² in Bishnupur and Thoubal districts within a basin of 6,872 km², these wetlands are the largest source of fish, edible plants and freshwater; providing water and food security for a large population dependent on wetland resources for sustenance. Loktak Lake, the largest wetland of the complex, is characterised by floating chunks of vegetation, locally called *phumdi*¹. Keibul Lamjao in the southern part of Loktak has a single contiguous mass of *phumdi* area, spanning around 40 km². It serves as a natural habitat for globally endangered ungulate species *Rucervus Eldii* (Manipur Brow Antlered Deer, locally called Sangai), and has been noted as a National Park since 1975. Loktak was designated by the Government of India as a Wetland of International Importance under the Ramsar Convention in 1990.

Sustained provision of ecosystem services of Loktak is critically linked to its hydrological regimes. Loktak, like other wetland ecosystems, is adapted to

the spatial and temporal variations in water depth, flow patterns, water quality as well as frequency and duration of inundation, which determine its ecological character. However, developmental planning in the Manipur River basin, particularly implementation of water resource development projects for flood mitigation, hydropower generation and irrigation, have led to severe modification of the natural hydrological regimes of Loktak. Construction of the Ithai barrage in 1984, entailing regulation of lake levels for hydropower generation, converted a naturally fluctuating wetland into a reservoir. This caused inundation of peripheral areas, loss of migratory fisheries, reduction and degradation of the national park habitat, and decline in water quality. Flood attenuation capacity was further impacted by increased silt load received from degraded catchments. Inadequate sewerage in the upstream urban centers led to the dumping of untreated sewage and sewerage into the lake, leading to a decline in water quality.

The application of economic valuation is intended to focus on assessing overall ecological and economic efficiency of policy decisions, and in particular identify options for water management that can balance water allocation for human purposes (hydropower and irrigation) and ecological purposes.

Map 1: Loktak Wetland Complex during 2010



3.2. Biophysical Settings

The Loktak wetland complex is a series of shallow and highly vegetated wetlands located in the southern part of Manipur Valley, along Manipur River (Map 1 and 2). The presence of depressions along the river channel, a semi impervious substrate, constricted outflow at Ithai and a sudden rise in the riverbed downstream Ithai at Sugnu, create conducive conditions for the maintenance of this extensive wetland regime, locally called pat areas. The margins of Loktak wetland complex are diffuse and merge on the exterior with fish farms and rice fields, with small hillocks marking the boundary on the southern end. Spanning between 24.40°-24.72° latitudes and 93.76°-93.99° longitudes, the complex is constituted by shallow waterbodies formed in the interfluvial areas. Different tributaries and hill streams connect with the main river channel.

Arising near Karong village in Senapati district, Manipur River flows southwards, wherein it is joined by River Iril on its left bank at Lilong (Loumnabi). The river continues its southwards course, wherein it is joined above the village Mayang Imphal by the Thoubal River on the left bank. Waithou, Punem, Aongbikhong

Map 2: Loktak Wetland Complex during 1970s



and Uchepekpi wetlands are located in patches between the confluences of River Thoubal and Manipur River.

Loktak Lake, the largest wetland of the complex, flanks the right bank of Manipur River between Ishok and the confluence of Khuga River. It comprises about 20 small and larger pat areas, of which Loktak, Takmu, Ungamen, Laphu, Thaumnumacha, Khulak, Yena and Tharapokpi are major. During rains, these pat areas become contiguous, but can be discerned as separate waterbodies as the water level recedes. Loktak is connected to Manipur River via the Khordak channel. Four islands, namely Thanga, Karang, Sendra and Ithing, are located in the central part of Loktak. The overall area of the wetland complex, using satellite imagery from 2010-11, has been assessed to be 466.5 km² (Table 14). Loktak Lake is the largest wetland of the complex, accounting for 61% of the total area.

Hydrological regimes of the Loktak are primarily defined by surface water flows received from the lake catchment of 4,947 km². The Manipur valley, spanning an area of 1500 km², with an elevation of 760-800m amsl, forms a bowl-like depression, surrounded by mountain ranges with steep slopes and incised drainage. The hills, with an elevation of 800-2500m amsl, are predominantly covered with forests (73.6% of basin

The lake levels play a crucial role in determining availability of water for hydropower generation, since water can be taken for hydropower generation only when the lake levels are higher than that of the power channel

area) of which only 52% has canopy cover over 40%.

Geologically, the hills comprise young rock formations of tertiary orogeny of the Himalayas. The valley bottom is covered in alluvium composed of clay and mud, derived from the weathering of argillaceous rocks and deposited by the rivers and streams flowing into the lower gradients.

Hydrological regimes of the Loktak wetlands are regulated by hydraulic structures both on the upstream as well as downstream rivers. All the major inflowing rivers are dammed for various purposes. While the western catchment flows directly into the lake, the flows from the Imphal, Iril and Thoubal basins are received into the wetland complex through Manipur River. Flows from the Heirok and Sekmai basins are largely diverted from the basin through irrigation schemes, limiting the effective catchment area to 4,241 km². The outflow of the lake is regulated by structures constructed under the Loktak Lake, a multi-purpose project aimed at controlling floods and reclaiming shallow areas of the lake for agriculture (PWD, 1967)². The project designed in 1967 also envisaged diverting lake waters for irrigating 12,100 ha (30,000 acres) of agricultural land and generating 70 MU of hydropower. Loktak and its associated wetlands were visualised as natural reservoirs of water, harnessed through the

construction of a barrage at the confluence of Manipur and Khuga Rivers. Water was diverted to a 105 MU hydropower generation station at Leimatak through a water conductor system adjoining Ningthoukhong town on the western margin of the lake.

Inflows to Loktak are received through 34 streams from the western catchments and Manipur River (via the Khordak and Ungamel channels), whereas the outflows take place through the power channel (for hydropower generation) and release through the barrage. Water balance of the lake³ for a full water year (2000-01 chosen based on availability of full and consistent data on various parameters) indicates an overall inflow of 1589 Mm³, of which western catchment streams and Manipur River contribute 55% and 21% respectively, the rest being rainfall. The outflows were estimated to be 1,156 Mm³, of which water abstraction for hydropower and releases from Ithai barrage account for 67% and 20% respectively. The balance 13% is on account of evaporation and evapotranspiration. During the period of May-October, the lake is a net store of water, which is then subsequently drained during the lean seasons. The control of Ithai Barrage on the overall outflows is apparent.

The lake levels play a crucial role in determining availability of water for hydropower generation, since theoretically, water can be taken for hydropower generation only when the lake levels are higher than that of the power channel. The Lake is quite shallow at its margins, and at its deepest portion, is only 4.5 meters deep. The Keibul Lamjao National Park (KLNP) at an average elevation of 766 m amsl, is 2.5m higher than the central part of the lake. The power channel, through which water is abstracted from the lake for hydropower generation is located at 766.2m amsl at the western margin of the lake. Overall, the lake level increases during monsoon (May-July) and then gradually declines. The annual range is a maximum of 2 meters, as compared to 3 meters in the pre-barrage situation. The decline in lake levels is however much more gradual than that observed before hydrological

Table 14: Seasonal variations in land use / cover within Loktak wetland complex

Land use / Land cover category	Area (in ha)	
	March 2010	January 2011
Open water	7657	9662
Marsh	28526	23761
Fish farms	3700	9486
Agriculture	4754	1728
Settlements	979	979
Forests	1049	1049
Total	46665	46665

² Water Balance = Surface Inflows (Stream input from catchments + Manipur River (via Khordak and Ungamel) + Rainfall) – Outflows (Abstraction for hydropower + Releases through Ithai + Evaporation + Evapotranspiration). The computation is still indicative as it assumes no groundwater interactions, and exchanges from other wetlands while being connected during the monsoon season. There is also direct abstraction of water for domestic usages. The lift irrigation scheme is currently dysfunctional and therefore has not been accounted for in the current equation.

regulation, with the levels maintained above 768m amsl for almost entire year. In contrast, the lake levels in 1956-66 did dip to levels below 767m amsl during the lean flow period.

Estimation of the water holding capacity of the lake was carried out in the year 2000. Accounting for the losses due to *phumdi*, islands and fish farms, the net capacity has been estimated to be 448 Mm³ at 768.5m amsl³. Bathymetric surveys carried out by WAPCOS in the 1980s indicated the capacity to be 600 Mm³ at the same water level. There are two apparent reasons for this loss in water holding capacity, i.e. siltation from the catchments and changes in land use, especially on the peripheral regions of the lake. The annual average sediment input into the lake has been estimated to be 650,000 MT, with the degraded hills of the western catchments accounting for 65% of the total yield. The natural profiles of the link channels have also undergone volumetric

reduction. After the construction of the Ithai barrage, the number of fish farms has increased tremendously in the peripheral regions of the lake. As per remote sensing imageries, the area under fish farms has increased from 97.6 km² (12,568 fish ponds) in 2003, to 107.48 km² (around 13,800 fish ponds).

The water quality of the Loktak Lake, in general, falls within class C to E as per the Central Pollution Control Board (CPCB) designated best use criteria. The lake water is not fit for direct drinking without treatment, but can be used for irrigation and ecological purposes. A comparative analysis of water quality of different zones indicates significant levels of pollution in the Northern Zone and Southern Zone.

High intensity of fertiliser usage in agricultural fields and the practice of fish farming contribute significantly to water quality deterioration in the Northern Zone. The Nambol and Nambol rivers also discharge pollutants in this zone. The Southern Zone is polluted, as all the pollutants flow finally here and get accumulated due to poor flushing. A large population of 0.28 million people living within the Nambol catchment generates 72.23 million tonnes of solid waste and 31,207 cum of sewage on daily basis. Nambol also contributes 4.9 million tonnes of solid waste and 2,121 cum of sewage annually. All the waste directly or indirectly find its way into Loktak Lake.

In KLNP, the pH value remains acidic, ranging from 4.5-8.5 at the surface and from 4.1-8.3 at the bottom. At some spots, its value remains below 6, which is unhealthy. Higher values of free carbon dioxide and low values of DO show relatively high process of respiration and decomposition over photosynthesis of phytoplankton and aquatic vegetation. This may be attributed to the fact that most of the areas are covered by *phumdi* and almost no light can penetrate inside the water.

Loktak wetland complex, with its numerous floating lands, covers a variety of habitats that sustain rich biological diversity. Available information on species richness collated from various sources, analysed for conservation status is presented in Table 15.

The Keibul Lamjao National Park located in the

Figure 16: Sangai deer population in KLNP

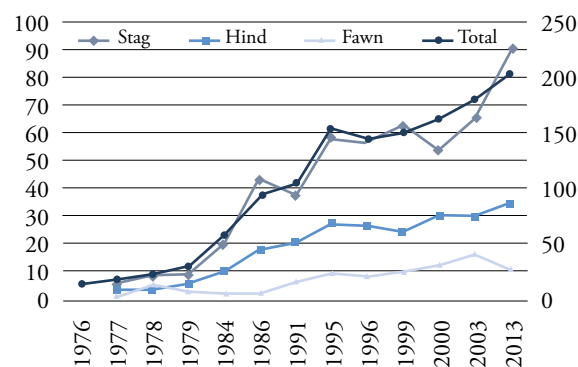
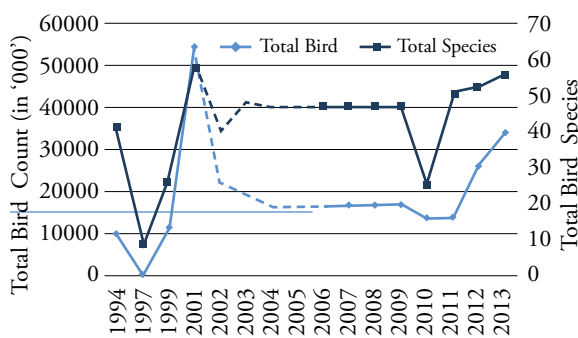


Figure 17: Waterbird population in Loktak Wetland Complex



⁴ While the overall capacity of the lake at 768.5 m amsl is 519 Mm³, 13% is reduced to presence of islands, *phumdi* proliferation and construction of fish farms.

southern part of the lake, is a unique floating wildlife reserve and is a refuge for the highly endangered brow antlered deer, locally called Sangai (Figure 16). The lake has also been the breeding grounds for a number of riverine fishes and continues to be a vital fisheries resource. It supports a significant population of migratory and resident waterbirds (Figure 17).

Closure of many feeder channels and regulation of the barrage has affected the upstream migration of fishes from Manipur River to Chindwin River. As a result, the seasonal appearance (during rainy seasons only) of *Labeo angra*, *L. bata*, *L. dero* and *Osteobrama belangeri* has declined. These species usually used the Nongmaikhong and other streams to enter the lake for breeding. Exotic catfishes such as *Clarias gueripinnus* and a riverine species *Aplocheilus punchax* have been recorded in the lake. Twelve fish species reported earlier by the Fisheries Department (1981) (Singh and Singh, 1994; Singh, 1996) have not been observed in recent studies, which is attributed to the blockage of migratory pathways of fishes.

The proximity of Loktak Lake to the Central Asian Flyway and East Asian Flyway makes Loktak an

important site for feeding, foraging and roosting of migratory waterbirds. Over 100 species and 40 major congregation sites of waterbirds have been recorded here.

3.3. Socio-economic settings

Loktak wetland complex forms a part of the Manipur Valley, which is the economic hub of the state. Physiographically, the valley region forms only 10% of the total geographical area of the state, but is inhabited by 59% of its population, giving rise to a high population density of 635 persons per km². Population trends indicate increasing pressure on the valley region, with the valley districts registering a decadal growth rate of 24.86 % in 1991-2001, against the national average of 21.56%. Meiteis constitute a majority of the valley population. The population in the hills is mostly of tribes, of which Naga, Kuki, Aimol are major.

There are 85 villages located around the wetland complex margins and the islands. Traditionally, fishing and farming formed the main source of livelihoods of these communities. Connectivity with the riverine environment ensured highly productive fisheries. As

Table 15: Record of species at Loktak Wetland Complex and their conservation status

Biodiversity		No. of Species	Observation period	Conservation State						
				CR	EN	VU	NT	DD	LC	NE
Flora										
	Phytoplankton	70	2002-2004							70
	Macro vegetation	130							34	96
Fauna										
	Zooplankton	171	2002-2003							171
	Annelids	15	1992-1993							15
	Molluscs	10	1992-1993						9	1
	Insect	7	Feb-Jul, 2008						3	4
	Fish	54					6		37	11
	Amphibia	28	1992-1993; 2004-2007					2	26	
	Reptile	40	1992-1993		1	3	1		9	26
	Aves	78				3	2		72	1
	Mammal	22			3		3		13	3

Conservation Status as per IUCN Red List of Threatened Species

CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near Threatened; DD=Data deficient; LC=Least Concern; NE= Not Evaluated

⁵ Tombi Singh (1994), Pishak Singh (1996)

the inundated area shrunk during winters, highly fertile floodplains were exposed and used for agriculture. Construction of the Ithai Barrage affected a major change in hydrological regime and triggered a shift in livelihood patterns. Operation of the barrage for maintaining lake levels around 768.5m amsl led to the submergence of large agricultural areas on the wetland periphery.

Permanent inundation induced a shift towards fisheries based livelihoods. As more people moved into capture fishing, crafts and gear became more exploitative. The period of the early 1990s witnessed an increase in the use of nylon nets of finer mesh sizes. Use of *athaphum*, a fishing technology using *phum* enclosures, as a fish aggregating device in open waters intensified significantly. Between 2000 and 2005, the number of *athaphum* in Loktak virtually exploded, and the government had to finally resort to the use of force to eliminate its practice in Loktak. Meanwhile, the marshes located on the wetland fringes were extensively converted for fish farms and permanent agriculture. Thus, in the last six decades, livelihoods transformed from being based on capture fisheries and seasonal agriculture, to those dominated by fish farming and agriculture, with capture fisheries greatly marginalised. Figure 18 shows the occupation profile of households living in different zones of the Loktak Wetland Complex.

Apart from providing a source of fish, the wetland complex provides a range of products that are used in the day-to-day life of these communities. In the absence of piped water supply, water from rivers and wetlands is an important source of water for several households. The complex also provides a means of navigation for these communities.

Besides direct and indirect occupational dependence on the wetland complex, the various ecological aspects and wetland features find inextricable reflections in social customs and belief systems. Varied references in local mythology, folklores, festivals and customs are a testimony to the connection that exists between Manipuri society and its most prominent wetland regime. These cultural linkages have formed the basis of several forms of local regulations, which have been important for wetland management in the past.

The average annual household income ranges between ₹0.74 and 1.92 lakh, with an average of ₹1.37 lakh. Annual incomes are higher wherein the proportion of communities engaged in fish farming is higher. The island communities reported to have the least income,

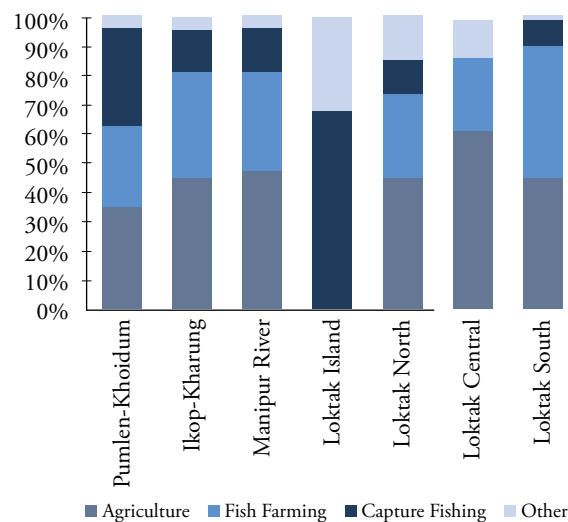
as opportunities for income diversification were lower.

Access to clean energy sources was observed to be low, with around 27% of households reporting to use LPG as the primary source of energy for cooking. Piped water was available to 33% of the people in and around the wetland. The rest depended on village ponds, rivers and lakes for their domestic water needs, the majority being culture and capture fishers. On an average, only 60% of the households had toilets in Pumlén-Khoidum and Manipur River. Only 45-50% of capture fishers households in the wetland complex had toilets. The Ikop-Khraung region reported 100% sanitation. Fish farming communities fared better in terms of individual asset ownership.

Community institutions (which include organisations as well as norms and belief systems that influence individual and social behaviour) have played an important role in the ecological status of the wetlands. The main organisation within the villages around the complex is the gram panchayat, headed by a pradhan (village head), and assisted by the upa-pradhan (assistant to the village head) and members in the management and administration of village affairs. It is an important instrument for dealing with matters concerning the activities of the local community. Often, the decisions are made collectively by the entire villager community, and not just the Panchayat. Leikai, informal village bodies, play an important role in making decisions about village affairs.

Meira Paibis (Women Torch-bearers) is a

Figure 18: Occupation profile in different zones of Loktak Wetland Complex



Historically, the kinship prevalent around the wetland complex enabled several practices that helped maintain various wetland values. In recent times, though, the extent of community influence in wetland management has been significantly reduced

prominent women's organisation of the society, which plays an important role in ensuring women's participation in economic, social and political spheres of daily life and in safeguarding their rights. They are known to fight for the rising disorder in the society by doing night vigils/patrols in their respective leikais (locality). Every leikai in Imphal, Thoubal and Bishnupur districts has a Meira Paibi. It comprises virtually the entire adult Meitei female population. A formal body exists comprising a president, secretary, treasurer and advisor. In several areas, fishermen groups have been formed which lease specific areas of the lake for fishing. There are several NGOs, CBOs and youth clubs that undertake developmental activities at the village level. Marups or informal savings credit groups are an important part of all societies, providing credit in times of need.

Historically, the kinship prevalent around the wetland complex enabled several practices that helped maintain various wetland values. Fishing during migration seasons was banned. During specific times in a year, the inlet and outlet channels were cleared of vegetation and silt. *Phum* spread in the central sector of Loktak and Pumlun were checked by cutting into small sections and draining through the outlet channels. While the national park was a game reserve, poaching of Sangai was considered to be criminal, to be punished by the chopping of both hands of the convict. These practices were instrumental in maintaining the various values of the wetland complex for a long time, albeit, during a period of low population and lesser demands on wetland resources.

In recent times, the nature and extent of the influence of community institutions on wetland management has greatly reduced. The whole process of implementation of the Loktak Multipurpose Project has been highly contested. Organisations such as the 'Loktak Project Flood Affected Association' contest the extent of rehabilitation offered after the project. Local communities had very limited say in either the design or implementation of the project, and were largely treated as beneficiaries.

There are several instances of conflicts related to the exercise of private land rights in and around the complex. Private land rights have been granted for the entire area of the wetland complex, barring those under permanent inundation. The enactment of The Loktak Lake (Protection) Act, 2006 has led to the demarcation of a core and a buffer zone within the Loktak area, wherein a range of restrictions apply. In 2011, when the entire central zone of the lake, which forms the core zone as per the Act, was cleared of *athaphum*, and a surge of protests were made against the government of Manipur and Loktak Development Authority (LDA). The action was perceived as an infringement of rights on a common property resource. Similarly, on the fringes, those with private land rights have been converting marshes into fish farms and agriculture areas. While the gains from such conversions are private, the damages in terms of lost ecosystem service values accrue to the entire society.

There are still some instances of positive action by community organisations. The self-imposed bans on destructive fishing practices (such as the use of explosives) and chemicals (such as endosulfan) are good evidences in this context. Several NGOs have become watchdogs for the implementation of projects related to wetland management, regularly airing their views through print and electronic media and communications to the ministry and other organisations.

3.4. Ecosystem Services

Communities living in and around Loktak and its associated wetlands have depended on lake resources for sustenance since historic times. The seasonal variations in inundations have supported agriculture in the dry season and enabled communities to harvest fishes, molluscs, aquatic vegetation and water in monsoon. There was an abundance of fish, fodder and fuel for cooking, vegetables and household construction materials in the wetland. The lake was managed on the community level and there was ample food security. Table 16 details the ecosystem services and their enabling bio-physical and socio-economic situations.

3.4.1. Fisheries

Loktak is the largest fishery resource of the Manipur state, and accounts for over half of its fish producing area. Fish is an important source of animal protein for the people of Manipur, and thereby occupies a distinct place in local traditions and livelihoods. A mix of capture and culture fisheries is practiced in Loktak Lake. The open water surface of the central sector is largely used for capture fishing by the villages living in and around the wetland. They use a range of gear, of which nets (gill nets with mesh sizes ranging 14-140mm, dip nets, cast nets, lift nets and scoop nets), multi-pronged spears, line and hooks, and traps are the majority.

The marshes around the lake, particularly in the northern sector, have been extensively converted for culture fisheries, which produce a substantial amount of Indian Major as well as exotic carps. *Athaphum* fishing gained prominence, particularly after the construction of Ithai Barrage, but has been declared an illegal activity under the Manipur Loktak Protection Act (2006). The farmers were offered a one-time compensation as an incentive to abandon the practice, subsequent to which the *phum* circles were mechanically removed from 2009 to 2011. Simultaneously, LDA, with the support of the Department of Fisheries, also initiated the programme of artificial restocking through the release of fingerlings.

Assessments on fishery diversity and the productivity of Loktak were carried out during 1999-2003. Surveys carried out during the period identified the presence of 54 species, representing 17 families. Notably, the assessments recorded restricted presence of minor carp species (*Labeo angara*, *L.bata*, *L. Dero* and *Oesteobrama belangiri*). The annual production ranged between 1,261 and 1,685 MT during 1999-2003. *Athaphum* (reported to have increased from 217 in 1989 to 2,642 in 2004) contributed nearly 500 MT of production, or 40% of the total catch.

3.4.2. Aquatic Vegetation as Food, Fuel, Fodder and

Handicrafts

Vegetation plays an important role in the ecological processes and functions of the lake ecosystem, besides being of great economic and cultural significance to the people. The rich plant diversity of the lake is of considerable importance as food, fodder, fuel and value to the gene pool. Loktak Lake is a source of several plants used for various purposes by the communities. Some of the key economic uses are:

Food: 23 species are used as food plants, of which *Zizania*, *Polygonum*, *Nelumbo*, *Euryale*, *Nymphaea*, *Alpinia*, *Hedychium*, and *Ipomea* are widely found in the lake and harvested for consumption as well as income generation.

Fodder: 18 species are used as fodder. *Echinocloa*, *Capillipedium*, *Zizania*, *Alternanthera* and *Brachiaria* are widely found and harvested by the communities as feed for cattle.

Fuel: *Coix*, *Phragmites* and *Saccharum* species are used as fuel by the communities living in and around the lake, especially for fish drying, smoking and cooking.

Construction of hutments: 8 plant species, particularly *Arundo*, *Phragmites*, *Zizania* and *Saccharum*, are found in abundance and used for thatching, fencing and hutment construction.

Medicinal: 17 species are observed to have medicinal properties, of which 4 species viz. *Fuirena*, *Polygonum*, *Impatiens*, and *Malaxis* are found in abundance in Loktak. *Fuirena umbellata* rhizome is used for treatment of fever and jaundice. *Polygonum sp* is used by communities as a tonic. Rhizomes of *Arundo donax* are used as an emollient and diuretic. The flower of *Eichhornia crassipes* is used traditionally for treatment of skin diseases, particularly those of horses. *Enhydra fluctuans* is used in skin and nervous afflictions, and as anti-bilious demulcent. *Hedychium coronarium* rhizome is used in stomach and liver disorders and for treatment of inflammations. *Hedychium coronarium*, as well as

Loktak is the largest fishery resource of Manipur and provides a majority of the state's fish producing area. Fish is an important source of animal protein for the people of Manipur, influencing the extensive conversion of marshes around the lake for culture fisheries

shoots of *Mikania cordata*, are used as antidote for snakebites, the later also being used for fish poisoning.

Handicrafts: Sere pecies such as *Cyperus* and *Scirpus* are used in making mats, cushions, baskets, hats, and other handicrafts. These products, being ethnic, are in high demand in several parts of the country. Around 1200 ha of the wetlands were estimated to be under matting rush, locally called Kouna (*Schoenoplectus lacustris* and *Schoenoplectus mucronatus*) with cultivation concentrated mostly in Thoubal and Bishnupur district in Manipur (Jain, 2005). The earnings of each person during the peak season is estimated to be around ₹10,000, while during the lean season, it is ₹3,000.

Cultural: 11 species are used by communities for several religious and cultural purposes. Meitei households especially use twigs of *Echinocloa stagnina* for worship of their gods and goddesses. *Nymphaea* and *Nelumbo* species are also used in several religious ceremonies.

Food: In 2005-2006, Imphal market received a total volume of 68.63 tons of edible wetland plants, involving a business over of ₹9,077,78. Thoubal received 23.62 tons of vegetables, involving ₹3,11,436 while Bishnupur received 20.18 tons, with a trade of ₹2,41,080. Nearly 70% of the annual income from wild edible plants of the three major market of Imphal are generated by seven species (*Euryale ferox*, *Colocasia esculenta*, *Oenanthe javanica*, *Nelumbo nucifera*, *Polygonum barbatum*, *Hedychium coronarium* and *Sagittaria sagittifolia*), while the rest of the species contribute the remaining 30%. Among the individual species, *Euryale ferox* was sold in highest quantities (43.39 tons), followed by *Colocasia esculenta*, *Oenanthe javanica* and *Nelumbo nucifera*; *Lemna australis* was the most expensive species, as recorded in Imphal and Thoubal market; *Fagopyrum esculentum* was recorded as the cheapest among all the vegetables sold.

3.4.3. Nutrient Retention by Phumdi

Phumdi plays an important role in the maintenance of overall water quality, through filtering of mineral nutrients. A thick strip of *phumdi* in the northern sector is critical to the maintenance of water quality of the lake, by acting as a biological sink to the key nutrients. As per estimates, 478.6 tonnes of nitrogen, 39.6 tonnes of phosphorous and 157.2 tonnes of potassium are annually accumulated within the *phumdi* of the northern zone. The huge amounts of pollutants brought in by the rivers, particularly Nambul and Nambol, if not absorbed by these *phumdi* would have

been available in the water thereby leading to further degradation making the lake unfit for fisheries and other aquatic biodiversity.

3.4.4. Cultural Values

Loktak Lake is of immense cultural importance to the communities living in and around the lake. Given its central role in ensuring food and water security for the state of Manipur, Loktak lake is associated with immense cultural values. Loktak lake is viewed as "*Loktak Ema Lairembe*" (Mother Goddess Loktak) as it supports the livelihoods of people living in and around the lake. The lake has been an important center for holding cultural events, including Loktak Day, on which boat races are organized within the lake. The Lake is the only venue of water sport n the state. The cultural values are also linked to the rich biodiversity of the wetland system. Conservation of wildlife and natural habitats is part of Manipur's folk customs and beliefs. The endangered Brow Antlered Deer (Sangai) or the dancing deer to which Loktak is the only natural habitat, is Manipur's state animal and an important cultural identity. Varied references in local mythology, folklores, festivals and customs are a testimony of the inextricable connection that exists between Manipuri society and its most prominent wetland regime. A ten day long Sangai Festival is celebrated every year during the month of November with a lot of colorful programmes and festivities.

Mondummahadeva (stone image), a famous Lord Shiva temple, situated in the southwest part, about 63 km away from Imphal, near the Pumlen Lake, is one of the important pilgrimage sites in Manipur. Every Sunday and full moon day of the month, pilgrims visit the place to perform worship. Loktak and Keibul Lamjao National Park lake have huge tourism potential. Chaoba hill, Sendra hill and Chingthi, Karang are known major potential recreation sites in the wetland complex.

3.5. Sectoral Development and Ecosystem Services Transformation

Ecosystem services and the biodiversity of Loktak Lake complex are under stress due to lopsided developmental planning within the basin. Water resource development projects for flood mitigation, agriculture and hydropower generation have led to modification of hydrological regimes, seriously impacting the processes, functions and attributes of the wetlands. In particular, the construction of the Ithai barrage downstream of Loktak in 1984,

Table 16: Ecosystem services description

Ecosystem Services Description	Stakeholder	Existing biophysical environment enabling delivery of ES	
Provisioning			
<p>Fisheries Loktak lake complex is the largest fishery resource of the Manipur state accounting for more than 50% of its fish producing area. Loktak wetland complex are the largest capture fishery resources for the entire state. The open water areas in Loktak and Pumlun are the main fishing areas, whereas the extensive marshes in the eastern part of the complex also serve as important fish breeding grounds (particularly for air breathing fishes).</p> <p>Fish farms fringe the entire wetland complex and the river channels. Their concentration is high in the northern sector of Loktak and the eastern part of the complex along Ikop-Kharung and Pumlun- Khoidum.</p>	<p>Over 5,000 households depend on capture fisheries from Loktak. In addition, there are nearly 13,800 fish farms around the lake.</p>	<ul style="list-style-type: none"> ● Connectivity with the riverine environment which enables exchange of riverine fish species ● Sufficient water spread area during lean season ● Adequate level of nutrients and well- oxygenated environment 	
<p>Aquatic vegetation As per estimates, annually 4,699 MT of plant biomass is harvested for use as fuel; 350 MT for use as vegetables; the cultivation of species for handicraft manufacturing generates ₹22 lakh per annum</p>	<ul style="list-style-type: none"> ● 17,000 households extract aquatic plant for fuelwood ● Over 9,000 households harvest vegetables, whereas 1,000 household depend on the lake for fodder. 	<ul style="list-style-type: none"> ● Variable inundation regime and high nutrients create enabling conditions for submerged, floating and emergent vegetation. 	
Regulating			
<p>Nutrient retention by <i>phumdi</i> Phumdi is a natural feature of the wetland. Its spread in the northern and southern sectors is important for maintenance of overall water quality through filtering of mineral nutrients</p> <p>As per the estimates, 478.6 tonnes of nitrogen, 39.6 tonnes of phosphorous and 157.2 tonnes of potassium are annually accumulated within the phumdi of northern zone</p>	<ul style="list-style-type: none"> ● Nearly 50,000 households living in and around Loktak. 	<ul style="list-style-type: none"> ● The Phumdi layer acts as a biological sink to the key nutrients improving water purification function of the wetland 	

Existing socioeconomic environment influencing ES	Recent trends
<ul style="list-style-type: none"> ● Leikai, the village Panchayats and other informal village bodies play a major role in facilitating decision making over resource use 	<ul style="list-style-type: none"> ● Fisheries have been affected by reduced connectivity with rivers ● Changes in lake ecosystem especially rapid proliferation of phumdi in the past had led to decline in fish catch, impeded movement in lake, loss of fishing gear and crafts. ● Exploitative modes of fishing, such as use of nylon nets and widespread athaphum fishing led to crowding of fisheries leading to promulgation of Loktak Lake (Protection) Act, 2006 that prohibited the cultivation of athaphum and athaphum fishing ● Culture fisheries has acquired more prominence as source of income. Between 1970 and 2009, 112.8 km² of 272.8 km² of marsh areas were converted to fish farms and agriculture, fragmenting the overall wetland regime, stressing biodiversity habitats and further reducing the overall water holding capacity of the lake ● Culture operations are cost intensive besides having considerable environmental implications ● Culture fish production is sub-optimal due to due to inadequate infrastructure like hatcheries, connecting roads, post harvesting infrastructure, technical knowledge, institutional lacunae and capital investment
<ul style="list-style-type: none"> ● Commercial exploitation is prohibited under the Loktak Act, 2006 	<p>The growth and productions of fruit of <i>Trapa natans</i>, <i>Euryale ferox</i>, fruit and rhizome of lotus plant has decreased to a great extent. Production has also been impacted by degraded water quality.</p> <p>According to the State of Environment Report, 2007, there has been sharp decrease in the population of a number of economic plants (<i>Saccharum</i> sp., <i>Setaria pumila</i>, <i>Alpinia nigra</i>, <i>Hedychium spicatum</i>, etc).</p> <p>The thick and tall stands of <i>Phragmites karka</i> which provided shelter to the Sangai deer are now stunted in growth. As the major food plants like <i>Zizania latifolia</i>, <i>Carex</i> species, <i>Coix</i> species are on the decline, the main source of food for Sangai is visibly reduced.</p>
	<p>Phumdis profusely proliferated in the lake during 1989 – 2002 with the area of phumdis in the lake increasing from 116.4 km² to 134.6 km²</p>

Contd...

Ecosystem Services Description	Stakeholder	Existing biophysical environment enabling delivery of ES
<p>Freshwater use Key economic use is hydropower generation. With a design capacity of 448 MU power from Loktak hydroelectric project accounts for 35 % of the total energy drawl of Manipur</p> <p>The Loktak multipurpose project also provides irrigation to an area of 24,300 ha in the western half of Manipur Valley</p>	<ul style="list-style-type: none"> ● Population living in Loktak west. ● Entire population of Manipur and neighbouring states ● Agriculturists around Loktak 	<ul style="list-style-type: none"> ● Optimal lake water levels and water quality
<p>Cultural</p> <p>Recreational and cultural value Given its central role in ensuring food and water security for the state of Manipur, Loktak lake is associated with immense cultural values and is treated as Loktak Ema</p> <p>Keibul Lamjao National Park is the only natural habitat for the endangered dancing deer or the Sangai deer. Mondummahadeva (a stone image) famous Lord Shiva temple is situated in southwest part about 63km away from Imphal near the Pumlun lake is one of the important pilgrimage sites in Manipur.</p> <p>A ten day long Sangai Festival is celebrated every year during the month of November with a lot of colorful programmes and festivities</p> <p>Sendra Hill and Chingthi, Karang are known major potential recreation sites in the wetland complex</p>	<p>Region around Loktak; national and global community at large</p>	<ul style="list-style-type: none"> ● Presence of open water expanse ● Presence of Sangai deer and waterbirds

entailing regulation of lake levels for hydropower generation, converted a naturally fluctuating wetland into a reservoir. This led to the inundation of peripheral areas, loss of migratory fisheries, reduction and degradation of the national park habitat, and decline in water quality. Rapid growth of population in the hills has led to expansion of the area under shifting cultivation, enhancing lake siltation and loss of flood attenuation capacity. High levels of urbanisation within the upstream reaches, along with inadequate sewerage systems, has led to the dumping of untreated sewage and sewerage into the lake, causing decline in water quality. Inundation of the peripheral areas due to constant water levels has forced an occupation shift from traditional agriculture–fishery based livelihood systems to fisheries. The declining resource base, along with increasing population pressure, forced propagation of harmful fishing practices, ultimately leading to phumdi

proliferation and choking of the central sector of the lake. The ultimate effect has been disruption of livelihoods and increased poverty within wetland communities.

The variability of the inundation pattern has been greatly altered in the last three decades due to hydrological regulation and land use changes, particularly along the fringing marshes (Map 2). The Ithai Barrage operations do not allow for much lowering of water levels. There was considerable increase in open water areas post the barrage operation. The newly inundated areas were used for fish farming. Over a period of time, extensive conversion of marshes into fish farms has taken place. Land along the river channels has been reclaimed for permanent agriculture, enabled through water levels managed by regulators. Fragmentation is more extensive in the Ikop-Kharung segment, wherein the roads connecting Laisenthang, Tentha and Wabgai create three distinct components.

Existing socioeconomic environment influencing ES	Recent trends
<p>Water regulation is largely dictated by hydel power generation. Key departments being NHPC, IFCD, CADA, Minor irrigation There is no appropriate water use/ allocation plan for other sectors such as fisheries, maintenance of KLNP and lake ecosystem</p>	<p>During 1998 – 2003, the average annual power generated was 531 MU higher than the design capacity. In recent years abstraction of water has been much beyond the design capacity of the power plant.</p>
<p>Declaration of KLNP National park and enactment of Loktak Lake (Protection) Act, 2006 has positive impacts on wildlife habitats.</p>	<p>Habitat quality of Sangai deer has been impacted by near constant water levels in the lake</p>

The marsh areas to the left of Laisenthang-Tentha road have been converted for fish farms and agriculture. Similarly, the area between the river channel and the roads is converted to fish farms, with only a small part between Khelakhong and Khongmai channels maintaining marsh characteristics throughout the year. A buffalo farm has been constructed by the State Department of Animal Husbandry on the periphery of Wabgai marshes.

Similar changes can be observed in the Pumlun-Khoidum part, wherein marshes fringing the central portion have all been converted to fish farms. Only a small patch of Pumlun has an open water area round the year, the rest being marshes. Around Loktak Lake, the spread of fish farms can be observed to be most dense in the northern margins, followed by the western and southern margins. Table 17 and Figure 19 present a comparative picture of the changes in land use between 1970 and March 2011.

3.6. Current Management Arrangements and Gaps

The government of Manipur constituted Loktak Development Authority (LDA) in 1986 as a nodal agency for conservation and management of the lake. Constrained by the lack of an information base for the development of wetland management strategies, a six year project called ‘Sustainable Development and Water Resources Management of Loktak Lake’ was implemented during 1996-2003. Systematic inventory and assessment of hydrological, ecological and socio-economic features carried out under the project helped define baseline conditions and trends, as well as identify critical ecological components and processes for wetland management. Based on the project outcomes, a Manipur River Basin scale-integrated plan for conservation and management of Loktak Lake was formulated in 2005. The plan aims at conservation and sustainable use of Loktak and its associated wetlands for ecological security and

Table 17: Changes in land use/cover within Loktak wetland complex

Land use / Land cover category	Area (in ha)	
	1970	2011
Open water	6295	9662
Marsh	23313	23761
Fish farms	0	9486
Agriculture		
Settlements	1220	979
Forests	1518	1026

livelihood improvement of local communities through catchment conservation, water management, biodiversity conservation, fisheries development, management of aquatic vegetation and institutional development. The overall outlay of the management plan was estimated to be ₹494.72 crore (at 2007 prices), and the implementation was initiated in 2007 with an allocation of ₹50 crore by the Planning Commission, Government of India.

Implementation of the management plan was reviewed by the Planning Commission in 2007, and it was recommended to prioritise the plan in the form of a Short Term Action Plan (STAP) focused on immediate measures for ecological restoration of Loktak. The emphasis was on addressing the proliferation of *phumdi* in the central sector of the lake. Examination of past records and maps indicated that while *phumdi* was a natural feature of the wetland, its spread was limited only in the northern and southern parts. The use of *phum* enclosures of fishing was restricted to only certain parts of the central sector, and only in the winter. With the operation of the Ithai barrage, large areas were permanently inundated, forcing an occupational shift towards fish-based livelihoods. *Athaphum* fishing gradually spread to the entire central sector and transformed from seasonal to actively carried out throughout the year (Figure 20).

A major implication of the spread of *athaphum* was its contribution to *phumdi* proliferation in the central sector, fragmentation of the hydrological regime, degraded water quality, reduced area available for capture fisheries, impeding movement and reducing overall aesthetics.

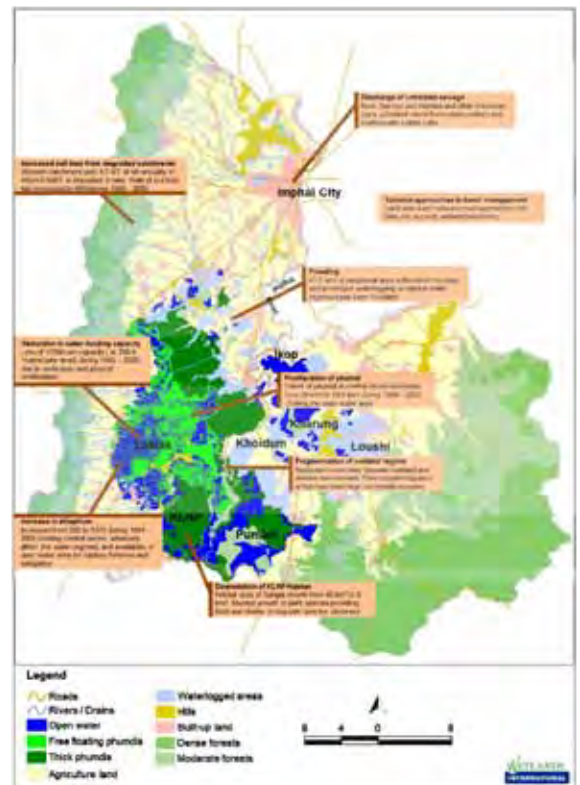
The STAP design therefore focused on restoring the open area in the central sector of Loktak. This was accompanied by interventions for revegetating degraded direct catchments, improving water regimes,

enhancing capture and culture fisheries and diversifying livelihoods to reduce pressure on lake resources. Building capacity for integrated management within LDA and strengthening park management were also included as means for improving lake governance. The Planning Commission approved an outlay of ₹373.99 crore for implementing STAP.

The STAP was implemented during the period January, 2009-March, 2013, entailing an expenditure of ₹255.63 crore⁴.

The outcomes of the STAP implementation are presented in Table 18. These have been classified into three broad categories: ecological benefits, socio-economic benefits and institutional benefits⁵. The ecological benefits mainly include state changes in wetland components and processes, and have been interpreted from the analysis of remote sensing images and monitoring data. The socio-economic benefits relate mostly to changes in the availability of resources, and have been derived from a survey. Institutional benefits include changes in institutional responses to lake management issues.

Figure 19: Key drivers and pressures impacting Loktak Lake

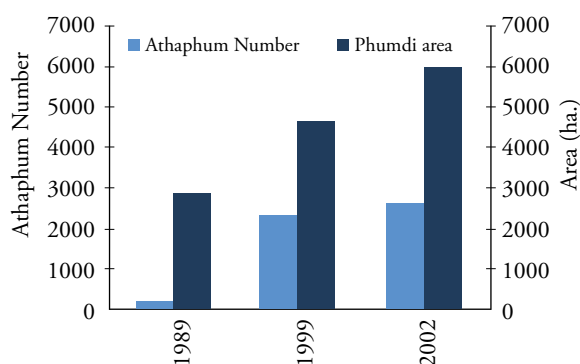


However, the envisaged restoration of Loktak Lake complex (as set in the Management Plan) could not be achieved till date. Some of the key limiting factors have been very limited investment in conservation of associated wetlands which form an integral part of the wetland complex. The waste management infrastructure within Manipur River Basin has not developed to the anticipated capacity thereby leading to continued stress on the wetland system. Interventions for livelihood transformation have had a delayed start due to various reasons. Institutional arrangements, especially inter-department coordination needs further strengthening. Loktak Lake continues to be in Montreaux Record as the adverse change in its ecological character are yet to be comprehensively addressed.

The following issues have also emerged as being of key concern to wetland management:

- Conversion of marshes: The marsh systems within Loktak Lake complex have been extensively converted for fish farms and agriculture. Assessments based on remote sensing imageries indicate that 112 km² of natural marshes were converted since 1970, leading to reduced capacity to regulate hydrological regimes, cycle nutrients, support biodiversity and community livelihoods.
- Fragmentation of hydrological regimes: The overall connectivity of Manipur River with the Loktak Wetland Complex as well as within the wetland system has been severely impeded through construction of embankments, diversion of natural flows, channel siltation and aggradation. Reduced ability of the wetland complex to regulate flow regimes has increased instances of floods and reduced connectivity between biodiversity habitats.
- Increased pollution loading: Inadequate sanitation infrastructure within highly populated and rapidly urbanizing Manipur Valley is leading to an increased discharge of untreated sewage and solid-waste into Loktak Wetland Complex. This is one of the key factors promoting growth of luxuriant vegetation impacting natural ecosystem processes and functions.
- The current provisions under Wetland (Conservation and Management) Rules, 2010 and Manipur Loktak

Figure 20: Trends in number of athaphum and phumdi area in central sector of Loktak



(Protection) Act, 2006 restrict unsustainable use of wetland resources. However, the act has not been effectively applied in the absence of requisite institutional infrastructure. The regulatory framework also does not create a basis for creating positive incentives for community stewardship, which is vital for sustainable management of the wetland system.

- Climate change risks: The climate risks are still very weakly addressed in management planning processes. Further research and assessments are required to build suitable adaptation measures in the management plan implementation.

3.7. Economic Valuation of Ecosystem Services

The assessment of wetland features reveals the key ecosystem services that are critical for sustaining livelihoods of people in Loktak Wetland Complex. An economic valuation of wetland ecosystem services has been carried out using market and non-market based methods.

Quantum of harvest of wetland products (fish and aquatic plants) have been estimated based on household surveys in the absence of monitoring data. Market prices have been used to estimate economic value, as full information for adjusting the prices for externalities and market distortions could not be generated. Production function method was used to estimate the economic

⁴ Of the total expenditure of ₹ 255.63 crore, the Planning Commission provided ₹222.79 crore. ₹32.53 crore was received as matching grant from state government and ₹4.31 crore from the Twelfth Finance Commission.

⁵ A more comprehensive approach for identification of benefits would have been through systematically designed strategic impact assessment, building on ecological, hydrological and socio-economic monitoring. In this assessment, project costs emerging as a result of implementation of activities (for example reduction in catch from athaphum fisheries) have been excluded. Similarly, the benefits are not evaluated in terms of sustainability.

Table 18: Outcomes of STAP interventions

Project results	Indicator	Unit	
Ecological Benefits			
Increase in open water area in 4 central sector	Open water area in central sector	km ²	
Improvement in water quality / (water quality maintained despite increasing pollution loading from the inflowing rivers)	pH	Logarithm of hydrogen ion concentration	
	DO	mg/l	
	Transparency	m	
	Nitrate- nitrogen	mg/l	
	Phosphate- phosphorus	mg/l	
	Total coliform	MPN/100ml	
Increase in water holding capacity due to reduction in area under phumdi in central sector		MCM	
Increase in vegetative cover in direct (western) catchments	Total vegetated area in western catchment	ha	
Decrease in area under shifting cultivation	Area under shifting cultivation in western catchment	ha	
Enhancement of lake as a waterbird habitat	Number of waterbird species using the lake as habitat	Number of species	
	Population of waterbird species using the lake as habitat	Population	
Increase in overall aesthetics	Community perception	Rank on a scale 0 -1	
Reduced risk of phumdi proliferation from athaphum	Lake area under athaphum	ha	
Increase in area under submerged vegetation	Area under submerged vegetation	ha	
Socioeconomic Benefits			
Increase in catch of capture fisheries	Annual catch	MT	
Improved navigation and access to lake	Perception ranking on a 0 – 1 scale	Rank	
Decreased damage to fishing gear due to moving phum	Amount in ₹lost/year	₹	
Increased use of toilets in lakeshore villages	Household use of toilets	% to total households	

Post Project		Pre STAP	
Value	Date and Data Source	Value	Date and Data Source
65.55	Analysis of remote sensing imagery of November 2012 (IRS Resourcesat-2)	46.08	Analysis of remote sensing imagery of March 2007 (IRS Cartosat – 1)
6.2-7.3	LDA monitoring data (2010-12)	6.2-7.6	LDA monitoring data (2000-01)
2.79-8.21	LDA - Average of monthly observations from 18 stations (2010-13)	2.8-8.9	LDA monitoring data (2000-01)
0.36-1.53	LDA -Average of monthly observations from 18 stations (2010-13)		
		0.27-0.42 0.13-0.8	Sharma and Sharma (2009) ⁹ LDA monitoring data (2000-01)
		0.12-0.32 0.03-0.31	Sharma and Sharma (2009) LDA monitoring data (2000-01)
8-421	LDA -Average of monthly observations from 18 stations (2010-13)	130-520	LDA monitoring data (2000-01)
9.81	Estimated based on change in area under phumdi in central sector		
23,896	Analysis of remote sensing imagery of November 2011 (IRS Resourcesat – 2)	23,068	Analysis of remote sensing imagery of November 2011 (IRS Resource sat – 2)
2,524	Analysis of remote sensing imagery of November 2011 (IRS Resourcesat–2)	2,171	Analysis of remote sensing imagery of November 2011 (IRS Resource sat – 2)
56	Waterbird census estimate for the period 2010-2013 reported by CCNCS	15	Waterbird census for the period 2006-09
34,369	CCNCS (2012-2013)	16,736	ESRSPF (2004)
0.75	Household survey (2013)	0.15	Household survey (2014)
Negligible	Analysis of remote sensing imagery of November 2012 (IRS Resourcesat-2)	2258	Analysis of remote sensing imagery of March 2007 (IRS Cartosat – 1)
2,325	Analysis of remote sensing imagery of November 2012 (IRS Resourcesat-2)	Very limited area as the central sector choked with athaphum	
3,800	Household survey (2013)	1,473	Average annual catch for 2001-03 (Trisal and Manihar, 2004)
0.66	Household survey (2013)	0.13	Household survey (2014)
10,607	Household survey (2013)	14,643	Household survey (2014)
79	Household survey (2013)	26.6	Household survey data (2001-02)

Contd...

Project results	Indicator	Unit
Increased diversity of use of capture fishing gears	% fisher households using capture fishing gear	% to total fisher households
Improved convergence of schemes within line departments to support implementation of STAP	State funds made available for implementation of project activities	₹ crore (over the project implementation period)

cost of Loktak Lake waters as an input to hydropower production, referenced to assessments of ecological and social limits of use of water for various economic and ecological purposes. Cultural values were estimated through analysis of individual household behaviour in hypothetical markets.

The economic analysis presented in the report is based on rapid assessment, and uses to a large extent secondary datasets. Assessment of project benefits has been done through interpretation of remote sensing imageries (for status of western catchments and extent of *phumdi* proliferation), assessment of existing monitoring data (on water quality, water levels, biodiversity), information from project evaluation reports⁶ and monitoring records for the period 1999-2003 pertaining to SDWRML⁷ project.

Ecosystems are inherently complex with non-linear characteristics. The study uses market prices and financial costs given the short time frame for assessment. For future assessments, these would need to be adjusted for market distortions, as well as reviewing the opportunity costs of alternate investment opportunities.

Fisheries: While fisheries assessments have been discontinued since 2003, an attempt to assess the current catch levels was made through surveys of fishers. Data on catch, fishing gear, fishing days, prices, marketing and consumption patterns was collected from 260 fisher households from 21 villages. As per the assessment, the current annual fish catch from capture sources is around

3,800 MT (Table 19). There is also an overall transition in fisheries observed during 2003-2013 (Table 20). While there has been a decline in *athaphum* fisheries, there has been an increase in capture fisheries as well as culture fisheries in the peripheral areas. The area under fish farms has increased from 97.6 km² (12,568 fish ponds) in 2003 to 107.48 km² (around 13,800 fish ponds) in 2012.

The gross economic value of annual capture fisheries catch, using market prices⁸ weighted by catch composition is ₹53.34 crore⁹.

Aquatic vegetation for various economic uses: Loktak Lake is a source of several plants used for various purposes by communities living in and around. Overall 132 plant species associated with *phumdi* have been identified which are utilized by the people as vegetables, food, fodder, fuel, thatch, fencing material, medicines, raw material for handicrafts, and for religious & cultural purposes.

As per survey, 56% of the communities living in and around wetland reported harvesting aquatic vegetation for various purposes. The total amount of biomass harvested for various economic uses was assessed to be 11,700 MT.

The annual quantity of biomass used as fuel per household in and around Loktak has been assessed to be 1825 kg, of which 36% is sourced from the wetland system. Using this estimate of annual average household consumption of fuelwood, the total annual harvest of fuelwood from Loktak Lake has been estimated at

The study uses market prices and financial costs because of the short assessment time frame. Future assessments need to adjust for market distortions, and review the opportunity costs of alternate investment opportunities

	Post Project		Pre STAP	
	Value	Date and Data Source	Value	Date and Data Source
	85	Household survey (2013)	32	Household survey data (2001-02)
	59.74	Project financial statements	0	

4,669 MT. The economic value of the fuelwood is derived using the prices of conventional head load sold in the market. Using the prices of ₹110 / mon (1 mon = 40 kgs), the value is estimated to be ₹5.14 crore.

Communities also harvest 2,500 kgs of aquatic vegetation daily from Loktak, both for personal consumption as well as for sale in the markets. The average availability of vegetables from the lake is for 4.66 months, or 140 days. Therefore the total annual harvest of vegetables from Loktak is 350 MT. Since species disaggregated data is not available for the vegetable harvest, valuation is done using a weighted price, assuming that all species are consumed in equal proportion. The average weighted price of vegetables is ₹37.16 / kg. The annual monetary value of aquatic vegetation harvested from Loktak for use as vegetables have been assessed to be ₹13.01 crore.

Further, as per the field surveys, 400 households in 8 lakeshore villages are presently engaged in cultivation of Cyperus and Scirpus species for use in handicrafts. Cultivated across 200 ha, the activity generates ₹22 lakh per annum as raw materials.

Freshwater: Loktak is a major freshwater resource. A key economic use is for hydropower generation through abstraction by the Loktak Hydro-electric project operated by the National Hydroelectric Power Corporation. The average annual production from the hydropower unit which was designed at 448 MU, has been always above these targets for almost all the years since 1989. Power from the Loktak Hydroelectric project accounts for 35% of the total energy drawal of Manipur¹³. The average per unit price of power from other power sources in 2002-03 were higher by 171% as compared to the unit price charged by NHPC. The state also receives 12% of the total power generation free of charge (as per guidelines for operation and establishment of central sector power plants in the northeastern region of India), which accounted for 13% of the total energy drawal for state in 2002-03¹⁴. Power from the hydroelectric project is shared by seven other northeastern states, including Arunachal Pradesh (4.76%); Assam (25.97%); Meghalaya (9.14%); Mizoram (6.70%); Nagaland (7.24%) and Tripura (14.38%).

Table 19: Details of fishers and capture fisheries catch of Loktak (2013)

		Island Villages	Villages around Loktak	Total
Fisher households	Number	3100	1,950	5,050
Fishing days	Per Year	236	173	212
Active fishers	Per Household	1.25	1.01	1.22
Catch	per kg / day	3.05 ¹⁵	2.89	2.89
Total catch	MT / Annum	2,789.22	984.69	3,773.91

⁶ Final Report of Third Party Evaluation of Short Term Action Plan for Conservation and Management of Loktak Lake and associated Wetlands integrating Manipur River Basin submitted by Water Institute, Karunya University to Loktak Development Authority in June 2013

⁷ Sustainable Development and Water Resources Management of Loktak Lake' was implemented during 1996-2003 by Loktak Development Authority (LDA)

⁸ Prices used: Indian Major Carp (₹125/kg), Minnows (₹175/kg) and others (₹80/kg)

⁹ For the present exercise, the value of culture fisheries has been excluded. Major expansion of fish farms is through conversion of marshes which play a significant ecological role in sustaining the wetland. STAP did not intend to address sustenance of culture fisheries.

¹⁰ Catch composition: Indian Major Carps (39%), Minnows (45%) and others (16%)

Table 20: Changes in fish yield from Loktak during 2003-2013

	Fish catch / yield (MT)	
	2003	2013
Capture fisheries	1,473 ¹¹	3,800
Culture fisheries	10,500	11,500 ¹²
Athaphum fisheries	550	Negligible (declared illegal)

There is no specific allocation of water for other sectors, partly because the demand for industrial and domestic purposes is negligible and partly because the other activities, except incidence of surplus releases with consequent flooding, being located and executed within the lake itself are not expected to experience difficulties. The quantum of water used for lift irrigation directly from the lake is variable and not estimated.

Estimation of economic value of water used from Loktak for hydropower generation is done through use of production function approach. The specification of the function involves total hydropower generated from the project as a dependent variable, and water used for hydropower generation, and operational and maintenance cost (as proxy for capital). Evaluation of benefits derived through sale of hydropower has been done at the current sale price of electricity. Cost of abatement of sedimentation induced by the Ithai barrage has been used as a proxy for the sedimentation impact of the barrage. Cost of mechanical removal of *athaphums* constructed as a response to inundation brought about by barrage has been used as an indicator for *phumdi* proliferation. Valuation of crop losses due to inundation has been done using market prices of crops and the affected area. Impacts on fisheries have been estimated as the opportunity cost of fisheries lost due to reduced migration. Impacts on KLNP have been assessed by developing a functional linkage between water level fluctuations, habitat availability of Sangai and willingness to pay for biodiversity.

A Cobb-Douglas specification is used for the production function, estimated using standard ordinary least squares procedure applied on annual data values for the period 1986 - 2003. Estimation yielded the

following equation:

$$\ln(Y) = 0.918 \ln(W) + 0.131 \ln(C) - 1.103$$

All the estimated coefficients were found to be statistically significant at 95% confidence, and the value of R-square was observed to be 0.755.

The economic value of water used for hydropower generation has been estimated using the coefficient for water (as derived in the previous equation) for a production value of 400 MU. This is estimated to be ₹18.33 crore. This value is almost commensurate to the commercial revenue generation from the sale of units.

Nutrient retention by *phumdi*: *Phumdi* plays an important role in maintenance of overall water quality through filtering of mineral nutrients. A thick strip of *phumdi* in the northern sector is critical to maintenance of water quality of the lake by acting as a biological sink to the key nutrients. As per the assessments carried during 1999-2003, 478.6 tonnes of nitrogen, 39.6 tonnes of phosphorous and 157.2 tonnes of potassium are annually accumulated within the *phumdi* of northern zone. The huge amount of the pollutants brought in by the rivers, particularly Nambol and Nambol, if not absorbed by *phumdi* would have been available in the water thereby leading to further degradation making the lake unfit for fisheries and other aquatic biodiversity.

Estimation of nutrient retention function of *phumdi* has been done using replacement cost technique. This function of *phumdi* can be most closely replicated through the use of constructed wetlands¹⁵ designed for wastewater treatment. Estimation of required area is done using a k-C model with the following generic form:

$$\ln\left(\frac{C_e - C^*}{C_i - C^*}\right) = \frac{k}{q}$$

C_e = outlet target concentration, mg/L; C_i = inlet target concentration, mg/L; C^* = background concentration, mg/L; k = first order areal rate constant, m/yr; q = hydraulic loading rate, m/yr

Data for estimating the equation were used for Nambol River (which flows into the Northern Sector)

¹⁶ Average catch for 1999-2003. Data source: SDWRML project, published as Trisal and Manihar (2003)

¹⁷ Based on stocking density derived from sample survey data (IMC: 4600 fingerlings, exotic: 775 fingerlings; minnows and others: 2200 fingerlings) and considering 50% mortality during growth period. Harvest size derived from sample survey data: IMC (0.5kg), exotic: 0.75kg, minnows and others: 80 g. Effective farm area has been taken as 70% of the total land area. Production data for 2003 has been derived assuming a farming technology similar to that presently used.

¹⁸ Department of Power, Government of Manipur, 2003

¹⁹ Department of Power, Government of Manipur, 2003

Estimations suggest that an annual savings of ₹11.33 crore is made through nutrient retention function of the phumdi in the northern sector of Loktak. The restoration of phumdi in the northern sector carried under STAP is likely to further increase the nutrient retention capacity of Loktak

and central sector of Loktak Lake and pertain to 2003-04 (Table 21). The sum of capital and operation and maintenance costs of the surface flow wetland is being used as a proxy of the economic value of the ecosystem service.

The basic investment costs for constructed wetlands include land, site investigation, system design, earthwork, liners, filtration or rooting media, vegetation, hydraulic control structures and other miscellaneous. The total capital investment is also known to vary from low estimate as US\$ 29 per m² in India (Billore et Al., 1994) and US\$ 33 per m² in Costa Rica (Dallas et al., 2004) to Euro 257 per m² in Belgium (Rousseau, 2004). For the present study, the capital and operational costs (\$ 44,622 / ha and US\$ 400/acre respectively) suggested by Kaldec and Knight (1995) for surface flow wetlands at 1993 prices have been used.

To obtain comparative cost savings made due to natural functioning of the wetland, the costs have been converted in Rupees using Purchasing Power Parity exchange rate, and annualized using a 4% discount rate.

Based on the above estimations, an annual savings of ₹11.33 crore is made through nutrient retention function of the *phumdi* in the northern sector of Loktak. The restoration of phumdi in the northern sector carried under STAP is likely to further increase the nutrient retention capacity of Loktak.

Flood buffer: In its natural regimes, Loktak accommodated a huge proportion of monsoon inflows from Manipur River thereby providing flood protection to communities living in and around. However, with

commissioning of Ithai Barrage and regulation of natural regimes, this ecosystem services has been highly curtailed and the adjoining settlements, especially located in southern, eastern and western margins frequently experience prolonged waterlogging. This has therefore been excluded from the current analysis.

Cultural Values: Loktak Lake is of immense cultural importance to the communities living in and around the lake. The lake itself is referred in the folklore as 'Loktak *Emá*' meaning mother goddesses.

The cultural values do not find an expression in the current markets. Hence, a contingent valuation survey was used to elicit willingness to pay for conserving and sustaining cultural values. The respondents were asked to rank statements which symbolized the existence, option and bequest values of the lake. The mode of payment for WTP was in the form of voluntary contribution of time and/or money to a hypothetical Loktak Lake conservation fund designed as an investment instrument for projects aimed at conserving cultural values. Willingness to pay in terms of labour were converted into monetary equivalent and the maximum annual aggregates of the contributions were used to model the WTP. Of the 260 responses, 196 responses were used for analysis after screening of missing responses as well as extreme values. 192 respondents elicited positive WTP whereas four respondents expressed their inability to pay because of money and time constraints. 53.5 % of people felt that Loktak Development Authority was responsible for conservation of Loktak Lake. 68.5 % people strongly felt that they too owed the collective responsibility to conserve the lake.

¹⁵ Constructed wetlands are engineered systems that have been designed and constructed to utilize natural processes involving wetland vegetation, soils and associated microbial assemblages to assist in treating wastewaters. They can be classified based on the life forms of dominating macrophyte (as free floating, floating leaved, rooted emergent and submerged macrophytic types); flow direction (horizontal and vertical) and hydrology (surface or sub-surface) types. Use s of constructed wetland technologies have ranges from treating wastewater from petrochemical, paper and pulp wastewaters, abattoir, textile and tannery industries, distillery and winery, pig and fish farms, nursery runoffs etc.

Table 21: Required artificial wetland area to provide nutrient retention function equivalent to phumdi

Inflow from Nambul River	m ³ /day	Q	44,109.59		
			BOD	TN	Organic N
Influent concentration of Nambul River	mg/L	C _i	50	13.4	1.7
Effluent concentration (at Loktak)	mg/L	C _e	6.8	1.67	1.6
Wetland background limit	mg/L	C*	6.15	1.5	1.5
Reduction fraction to target		Fe = 1-C _e /C _i	0.864	0.86	0.059
Reduction fraction to background		Fb = 1-C*/C _i	0.877	0.89	0.12
Areal Rate constant	m/yr	K	34	22	17
Required Wetland Area	ha	A	1,994.30	3,109.13	696.45
Area of artificial wetland required = 3109.13 ha					
Capital cost equivalent for Loktak = ₹4,46,72,86,283 ¹⁶					
Average annualized value based on 4% discount rate (over 50 years) = ₹3,10,96,394					
Operational cost (2012 / ha) using 4% increment per annum = ₹26,440					
Total annual operational cost = ₹8,22,08,373					
Total annual cost = ₹11,33,04,767.					

The data were analysed by a variety of statistical methods including descriptive statistics (mean values, standard errors, skewness and kurtosis). The variables were log transformed in order to ensure a normal distribution. All analysis were performed using SPSS version 16.0. The linear relationship of WTP for the ecosystem services was modelled by means of linear regression. The linear regression analysis was performed using the following variables based on responses obtained from the survey questionnaire:

AGE = age of the respondent

EDU = Years of formal education

HHSIZE = Household size

INCOME = Annual household income from all sources

EVLD = Existence value of Loktak value expressed in terms of ranks related to expression of cultural linkages

OVSA = Option value of Loktak value expressed in terms of ranks given to conservation of the lake as a societal asset though no direct benefits are being derived by the respondent

EVSD = Existence value of Loktak value expressed in terms of ranks given to conservation of the *Sangai Deer*

BVLD = Bequest value for Loktak Lake expressed in terms of ranks related to conservation of Lake for

future generations

Stepwise method was used for entering the variables which uses the change in predictive values of variables to enter and remove variables at each step. Four variables were included in the final model: EVLD, Income, EVSD and OVSA as per the following regression equation:

$$\ln WTP = -11.269 + 7.265 \ln EVLD + 0.494 \ln Income + 2.342 \ln EVSD + 0.441 \ln OVSA$$

The R² value indicates that about 48.8 % of the variance is explained by the four predictor variables. There is a significant relationship between the predictor variables and the WTP. All the variables included in the model are significant as indicated by the β -values which are under 0.05. The values indicate the relative influence of the entered variables, that is Log EVLD had the greatest influence on WTP (=0.46), followed by income (0.31) followed by EVSD (=0.21) and OVSA (=0.17). Rest of the variables did not meet the entry requirements. Regression statistics relate to the explained portion of the variance. The positive values of the Beta values indicate that all the four variables have a positive loading on the Willingness to Pay (Table 22 and 23).

The Mean annual WTP for the cultural ecosystem

¹⁶ Conversion based on Exchange Rate of US\$ 1 = ₹58 indexed at a Purchasing Power Parity of 4.5. Effective exchange rate, therefore is ₹58 / 4.5 = ₹12.88

Harmonizing water allocation for human purposes with ecological demands for maintenance of wetland ecological character is central to ensuring conservation and wise use of Loktak and associated wetlands

services of the Loktak Lake is estimated to be ₹1881.81. Projecting this amount to the total lakeshore population (earning members of households, factoring in for households expressing null WTP), the gross WTP is estimated to be ₹26.33 crore.

Collating benefits derived from ecosystem services indicates a minimum annual value of ₹127.7 crore, which represents an asset value of ₹6,385 crore (at 2% discount rate in perpetuity; Figure. 21)

3.8. Water Management Options for Rebalancing Ecosystem Services

The analysis in the previous section indicates the role of water regimes in governing ecosystem services. Harmonizing water allocation for human purposes (i.e hydropower generation, agriculture and domestic use) with ecological demands for maintenance of wetland ecological character (maintenance of KLNPH habitat, fish migration, lake water quality and overall ecosystem health) is central to ensuring conservation and wise use of Loktak and associated wetlands.

Identification of objectives that need to be met through managing water regimes of Loktak forms the basic foundation of defining the tradeoffs.

Establishing water management objectives also needs to be referenced to the fact the Loktak wetland complex has already gone through a phase of rapid modification particularly in the last three decades,

and therefore the system no longer exists in its natural regimes. Several processes, including regulation of outflows, channelization, construction of fish farms, reduced connectivity with other wetlands within the complex, can be variably attributed as causative factors. The demands from water management have also changed with societal needs and economic development, particularly with respect to the role of hydropower in socioeconomic development of the northeastern region. Under these circumstances, revising the operation of hydraulic structures cannot serve as the “silver bullet” for restoration of ecological character of Loktak.

Revision of water management planning would require addressing allied processes which effect hydrological regimes, primarily restoration of the catchments, preventing further fragmentation of Loktak Wetland Complex (and undertaking measures for enhancing connectivity), improvement of water quality, and ensuring livelihood systems compatible with the dynamic hydrological regimes of the wetland

Table 22: WTP regression model summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.699	.488	.468	.958	1.612

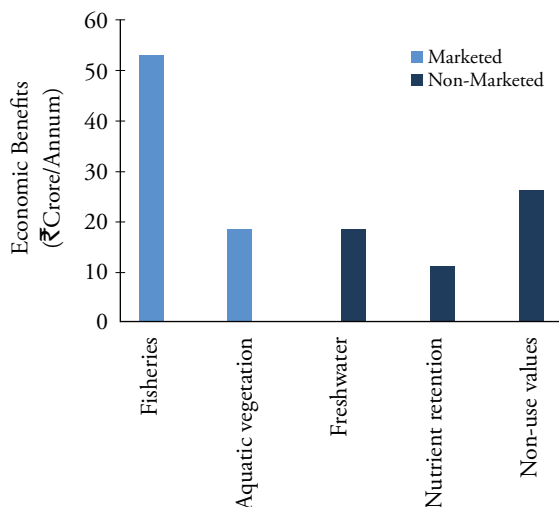
Predictors: (Constant), logEVLD, logIncome, LogEVSD, logOVSA
 Dependent Variable: logWTP

Table 23: Summary statistics, correlations and results from the regression analysis

	Coefficients	values	t	Sig	Correlation with logWTP
(Constant)	-11.269		-5.489	.000	
logEVLD	7.265	.465	5.633	.000	.478**
logIncome	.494	.308	4.057	.000	.265**
LogEVSD	2.342	.205	2.483	.015	.581**
logOVSA	.441	.166	2.182	.031	.022

** Correlation is significant at the 0.01 level (2-tailed).

Figure 21: Economic benefits from Loktak ecosystem services



system.

Water management objectives and required hydrological conditions in the wetland have been identified based on stakeholder consultations (Table 24).

3.9. Scenarios

From comparison of different water management objectives for Loktak Lake (Table 24), it can be observed that all objectives, except objective 1 and 9, can be achieved by operationalizing a lake level management close to natural regime. However, the objectives related to hydropower generation and to certain degree maintenance of culture fisheries require stable and regulated lake level conditions. One way to explore the range of options is to explore different water management scenarios and evaluate their impacts on multiple criteria. The current water management regime, which is dictated by the needs of hydropower generation, and the baseline natural regime (which addresses ecological needs on a priority) can be taken

as two extreme ends of scenario development. The following three scenarios have been considered to assist understanding of implications of changes in water management:

Scenario 1: Mimicking natural regime – prioritizing biodiversity conservation

Scenario 2: Multiple objectives – allocation of water for hydropower generation, biodiversity conservation and flood control

Scenario 3: Business as usual – prioritizing hydropower generation.

The following empirical relationships were used to develop the lake level scenarios:

- Monthly water balance for Loktak wetland based on hydrological modelling (Figure 22)
- Area – elevation – capacity relationship developed on the basis of bathymetric survey of 2000 (Figure 23).
- Water level – KLNP phumdi grounding relationship developed based on the outcomes of hydrological and ecological survey conducted in 2000 (Figure 24).
- Hydropower production – water utilization relationship based on records provided by NHPC (Figure 25).

An appropriate understanding of the inflows and outflows from a wetland system is an important basis for water management planning. This is usually achieved through analysis of a longer term hydro-meteorological datasets. However, the current hydrological observations for Loktak are of very limited time period and patchy. Attempt was therefore made to address this issue through hydrological modelling making the best use of available information. The objective was firstly to arrive at the gross picture of water resources availability in the Manipur River Basin, particularly that available at the downstream of Loktak Lake, and secondly building a water balance for the wetland. The modelling was done using the SWAT (Soil and Water Assessment Tool), developed by the United States Department of Agriculture and an open

Establishing water management objectives also needs to be referenced to the fact that the Loktak wetland complex has already gone through a phase of rapid modification particularly in the last three decades, and therefore the system no longer exists in its natural regimes

Figure 22: Monthly water balance for Loktak wetland

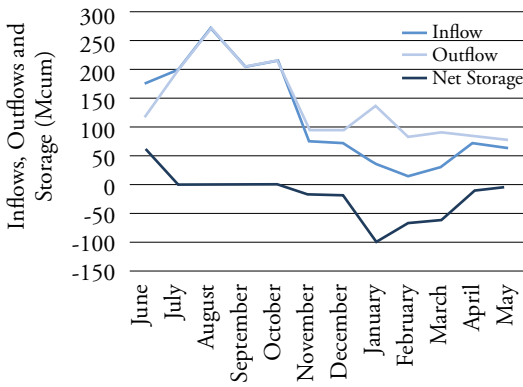


Figure 24: Water level – KLNP phumdi grounding

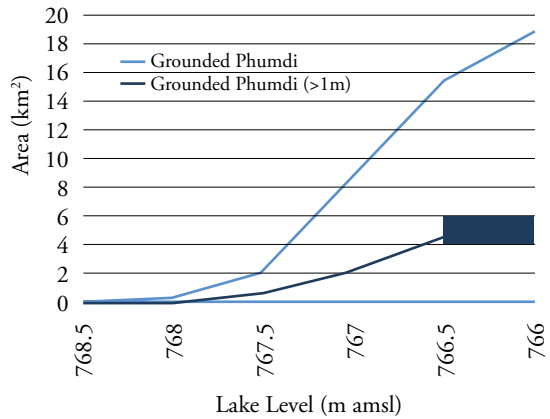


Figure 23: Lake elevation – capacity relationship (2000)

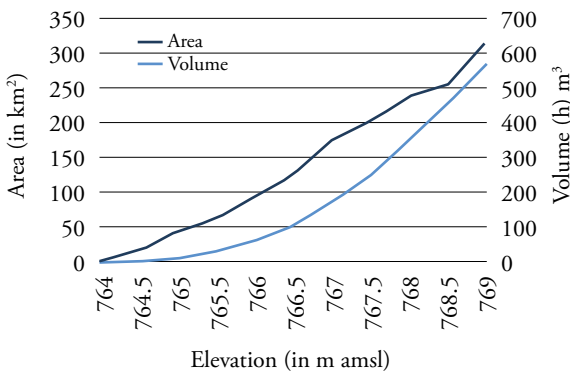
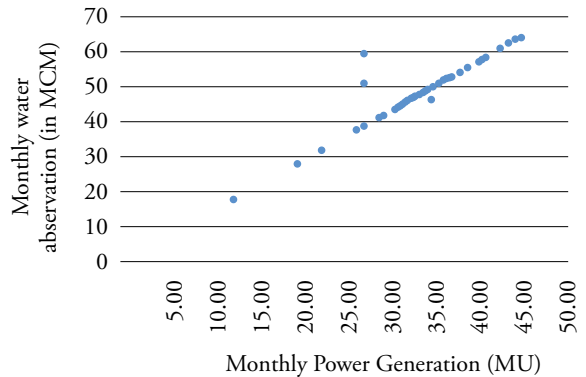


Figure 25: Power generation and water abstraction relationship



source community of scholars and practitioners since the 1990s. SWAT can be run stand-alone or linked to ArcGIS platform. For Loktak, the ArcSWAT plug in to ArcGIS was used.

The SWAT model is based on a semi-distributed framework in which unique combinations of Land Use, Soil Type, and Slope comprise individual hydrological response units (HRUs). Each HRU produces a certain water yield based on meteorological forcings. The models were calibrated using observed flow values for Iril, Thoubal and Nambul stations. Comparison of averages and the standard deviations indicate that the SWAT model is slightly under-predicting the runoff in the Thoubal basin and over-predicting it in the Nambul basin, and very close to reality in the Iril basin. This is to be expected given the relatively large spatial extent of the Loktak drainage basin and the concentrated nature of rainfall

within in. With a more comprehensive, densely spaced network of meteorological stations, it is likely that these modelled vs. observed figures would converge. The correlations indicate close fit between observed and modelled datasets. The Nash–Sutcliffe Efficiency (NSE) indicates that the model has performed well for Iril and Thoubal but has not done as well for Nambul. Parameters for Iril and Thoubal were finally used for modelling.

Based on the above four relationships, a monthly rule for lake levels corresponding to the three scenarios and hydrological conditions are presented in Figure 26 and Table 25.

An evaluation of the scenarios, on the water management objectives identified by the stakeholders is presented in Table 26. It can be seen that Scenario 3 performs better in terms of objectives related to hydropower, but does not augur well for biodiversity

Table 24: Water management objectives for Loktak

Water management objective	Required water regime	
1: Maintenance of Keibul Lamjao National Park habitat	Lowered water levels during lean seasons allowing phumdi to touch the bottom and receive nutrient replenishment (achieve a target of 767.4 m amsl within the park ¹⁷ in January) Gradual increase in water levels within the park during the monsoon to prevent flooding	
2: Hydropower generation	Water level is maintained at 768.5 m amsl at power channel, and should not fall below the minimum drawdown level (766.5 m amsl) ¹⁹	
3: Maintenance of waterbird habitats	Maintenance of marshes on the wetland periphery	
4: Flushing of sediments	No obstruction to sediment laden inflows during monsoon.	
5: Providing water for irrigation	Water level in the lake be maintained high towards the end of monsoon to support irrigation during the lean season Retention of water in upstream structures (from the flows of Manipur, Thoubal, Iril and Sekmai) are rationalized to provide adequate downstream flow retention in Loktak	
6: Reduction in flooding in peripheral settlements and agricultural lands	Lake levels are lowered to below 768.5 m amsl to ensure flood attenuation Target level of 768 m amsl within the central section of lake is maintained during monsoon seasons, and barrage operated accordingly	
7: Phumdi management	Lake outflows are ensured during the monsoon to enable phumdi flushing	
8: Supporting fisheries (Capture)	Lake outflows are ensured during the monsoons to enable upstream migration	
9: Supporting fisheries (Culture)	Inter-annual variability of the lake levels be restricted to 0.5 to 0.7 m	
10: Maintaining lake aesthetics for tourism and water sports		

and lake ecosystem processes related objectives. On the other hand, the Scenarios 1 and 2 provide for lake ecosystem processes at the cost of reduced hydropower generation. Under scenarios 1 and 2, the power production during lean seasons is affected, with the impacts higher in 1 than 2.

The overall scenario analysis clearly indicates the trade-off between hydropower generation and maintain lake ecological character. There is a very narrow window of opportunity for achieving both the objective simultaneously, under the current constrained situations. However, given the fact that

the lake is a Ramsar site, and the government is committed towards maintenance of ecological character of the wetland, scenario options which improve maintenance of ecological character are clearly preferred. Hence, of the options 1 and 2, a variant of 2 could be translated into a suitable barrage operation rule.

The present analysis is quite restrictive in the sense that it does not currently address several sensitivities that could affect water availability within the basin. The important factor to consider is that of climate change. Since the General Circulation Models do not

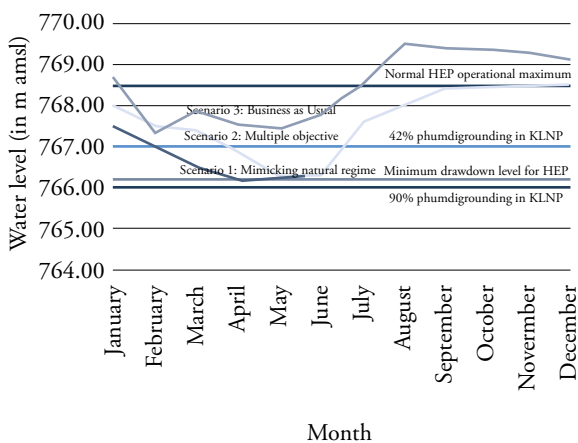
¹⁷This is recommended based on the observation of different water levels within the lake system

¹⁸One way to achieve this is through a regulator at Ungamel. However, any decision to construct such a structure should be based on a strategic environmental assessment.

¹⁹The maximum retention at Ithai barrage is 769 m amsl (source: NHPC Presentation to stakeholder's meeting, dated 23 March 2010)

Required lake condition	
	<ul style="list-style-type: none"> ● Circulation and flushing of water within the park to prevent development of anoxic conditions ● Flows from link channels to KLNP are regulated to ensure adequate lowering of water during lean seasons¹⁸
	<ul style="list-style-type: none"> ● Storage capacity within the lake is maximized to ensure water availability during the lean seasons ● Lake area within the central sector, especially near the power channel is kept clear of phumdi ● Highly acidic or alkaline conditions, silt content be avoided as they have potential to damage the hydropower generation units ● Catchment management practices ensure minimum silt delivery to the lake ● Hydrological connectivity with the marshes is maintained and fragmentation prevented
	<ul style="list-style-type: none"> ● High nutrient conditions in the lake are prevented as they contribute to proliferation ● Flushing within the park during the monsoons to ensure that anoxic conditions are not developed
	<ul style="list-style-type: none"> ● Central sector of the lake is maintained clear of phumdi ● Excessive nutrient enrichment is prevented

Figure 26: Scenarios of water allocation in Loktak Lake



provide high resolution information for small regions, the impacts of climate change on the northeastern region of India are relatively less known and explored. However, several studies (Das, 2004) also indicate a declining trend in summer monsoon rainfall. These trends need to be confirmed for the state of Manipur and Manipur River Basin in particular. More recently, an analysis of the impacts of prescribed global warming on the lake regimes indicate that the current water management infrastructure might not be capable to handle in projected rise in lake levels and the associated implications for land use in the lake periphery as well as lake biodiversity.³⁰

Table 25: Scenarios for managing water levels in Loktak

	Scenario 1	Scenario 2	Scenario 3
Scenario Objectives	Mimic natural regime – prioritize water allocation for maintaining park habitat	Multiple objective - Optimizing hydropower generation and irrigation while ensuring water allocation for maintaining park habitat	Business as usual ²⁰ – maximize and prioritize water allocation to hydropower
Lake level management rules	<p>January – April: Lake level drops gradually due to evaporation and water use for hydropower and agriculture. Other outflows are minimized</p> <p>May – With onset of monsoon, lake level is allowed to increase gradually to 768 m amsl so that the national park does not flood</p> <p>June to August – Lake level is maintained at 768 m amsl but is allowed to increase for short periods to create optimum conditions for flushing</p> <p>September to December – Lake is maintained at 768.5 m amsl to maximize storage for the lean season, and then gradually drops due to evaporation, and abstraction for hydropower, irrigation and domestic use</p>	<p>January – April : Lake levels are allowed to drop from 788 to 767.4 m amsl to ensure grounding of phumdi and flushing within the park. Water is made available for irrigation and hydropower generation (reduced availability)</p> <p>May : With onset of monsoon, the lake is allowed to gradually rise to 768.5 m amsl, ensuring that the park does not flood</p> <p>June - December : Lake level is maintained at 768.5 m amsl to ensure hydropower generation. Water does not exceed 786.5 m amsl to prevent flooding in peripheral areas.</p>	<p>January – May: Lake levels gradually drop by 1.3 m from 768.7 m amsl due to evaporation and water use for hydropower.</p> <p>June – August: Lake level gradually rises to 769.5 m amsl on account of monsoon driven inflows</p> <p>September – December: Lake level is consistently maintained above 768.5 amsl and drops from 769.5 m amsl to 769.1 m amsl on account of abstractions for hydropower, and evaporation, evapo-transpiration losses</p>

²⁰ Reference scenario – included to enable assessment of changes when decision is made to implement scenarios 1 – 2 instead of 3

Table 26: Outcomes of Scenarios evaluated by stakeholders

Water management objective	Scenario 1: Mimic natural regime	Scenario 2: Multiple objective	Scenario 3: Business as usual
1:Hydropower generation a) Total annual production b) Lean season production (Jan – April)	340 MU Operates at minimum drawdown levels for March and April; decline in production in April	360 MU Operates close to minimum drawdown levels on April and May; decline in production in February	600 MU ²¹ Production maintained as per initial projected schedule
2: Maintenance of KLNP habitat	Between Jan and March, 11 – 73% of the phumdi in KLNP is grounded. Rise in water levels due to onset of monsoons is gradual, preventing park flooding Flushing of water takes place within the park, preventing development of anoxic conditions	Between Jan – March, 1 – 20% of the phumdi in KLNP is grounded Rise in water levels due to onset of monsoons is gradual, preventing park flooding Partial flushing of water takes place within the park, preventing development of anoxic conditions	Negligible grounding takes places Rise in water levels can be rapid Negligible / no flushing of water takes place within the park, leading to development of anoxic conditions
3: Maintenance of waterbird habitats			
4: Reduction in lake sedimentation	Barrage releases available in monsoon months to ensure flushing of sediments	High barrage releases only in the month of September – October	Very limited release , often ad-hoc
5: Providing water for irrigation	Availability of irrigation water from November – February (~100 Mm ³)	Availability of irrigation water from November – April (~180 Mm ³)	Limited availability
6: Reduction in flooding in peripheral settlements and agricultural lands	Limited flooding as water levels are maintained around 768.5 m amsl	Limited flooding as water levels are maintained around 768.5 m amsl	High flooding in peripheral settlements as lake levels move beyond 768.5 m amsl during monsoon seasons, and even beyond
7: Phumdi management	Opportunity for flushing phumdi through barrage	Opportunity for flushing phumdi through barrage	Limited opportunity for phumdi flushing
8: Supporting fisheries (Capture)	Conducive conditions for fish migration	Conducive conditions for fish migration	Limited opportunities for fish migration
9: Supporting fisheries (Culture)	Fluctuating water levels impact culture fisheries	Fluctuating water levels impact culture fisheries	Conducive condition as lake levels are regulated
10: Maintaining lake aesthetics for tourism and water sports	High opportunities for maintaining lake aesthetics	High opportunities for maintaining lake aesthetics	Limited opportunities for maintaining lake aesthetics

²¹ The NHPC hydropower plant was expected to produce 450 MU as per the original design



4. Kanwar Jheel, Bihar

4.1. Context

Kanwar Jheel is part of an extensive floodplain complex formed in the lower reaches of Gandak-Kosi interfan in North Bihar. Located at a distance of 21 kilometer from Begusarai town, Kanwar is the largest of several shallow permanent and ephemeral wetlands formed between River Burhi Gandak and paleo-channel of River Bagmati. During monsoon, Kanwar connects with 17 adjacent waterbodies to form a large inundated area extending to nearly 6700 ha. With retreat of monsoon, the inundation shrinks to around 600 ha mainly around two small patches, Mahalaya and Kochalaya, exposing nearly 2600 ha of grasslands, large parts of which are used for agriculture.

Kanwar Jheel is a multi-functional ecosystem supporting livelihoods of 22,000 farmer and fisher households. High soil moisture, better water availability and the highly fertile silt received from the riverine inundations underpin high resource productivity. Kanwar helps reduce flood risk for the adjoining settlements by acting as buffer and accommodating significant proportion of local runoff and bank flows of River Burhi Gandak. The wetland teems with waterbirds in the winters, and is one of the important congregation areas in North Bihar, particularly for migrating ducks and coots. Over 200 bird species have

been recorded here, of which nearly 56 are migratory waterbirds. Kanwar is also an important source of animal fodder. The island of Jaimangalagarh located in its southern part has high archaeological significance. Considering its high waterbird diversity, Kanwar has been designated as a sanctuary by the name of 'Kanwar Lake Bird Sanctuary' since 1989 under the provisions of Indian Wildlife (Protection) Act, 1972.

Despite such high ecological and socioeconomic significance, management of Kanwar has received little attention in the regional developmental programming. Driven by perceptions of being waterlogged wasteland, the wetland complex has been subject to extensive hydrological regime fragmentation and conversion for permanent agriculture. Such land use transformation has led to near complete decimation of fisheries, adversely impacted biodiversity habitats especially of migratory waterbirds and impaired ability of wetland complex to moderate hydrological regimes. Shrinking resource base has accentuated conflicts between farmers and fishers. Kanwar has gradually transformed into 'contested common' with wetland use made subservient to conflicting sectoral and stakeholder interests. Existing institutional arrangements crafted to preserve biodiversity values are insufficient in addressing ecological connectivity with rivers or aligning private property rights prevailing within the wetland with its wide ranging ecosystem services and biodiversity.

The Government of Bihar has identified Kanwar Jheel as a priority wetland for restoration and sustainable management. An integrated management plan for securing diverse ecosystem services and biodiversity values of the wetland complex alongwith livelihoods of dependent communities is being prepared by Wetlands International South Asia for the Forest and Environment Department, Government of Bihar. The economic assessment of ecosystem services and biodiversity of Kanwar Jheel under TEEB-India aims at complementing management planning through:

- economic analysis of tradeoffs associated with land use changes within wetland regime;
- assessing distribution consequences of land use land cover changes;
- recommending measures for recognizing full range of ecosystem services and biodiversity values in site management.

Data for economic analysis has been obtained through primary survey of 481 households of 17 villages located around the wetland complex. Remote sensing and GIS analysis has been carried out to analyze landuse and landcover changes. Detailed participatory appraisals have been conducted in eight villages to assess ecosystem services bundle preferences and restoration options. The analysis is presented in eight sections. Following the context setting in section one, the biophysical and socioeconomic set up of the wetland is discussed in sections two and three. Identification of ecosystem services has been done in section four. This is followed by discussion on sectoral development and ecosystem services transformation in section five, and quantification and valuation of ecosystem services in section six. An economic analysis of distributional consequences is discussed in section seven. Section eight concludes with recommendations for integrated management of Kanwar.

4.2. Biophysical Settings

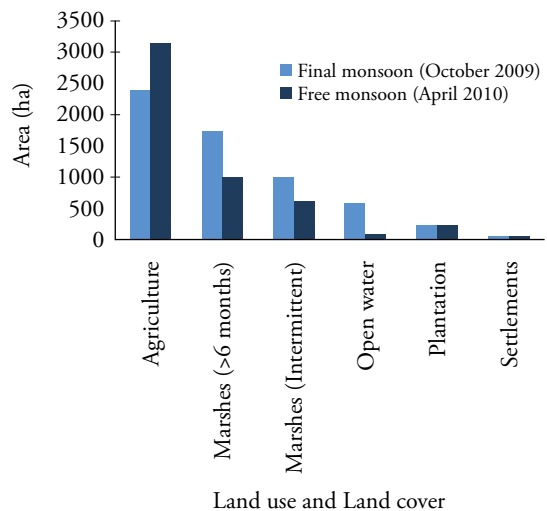
The Indo-Gangetic biogeographic region is characterized by the presence of numerous palaeo levees, cut off loops and ox-bow lakes formed by meandering of river channels. Such channel avulsion has left many natural depressions and cut-off meanders, later fed by rainwater and overbank flows to form marshes and intermittent lakes locally called as maun, chaur, taal and jheel areas. Kanwar Jheel is the largest of a complex of 18 such interconnected wetlands formed in the lower reaches of River Burhi Gandak (Map 3).

Kanwar Jheel contains a mosaic of landforms including open water, marshes, plantations, agricultural

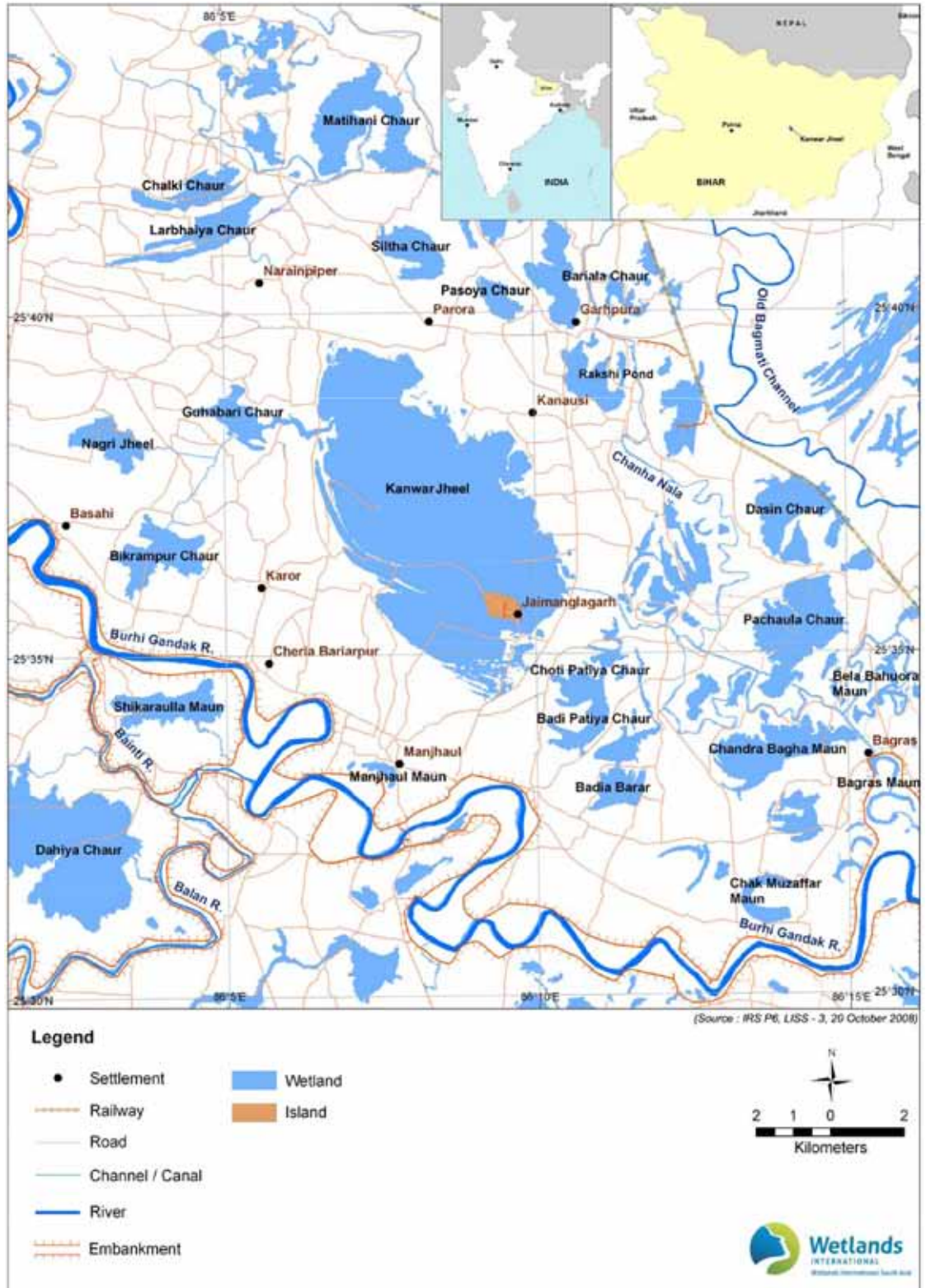
lands and interspersed settlements. The entire complex gets inundated with monsoon to a maximum depth of 1.5 metres. The eastern part maintains open water and marsh areas almost round the year, whereas in the rest, dried out marsh areas are cultivated. Seasonal dynamics of land use and land cover within the wetland complex is elucidated in Figure 27 based on analysis of remote sensing imageries of October 2009 and April 2010.

Kanwar wetland complex is located in the basin of River Burhi Gandak. Burhi Gandak is a perennial river originating from the upper plains in West Champaran District (Chautarwa *Chaur* near Bishambharpur). It flows through a length of 550 km draining 13300 km² of alluvial plains before merging into River Ganges on its left bank near Khagaria. The basin has a north-south elevation profile. The crest, accounting for 15% of total area has elevation ranging between 100-500 m amsl, followed by extremely gentle relief ranging between 50–100 m amsl within 57% of basin area. The remaining segment of the basin (28%) which gradually merges into River Ganges has an extremely gentle relief ranging between 25 – 50 m amsl. Agriculture accounts for nearly 70% of land use in the basin. Forests are marginally present in the basin's crest and confined to areas around Someshwar hills from where the river emerges. The lower reaches of the basin have larger wetland complexes in the form of intermittently to permanently waterlogged areas which connect to the rivers with flood pulses increasing significantly in size during monsoon and post monsoon periods, and rapidly shrinking in the summers.

Figure 27: Seasonal dynamics of land use and land cover change in Kanwar (2009-10)



Map 3: Location of Kanwar wetland complex



Rainfall, overbank inundations received from River Burhi Gandak and groundwater are the major sources of water inflow into Kanwar. The River Burhi Gandak is banked in its lower reaches. Overbank flows from River Burhi Gandak are mainly received during floods when river is in unusually high stage and sometimes as a result of breaching of embankments. Severe erosive action on the banks causes frequent breaches in the embankments even in medium floods almost every year. In a normal monsoon year, the wetland receives 26.9 MCM of water, which is lost to evapotranspiration and direct and indirect extraction for agriculture. There is a net recharge of groundwater from the period May–October, and a net discharge for rest of the period. Groundwater flux plays an important role in maintaining the inundation areas. Notably, agriculture has been reported in dry months of April within Kanwar, wherein in areas adjoining wetland land is usually left fallow due to lack of water. Kanwar is undergoing a phase a shrinking inundation regime. Peak inundation areas that were reported to be around 6700-7400 ha in the early fifties shrank to nearly 4100 ha. Available rainfall data indicates a decline during 1989 – 2012, particularly during south - west monsoon which in a normal year contributes nearly 80% of the total precipitation.

Kanwar Jheel is a shallow, well oxygenated, alkaline, nutrient rich freshwater wetland. Water is alkaline with an average pH of 7.8 (CPCB, 2012). Despite high phosphate concentration, algal blooms are absent in the wetland. High total and faecal coliform numbers have been observed indicating water of Kanwar Jheel is unsuitable for human use like drinking or bathing. Groundwater in areas surrounding Kanwar is alkaline (pH - 7.4), hardness (330-345 mg/l), and has high iron content (0.43 mg/l). The sodium absorption ratio, residual sodium carbonate, percent sodium and electrical conductivity place the groundwater under the class C3S1 (at Manjhaul and Cheria-Bariarpur) of irrigation water i.e. with medium to high salinity

hazard. Begusarai is amongst the six districts declared arsenic affected by Central Ground Water Board.

Hydrological and ecological connectivity between the river channel, riparian zone, and floodplains underpin the high biological diversity and habitat heterogeneity found in floodplain wetlands as Kanwar. Floods and flood pulses connect the various lotic and lentic environments facilitating exchange of matter, species and energy. The importance of cyclic inundation for biodiversity of floodplain wetlands of North Bihar is apparent. Exchange of fish brooders and juveniles between the river channel and the floodplains sustain high fish biodiversity and productivity of the entire Indo- Gangetic plains.

The relative dominance of emergent, submerged and floating vegetation as seen in different seasons in Kanwar is also linked with flood pulses. With the onset of monsoon, high inundation with nutrient flux favours growth of submerged and floating vegetation. The dominance shifts in favour of floating vegetation as water recedes and lotic pockets emerge in the wetland. The peripheral marshes are dominated by emergent macrophytes in the post monsoon and winter season. This also favours growth of benthic organisms which are important food sources for migrating waterbirds. Habitat fragmentation, particularly due to construction of flood control embankments, roads and other infrastructure has adversely affected the biodiversity of river as well as floodplain wetlands.

The richness of biodiversity in Kanwar is indicated by the recorded presence of 44 phytoplankton, 75 terrestrial plants, 46 macrophyte, 70 zooplankton, 17 mollusc, 50 fish and over 200 bird species (Table 27). High avian diversity of Kanwar has been one of its most prominent features. Personal records of local bird watchers indicate the number of species to be over 200. The wetland has supported large numbers of waterbirds in the past. It is estimated that around 70,000 ducks, coots and other waterbirds were netted at the site during the winters of 1981-82 (Shahi 1982). State Forest Department report (referred in WWF, 1993) mentions

Hydrological and ecological connectivity between the river channel, riparian zone, and floodplains give floodplain wetlands, like Kanwar, high biological diversity and habitat heterogeneity

Table 27: Record of Species at Kanwar and there conservation Status

Species Group		No. of Species	Record Date	Status						
				CR	EN	VU	NT	DD	LC	NE
Flora	Phytoplankton	44	1988-91							44
	Plants	121*	1988-91					2	35	84
Fauna	Zooplankton	70	1988-91							70
	Mollusca	17	1988-91						16	1
	Insecta	39	1988-91						6	33
	Pisces	35**	1988-91				2	1	28	4
	Amphibia	7	1988-91						7	
	Reptilia	5	1989-90						2	3
	Aves	221	2001-13	5	3	5	14		194	

CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near Threatened; DD=Data deficient; LC=Least Concern; NE= Not Evaluated

* Includes 46 macrophytes and 75 terrestrial species

** ZSI has reported presence of additional 15 species when the wetland connects to the river during floods, however, no list has been provided

135,000 birds being trapped at Kanwar during the winters of 1984-85. Considering these values, Kanwar has been designated as an Important Bird Area for congregatory and threatened birds migrating along the Central Asian Flyway and is a potential Ramsar site. However, recent observations indicate a decline in number of waterbirds visiting Kanwar. Kanwar Waterbird Census conducted by Mandar Nature Club as a part of Asian Waterbird Census programme for parts of Kanwar indicate 2,263 numbers of 20 species in 1999. Interviews with local communities confirmed a declining trend in visiting waterbirds, especially since the reduction in inundation regime.

4.3. Socio-economic settings

The ecological state of Kanwar influences as well is influenced by livelihood systems linked directly and indirectly to the wetland. The social, economic and political contexts in which wetland ecosystem services integrate with livelihood assets provide important insights for defining wise-use strategies.

The Kanwar wetland complex spans within six blocks of Begusarai District and one block of Samastipur District (namely Cheria Bariarpur, Naokothi, Bakhri, Garhpura, Chhorahi, Khudabandpur, and Hasanpur). The district occupies an important position in agricultural as well as industrial landscape of Bihar. Located in the highly fertile floodplains of River Ganges, agriculture is the key economic activity, accounting for nearly 40% of the land use, and livelihood source for 89% of working population.

The wetland complex is located in a rural agrarian

setting, and surrounded by 23 villages, 10 of which are located within the sanctuary boundary (GoB, 2004). The overall population of these villages as per 2001 census was 125,841. Fishers and farmers are the major groups inhabiting these villages. While farmers engage mostly in agriculture within and outside the wetland area, fishers have diversified into a range of activities including wage labour, small and marginal farming and running petty businesses. Marginal farmers (those who cultivate areas less than 1 ha are predominantly sharecroppers) constitute 85% of the farming households.

Dependence on wage labour is very high in the region, as it forms secondary occupation for 35% of households, majority being fishers. Table 28 presents a profile of primary and secondary occupation of communities living around Kanwar. Households with members in service, large farmers and businessmen have better and higher assets as compared with marginal and small farmers, fishers and wage labourers. The quality of housing was observed to be related to incomes, with the farmers and small entrepreneurs having better quality housing as compared to others. The coverage of water and sanitation facilities was observed to be very low, with only 18% of the households having toilets and 2% separate drainage. For most of the occupation categories, less than one third houses reported having toilets, except large farmers (100%) and small businessmen (61%).

In terms of assets, ownership of agricultural land is one of the key factors influencing the overall livelihood status. While nearly half of the households owned land (52%), the average area put to farming

Table 28: Occupation profile of communities living in and around Kanwar

	% to total households	Primary and secondary occupation (%)				
		Agriculture	Fishery (Capture and Culture)	Small Business	Service	Wage labour
Farmers	37					
Marginal	28	100	2	1	1	39
Small	6	100	0	0	0	20
Large	1	100	0	0	0	0
Fisher	27	8	100	0	0	54
Entrepreneur	2	19	16	100	3	0
Service	6	20	5	0	100	0
Labourer	30	13	9	0	0	100

was highly variable. The large farmers tilled on an average 4.58 ha whereas it was 1.32 ha and 0.38 ha for small and marginal farmers respectively. Over half of the fishers owned agricultural land, tilling 0.53 ha on an average. Trends in ownership of livestock were almost similar to those of agricultural land holding. Wage labourers reported no agricultural land holding and less than one fifth owned livestock. Average annual household income ranged between ₹0.51–₹2 lakhs. Large farmers and those engaged in service had the highest incomes (₹1.2–₹1.9 lakhs), followed by those of small farmers and business (₹1.03–1.14 lakhs). Annual incomes of marginal farmers and fishers ranged between ₹0.61–₹0.74 lakhs. Wage labourers earned the least of all, average being ₹51,135. The overall adequacy of the income to meet household needs was reported to be low, with over two thirds (68%) of the respondents stating the current level of income to be insufficient. Food accounted for nearly half of the household expenditure.

Majority households (68%) reported supplementing income from local resources with migration, which is an important strategy for coping with low incomes and lack of opportunities for domestic employment, and since long, has been a part of livelihood strategy particularly in rural Bihar. The number of persons who migrated formed 24% of adult population and 34% of the overall working population. The proportion of income from migration sources constituted over 40% for the small and marginal farmers and fishers, whereas ranged between 15 – 25% for other categories.

Trends in migration have an apparent relationship with changing land use and productivity of the wetland. In the fifties, fisheries based livelihoods were predominant, and the instances of migration were very

limited. Reduction in water levels and concomitant expansion of agriculture forced the fishers into wage labour within the expanding farms. With increase in population and better earning opportunities outside the trend in migration has been increasing. Expansion of agriculture farming within the wetland complex has created local employment opportunities for the farmers as well as fishers. However, with very low land holding, the need for additional income sources is higher. The preference for wage labour is also attributed to low education. Migration is seasonal in nature, mostly concentrated during the months of October – March (wherein cropping is complete and maintenance of the crops is relatively less labour intensive).

Access to formal banking and credit institutions is low. Banking services are accessed by only 37% of the households, despite 63% reporting savings. Local money lenders were the major source of credit, accessed by 85% of the households. Average outstanding credit was 33% of the household income, and ranged from a minimum of 7% for large farmers to 93% for wage labourers.

Village Panchayats are the main community institutions existing in the villages around Kanwar. One third of the fishers are members of the fisher cooperatives, formed to enable participation in fishing lease in the *maun* and *chaur* areas. Not all fishers are members of the cooperative as only those who can invest capital are given the right to stock the waterbodies and fish. Similarly, farmer cooperatives exist to gain access to government support in the case of floods and droughts. The farmer groups also act as pressure groups to prevent acquisition of farming land for sanctuary purposes. On an overall, the degree of organization was low, within the villages as only 40% had membership to any formal

or informal institution. Participation of females in these institutions was further limited, with only 1% of the households having female members as members to any institution. Implicit within these statistics is the prevailing caste based power structures in the region, with the fishers belonging to lower social strata in terms of economic and political affluence.

4.4. Ecosystem Services

The wide ranging biological diversity, and linked biophysical and social setting enable Kanwar to deliver the following ecosystem services. Table 29 maps the relationship between ecosystem service and its enabling biophysical condition and influencing socioeconomic environment, as particularly the latter affects benefit sharing and equity. Conditions and trends in ecosystem services are also summarized.

4.4.1. Fisheries

Connectivity with the riverine environments and abundance of food makes Kanwar an important source of capture fisheries. In the past the Indian Major Carps have dominated fishery along with feather backs, catfish, *murrels* and *minnows*. Of the 36 species reported in the wetland (ZSI, 2002) 26 are of economic value and sold in local markets. Besides, Kanwar complex is also a rich source of edible molluscs. Communities around Kanwar collect four species of mollusks *Pila globosa*, *Bellamya bengalensis*, *Lamellidens marginalis* and *L. corrianus* as food.

Fishery forms the livelihood base of around 32% of households, particularly of Sahni community. The prospect of secure production through culture techniques has gradually shifted the focus of fishers to collective fishing in the *maun* and *chaur* areas associated with Kanwar. Majority of the associated *maun* and *chaur* areas are leased by the fisher cooperatives from the state fisheries department for semi intensive culture fishing since last three decades.

4.4.2. Wetland Agriculture

Flood pulses support high levels of nutrient enrichment and organic matter deposition within floodplains, making them highly productive ecosystems. As inundation recedes and marshes dry after monsoon, a large area of Kanwar is used for agriculture, supported by a combination of fertile silt, high soil moisture and nutrients. Agriculture forms the primary source of livelihoods for 31% of the households living around the Kanwar wetland complex. Presently over 2600 ha of wetland area is under agriculture supported largely by irrigation.

4.4.3. Aquatic Vegetation as Food and Fodder

Kanwar is an important source of fodder and fuelwood for the neighboring villages. *Leersia hexandra* (Garar), *Sacciolepis myosuroides* (Ghass), *Eichhornia crassipes* (Jalkumbhi) and *Commelina bengalensis* (Kankua ghass), *C. rotundus* (Chichorh), *Cyperus iria* (Mootha) are the major species used as fodder. Dried *Saccharum spontaneum* (Kans ghass), *Phragmites karka* (Narkat) and *Cyperus iria* are extensively used as fuel wood. The wetland is a source of fuel wood for 93% of the households.

Fruits of *Trapa natans*; whole plant of *Nelumbo nucifera*, flower of *Nymphaea nouchali*; leaves and stem of *Ipomoea aquatica*, and underground stem of *Colocasia esculenta* (Kacchu) are harvested from the wetland complex and used as vegetables. Communities harvest several aquatic plants for use as medicines. *Chaur* and *maun* areas are used for cultivation of makhana (*Euryale ferox*). Most of these harvests, barring *Euryale ferox*, are of very subsistence level, usually done by older fishers who no longer engage in fishing.

4.4.4. Groundwater Recharge

Groundwater dynamics have an important contribution in maintenance of wetland regime as well as an ecosystem service for the agrarian livelihoods prevalent

The ecosystem services of Kanwar include fisheries, wetland agriculture, and groundwater recharge. Agriculture and fishery form the majority of primary source livelihoods for households around the Kanwar wetland complex

in and around Kanwar. Water balance assessments indicate that in a given year, there is a net recharge of groundwater from the period May – October, and a net discharge for rest of the period. Agriculture has been reported in dry months of April within Kanwar, whereas in adjoining areas, land is usually left fallow due to lack of water.

4.4.5. Flood Control

A key indirect value of Kanwar to the communities living in and around is its ability to buffer extreme events. The plains of North Bihar are some of most susceptible areas in India prone to flooding, and have experienced frequent loss of life and property over the last several decades. The Kanwar Jheel, forms a saucer shaped depression in the landscape, accommodating surface run-off and proving flood buffer to communities living in and around. However, weak integration of role of wetlands in flood defence and focus on structural approaches as embankments has promoted fragmentation of natural regimes of the wetlands.

4.4.6. Cultural and Recreational Values

The scenic beauty of Kanwar, until the recent past, has made it a popular local recreation site. The island temple of Jaimangalagarh is associated with historical and religious values. Several excavations from the area have been dated to pre-historic and Mughal periods. It is also believed that the site was used by Buddhist scholars of Buddha's times. The temple holds an important place in the local culture, with several festivities and celebrations taking place nearly all the year round. An important feature here is the presence of a large number of monkeys (owing to which the island is also called "Monkey Island" in local parlance).

4.5. Sectoral Development and Ecosystem Services Transformation

Sustainable management of Kanwar has received little attention in developmental programming of the state. In the fifties, flows from Burhi Gandak River and the Chanha River constituted the major source of inflows into Kanwar. It has been reported that during floods, Kanwar received inflows from River Kareha as well. A significant proportion of the wetland remained inundated throughout the year. Marsh and open water regime provided landscape heterogeneity conducive habitats for waterbirds, fish and other forms of aquatic biodiversity. Agriculture was mostly confined to upland areas around Manjhaur and Cheria Bariarpur and a single crop was possible.

Support to policies for enhancing food security by bringing in additional areas under agriculture brought in tremendous pressure on the naturally fertile floodplain wetlands as Kanwar. Construction of flood embankments along River Burhi Gandak in 1954 created a significant impediment to connectivity of Kanwar with the rivers. This also coincided with the period wherein efforts to reclaim the inundated areas for agriculture gathered pace. A canal system connecting most of the water bodies around Kanwar was constructed that finally drained into River Burhi Gandak through a 12 km long channel. Channelization impeded sediment distribution in the wetland complex, and promoted accumulation within Kanwar. Floods such as those witnessed in 1987 and 2007 have deposited huge amount of silt in Kanwar Jheel.

Agriculture has gradually intensified with reducing inundation areas (from over 6000 ha in the 80s to 4100 ha in 2010), and traditional varieties giving way to more water demanding crops as sugarcane. Agriculture has transformed from small-scale subsistence farming to permanent multi-cropping system. Presently, the areas under permanent inundation are reduced to small patches around Mahalaya and Kochalaya. The wetland has turned in to an extensive landscape of agriculture fields. The wetland biodiversity and aesthetics have been adversely impacted.

Table 30 captures the landscape transformation during the period 1976-2010, based on analysis of remote sensing imageries (Map 4). The left column contains the class which has changed to a particular category as indicated by the row heading. The diagonal elements represent areas that have remained unchanged. For example in the first row, 2189.3 ha of open water area in 1976 has changed to marsh in 2010 whereas only 569 ha now remains as open water. The total area under open water in 1976 was 3675.6 ha.

4.6. Quantification and Valuation of Ecosystem Services

The analysis of biophysical and socioeconomic settings and landscape transformation patterns indicate the significance of inundation regimes in maintenance of biodiversity and ecosystem services values of Kanwar. The variable inundation regime enables a dynamic land use pattern which provides a range of resources as fish, wetland agriculture and vegetation for economic use. The inundation regime also influences vegetation and species exchange with riverine environment. An informal agreement between fishers and farmers enabled the two groups to harvest wetland resources in

Table 29: Ecosystem Services Description

Ecosystem Services Description	Stakeholder	Existing biophysical environment enabling delivery of ES	
Provisioning			
<p>Fisheries</p> <p>Kanwar is a capture fishery source, whereas associated wetlands are used for culture fishery. 26 of the 36 fish species reported in Kanwar are sold in local markets.</p> <p>Kanwar complex is also a rich source of edible molluscs. Four species of molluscs, namely <i>Pila globosa</i>, <i>Bellamya bengalensis</i>, <i>Lamellidens marginalis</i> and <i>L. corrianus</i> are collected from the wetland for household consumption as well as limited trade.</p>	<p>Fishery forms the livelihood base for 2850 fishing households of Sahni community.</p>	<ul style="list-style-type: none"> ● Connectivity with the riverine environment which enables exchange of riverine fish species ● Sufficient water spread area during lean season ● Adequate level of nutrients and well-oxygenated environment ● Calcium precipitation by emergent macrophytes provides conducive condition for molluscs to proliferate. 	
<p>Wetland agriculture</p> <p>Kanwar supports productive wetland agriculture that is aligned with inundation regimes. Traditionally the highland areas called rahi were cultivated for one or two crops, the nausi or lowland areas remained inundated.</p> <p>With a shift towards permanent agriculture systems around 2600 ha of wetland area is used for three or more crops. Cultivation is done throughout the year, with paddy is the major Kharif crop (June–November), wheat and sugarcane during rabi (December – April) and maize during garma (April – June).</p> <p>has emerged as a platform for farmers to voice their concerns</p>	<p>3200 farmers engaged in farming inside wetland</p>	<ul style="list-style-type: none"> ● High soil moisture ● Fertile silt received from riverine inundations. 	
<p>Aquatic vegetation</p> <p>Kanwar is an important source of fodder and fuelwood for the neighboring villages.</p> <p>Dried <i>Saccharum spontaneum</i> (Kans ghass), <i>Phragmites karka</i> (Narkat) and <i>Cyperus iria</i> are extensively used as fuel wood.</p> <p>Chaur and maun areas are used for cultivation of makhana (<i>Euryale ferox</i>)</p> <p>Fruits, flowers, leaves and underground stems of aquatic plants are harvested from the wetland complex and used as vegetables by local communities. Several aquatic plants are used as medicines.</p>	<ul style="list-style-type: none"> ● 3750 households extract fuelwood ● 1450 households harvest plants for fodder ● Harvest of aquatic plants form source of sustenance for old fishermen who can no longer engage in fishing 	<ul style="list-style-type: none"> ● Variable inundation regime and high nutrients create enabling conditions for submerged, floating and emergent vegetation. 	

Existing socioeconomic environment influencing ES	Recent trends
<ul style="list-style-type: none"> ● Culture fishery operations are managed by Fish Cooperatives. 	<ul style="list-style-type: none"> ● Use of variable inundation regime for capture fishery is based on an informal understanding between fishers and farmers for conjunctive use. Fishers attribute the right to capture fishery over private lands to a 1885 judgment, which awarded rights of fishing to the Sahnis community in the entire Kanwar area on payment of rent to landowners ● Reduced riverine connectivity has led to reduction in IMC and an increase in forage and air breathing fish. ● Rampant use of small mesh sizes further depresses catch ● Culture fish production is sub-optimal due to lack of appropriate technology infrastructure and water regime. ● Functioning of cooperative is skewed in favour of members with ability to invest capital.
<ul style="list-style-type: none"> ● Land is privately held and cropping decisions is individual ● Sanctuary declaration has imposed restrictions on transfer of land. Kanwar Bachao Sangharsh Samiti ● Policy environment supports agriculture 	<ul style="list-style-type: none"> ● Agriculture has intensified with multiple cropping cycles ● Water regimes have been modified to promote agriculture ● Indigenous crop varieties have been replaced with water intensive ones ● Increased groundwater draft for irrigation ● Increase in use of fertilisers and pesticides
<ul style="list-style-type: none"> ● Commercial exploitation is regulated as the area is declared as wildlife sanctuary. 	<ul style="list-style-type: none"> ● Proportion of emergent, particularly Phragmites karka has increased over the years ● Harvest keeps proliferation in check

Contd...

Ecosystem Services Description	Stakeholder	Existing biophysical environment enabling delivery of ES
Regulating		
Flood control		
Kanwar is a saucer shaped depression in the landscape functioning as a buffer for extreme flood events for the downstream southeastern areas from damaging bank inundations	The risk of damage to 23 settlements around the complex is reduced	Water holding capacity of wetland
Moderation of water regimes		
Groundwater dynamics have an important contribution in maintenance of wetland regime as well as an ecosystem service for the agrarian livelihoods prevalent in and around Kanwar. Water balance assessments indicate that in a given year, there is a net recharge of groundwater from the period May – October, and a net discharge for rest of the period. Agriculture has been reported in dry months of April within Kanwar, whereas in adjoining areas, land is usually left fallow due to lack of water	Region around Kanwar	Water holding capacity and geomorphological conditions
Cultural		
Recreational and cultural value		
The scenic beauty of Kanwar, until the recent, has made it a popular local recreation site. The island temple of Jaimangalagarh is associated with historical values.	Region around Kanwar; national and global community at large	<ul style="list-style-type: none"> • Presence of open water expanse • Presence of waterbirds.

Table 30: Landscape transformation matrix

Change from 1976	Change to 2010						
	Area(ha)	Open water	Marsh	Forest/ Plantation	Silt/ Current Fallow	Agriculture	Total (1976)
Open water		569.1	2189.3	68.7	311.9	536.6	3675.6
Marsh		26.4	356.3	28.9	218.4	788.8	1418.8
Forest/ Plantation		0.9	29.4	3.4	19.1	66.0	118.8
Silt/Current Fallow		1.7	78.7	17.1	130.9	514.5	742.9
Agriculture		3.8	99.6	19.9	157.1	472.4	752
Total (2010)		601.9	2753.3	138.0	837.5	2378.3	6709

a staggered manner thereby preventing conflicts.

Landscape transformation has triggered several changes in inundation regimes of the Kanwar wetland complex. In order to assess the associated tradeoffs, the following three scenarios have been considered:

Business as Usual (BAU) – Corresponding to the state of wetland complex in the last decade (2000-2014), BAU has a peak inundation regime of ~20 km².

Permanent agriculture is the predominant land use, and capture fisheries are nearly decimated. The riverine connectivity is fragmented due to embankments. The maun and chaur areas associated with Kanwar are used for culture fisheries, however the productivity is low, primarily due to lack of water availability.

SEM1 – Relates to a state of Kanwar with inundation regime as in 80s wherein a peak inundation

Existing socioeconomic environment influencing ES	Recent trends
<ul style="list-style-type: none"> • Silt accumulation due to hydrological regime and land use changes has led to reduced water holding capacity. 	
Use of groundwater is not regulated.	<ul style="list-style-type: none"> • Increased dependence on groundwater by culture fishers as well as farmers. • Increasing depth to ground water levels has been increasing in intensively cultivated areas
Prohibition of wildlife hunting has positive impacts on waterbird habitats.	<ul style="list-style-type: none"> • Decline in inundation regime and wetland degradation has reduced the aesthetic appeal

upto 48 km² is achieved. Communities practice a mix of capture fisheries and agriculture. Culture fisheries is practiced in limited *maun* and *chaur* areas, however, productivity is high on account of natural recruitment from the river and abundant water availability.

SEM2 – Relates to state of Kanwar with inundation regimes as in 70s wherein large parts of wetland complex remain permanently inundated. Capture fisheries assume a relatively predominant role in this state. Permanent agriculture is very limited. There is no culture fisheries.

The three scenarios essentially describe alternate states towards which wetland management can be targeted. The scenario analysis maps the prevailing biophysical condition in each of the scenarios into an economic value using existing prices and production technologies. The analysis therefore does not intend to capture temporal changes in welfare, but welfare changes at present likely to result from managing the wetland towards an alternate state. Further, for economic analysis, only capture and culture fisheries, wetland agriculture, aquatic plants and groundwater recharge

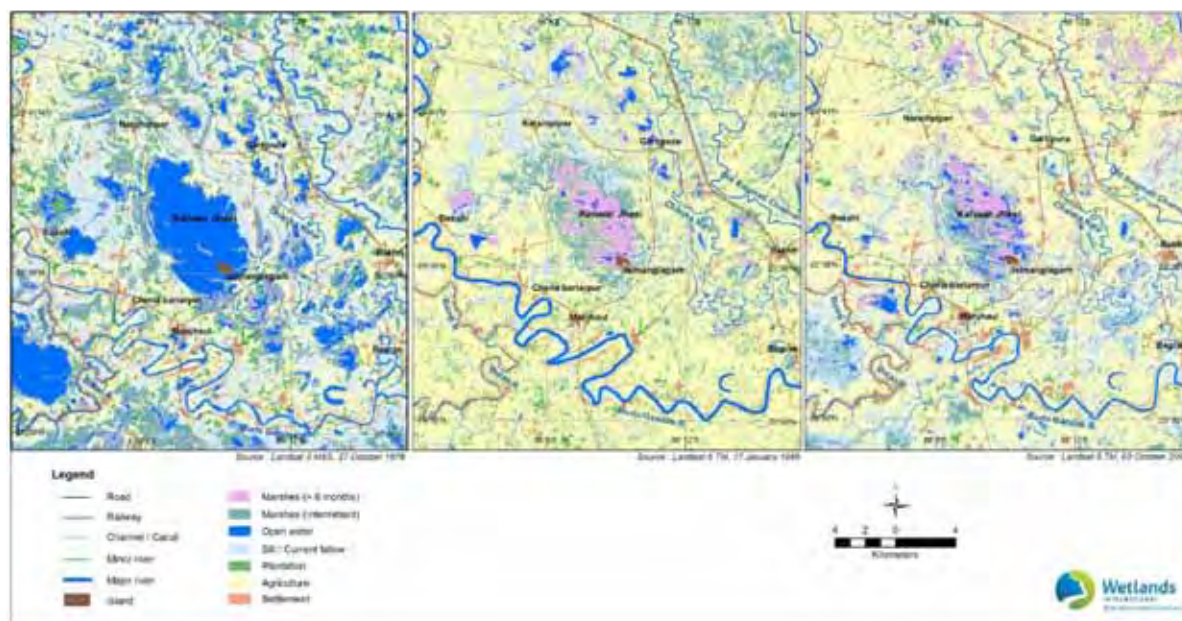
function have been considered due to availability of data.

2.6.1. Capture Fishery

Capture fishery from Kanwar has been assessed based on species composition and total annual harvest. Assessments of 2000 indicate presence of 36 species belonging to zoological order of Cypriniformes, Siluriformes, Beloniformes, Channiformes, Perciformes and Mastacembeliformes being abundant in catch throughout the year. Of these, 26 were identified as being of economic value and sold in local markets.

Capture fishery in Kanwar has been adversely affected due to habitat fragmentation and reduced connectivity with riverine environment. Active fish breeding areas as Mahalaya and Kochalaya have been affected due to decline in water depth as well as colonization by emergent macrophytes (*Phragmites karka*). Major carp breeding grounds as Channaha naladhar, Boharadhar, Sahara naladhar and Guhabari mouth have silted up.

Analysis of catch composition based on CIFRI records indicate a gradual increase in air breathing species

Map 4: Change in land use and inundation regimes

(*Clarias batrachus*, *Heteropneustes fossilis*, *Amphionous cuchia*, *Anabas testudineus*); catfishes (*Wallago attu*, *Mystus sp.*) and forage fishes. Fishes abundantly reported and harvested during 1970s and 1980, e.g. *Labeo gonius* (Khursa) and *Notopterus notopterus* (Bhuna) are seldom found. These trends have also been validated by the fishers during field survey. Temporal trends in species composition of catch from Kanwar derived from CIFRI records is presented in Table 31.

Catch statistics from Kanwar are not maintained. For the present study, catch estimates of Kusheshwarsthan have been used (Jha and Chandra, 1997), which is a wetland located in similar ecological setting but has limited hydrological fragmentation. The derived catch per unit area have been multiplied with

average annual inundation area obtained from remote sensing data of Kanwar.

Since fish is a marketed commodity, market price method has been used to derive the value of capture fishery of Kanwar. The species composition available from the records of CIFRI have been used to derive group specific catch. Species composition for scenarios SEM1 and SEM2 have been assumed to be similar. Existing market prices at Majhaul have been used to estimate the catch value, as almost entire fish catch is traded locally. To arrive at net value, the annually depreciated capital value of fishing implements have been deducted. As per household survey, the total value of fishing implements was estimated to be ₹8,044 per fisher household which aggregates to ₹22.925 million

Table 31: Trends in percent composition of fish catch in Kanwar Jheel

	IMC	Minor carp	Catfish	Feather- back	Murrels /Air breathing	Minnows
1981	21	24	12.5	13	6.5	27.5
1985	15	20.5	15	14	10.5	33
1990	9	19.5	18	14	11.5	41.5
1995	7	12	19	11.5	17.5	53
2000	5	7.5	14	10	20.5	56.5
2005	2.5	8.5	16.5	7.5	24.5	61
2011	1	6.5	16.5	6.5	29.5	67.5

Table 32: Economic value of Kanwar Jheel capture fisheries

Scenario	Catch	Gross Value (₹ Million) at current prices	Net Value (₹ Million) at current prices
BAU	50 MT	6.767	5.621
SEM1	230 MT	34.874	33.728
SEM2	360 MT	54.585	53.439

for the total fisher households. The annual depreciated value at 5% is estimated to be ₹1.146 million. It is assumed that the existing fishing implements can provide the capture fisheries harvest in all scenarios. The estimated gross and net annual value from capture fisheries is summarized in Table 32.

4.6.2. Culture Fishery

Kanwar Jheel is surrounded by a number of *maun* and *chaur* areas which are used for extensive to semi-extensive culture fishery. These areas are within the jurisdiction of State Department of Animal Husbandry and Fisheries and governed as per the provisions of Bihar Fish Jalkar Management Act (2006). The Department leases fishing rights in these waterbodies to fish cooperative societies currently for a period of 7 years at a time. Presently, fishing in waterbodies around Kanwar has been leased to four fisher cooperatives.

A mix of Indian Major Carps (*Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*) and Exotic carps (*Hypophthal michthys molitrix*, *Ctenopharyngodon idella*, *Cyprinus carpio* and *Hypophthal michthys nobilis*) are used for stocking. The culture operation begin with the onset of monsoon (July) and continues till late monsoon (October) with the stocking of fry, fingerling and advance fingerling, sometime mixed together or in phased manner (stocking of fry of *Labeo rohita*, *Catla catla*, followed with fingerling of *Hypophthal michthys molitrix*, *Ctenopharyngodon idella* and advanced fingerling of *Cirrhinus mrigala*, *Cyprinus carpio* and *Hypophthal michthys nobilis*). In general around 2000 -3000 of advanced fingerlings (approximately each weighing up to 100gm) is stocked in an acre of *maun* and *chaur*.

The harvesting is done by using drag nets which usually start from late February to April. Each cooperative has its own mechanism for selling the harvest and revenue sharing, however, is largely linked to the ability of individual members to invest capital for culture operations and payment of lease. A significant proportion of fishers mainly seek employment as wage

labour in culture fisheries operation.

Culture fisheries operations around Kanwar is rendered inefficient due to a number of biophysical and socioeconomic factors. Assessment by CIFRI in 2008 indicated that the current production levels in the *maun* and *chaur* areas (265 kg/ha) were significantly lower than the potential production of 1,500-2,000 kg/ha provided all ecological conditions are met (Sinha and Jha, 2008).

Production for BAU scenario has been estimated based on culture fisheries area (provided by State Department of Fisheries) and productivity as assessed by CIFRI. For SEM1, production corresponding to Majhaul *maun* with a productivity of 750 kgs / ha (derived from interviews with fisher cooperatives) has been taken. For SEM2, a productivity of 1200 kgs / ha has been taken. Gross value of fish yield has been estimated based on existing market prices of Indian Major and Exotic Carps. To arrive at the net value, annual operation costs and lease value have been deducted. Data from Majhaul *Maun* indicated that during a year, ₹10,789 / ha is incurred as costs (including lease value spread over 7 years, fingerlings, pond preparation, and labour for the entire duration of operation cycle). For scenarios SEM1 and SEM2, costs have been assumed to increase in proportion with productivity. The gross and net value added by culture fisheries in the wetland complex is presented in Table 33.

4.6.3. Wetland Agriculture

Changes in inundation regimes over the years have brought about significant changes in farming systems within Kanwar. Till early seventies, agriculture was limited only to areas around major villages such as Manjhaul, Cheria-Bariarpur and Karor. Upland areas in wetland locally called *rahi* were used for cultivation during dry season. Millets were the major crops. Farm productivity was low and most of the agricultural produce was consumed by the farmer's family.

Table 33: Economic value of fish yield from culture sources in Kanwar complex

Scenario	Yield (MT)	Gross Value (₹ Million) at current prices	Net Value (₹ Million) at current prices
BAU	76.82	10.601	7.473
SEM1	217.42	30.004	21.153
SEM2	347.88	48.007	33.844

As the areas under permanent inundation receded, more and more areas were brought into permanent farming. High yielding varieties of wheat and maize were introduced, with major expansion happening during 1970s and 1980s. At present the impetus is on cultivation of crops such as mustard and sugarcane for which markets are available. Cultivation of sugarcane has intensified all around the wetland periphery particularly on the eastern side. Farming has shifted from a subsistence rainfed system to that with groundwater irrigation dependent. The expansion and intensification of agriculture within the wetland complex is entirely based on groundwater extractions.

For the scenario analysis, production estimates have been derived for two major crops, namely wheat and rice (Table 34). Productivity has been estimated from primary data collected from 47 farmers and participatory appraisals in 8 villages. Crop specific areas have been derived from crop area ratios (obtained from household survey) and wetland area used for agriculture based on remote sensing imageries. Economic values have been derived from existing Minimum Support Prices (Table 35).

4.6.4. Aquatic Vegetation for Human Use

The ability of Kanwar to provide aquatic vegetation for human use is closely related to inundation regime. The deeper parts as Mahalaya and Kochalaya have extensive beds of lotus (*Nelumbo nucifera*) and Singhada (*Trapa natans*), harvested during the months of July to October. The harvest of these species has however declined considerably in the recent times, and is mostly done for subsistence, usually by older fishers who no longer engage in fishing. Decrease in inundation has

reduced the availability of fodder species such as *Leersia hexandra* (Garar) which also used to provide food and shelter for animals and many water birds. Decreased soil moisture conditions have also affected other fodder species growing wildly in wet conditions such as *Commelina benghalensis* (Kankua ghash) as *Sacciolepis myosuroides* (Ghass), *Cyperus rotundus* (Chichorh) and *C. iria* (Mootha).

As inundation regimes have shrunk, availability of fuelwood from Kanwar has increased. The household dependence on fuelwood from the wetland has remained high though the level of dependency has decreased from 1970s till now. There has been only minor variation in energy source pattern. Wood remains the primary energy source even in the present times. The access to clean energy sources remains low, with only 6% households using LPG as the primary source of energy for cooking. In the present scenario as well, around 24% of the households extract fuelwood from Kanwar. The rest of fuel wood requirement is met nowadays through market and available farm refuse.

For scenario analysis, quantity and value of fuelwood has been estimated. Annual harvest of fuelwood from Kanwar for three scenarios has been estimated from primary surveys of 481 households. Data on percentage households using fuelwood from Kanwar has been used to derive total annual harvest pertaining to the three scenarios.

4.6.5. Groundwater Recharge

The groundwater recharge function primarily benefits farming within as well as around the wetland. The decline in inundation area has been reported to lead to decrease in groundwater levels, which subsequently affects the overall farm economics by increased cost of pumping.

Economic value of groundwater recharge has been derived from agriculture production function for wheat crop which is the main dry season crop and requires irrigation. With a decline in inundation area, the decrease in groundwater recharge has manifested

Table 34: Economic value of produce from wetland agriculture in Kanwar complex

Scenario		Total area (ha)	Gross Value (₹ Million) at current prices	Net Value (₹ Million) at current prices
BAU	Wheat	1850	62.328	31.090
	Rice	770		
SEM1	Wheat	1550	51.330	40.800
	Rice	600		
SEM2	Wheat		21.780	18.425
	Rice	450		

Table 35: Economic value of produce from wetland agriculture in Kanwar complex

Scenario	Fuelwood harvest (MT)	Economic Value (₹ Million)
BAU	540	1.012
SEM1	8075	15.140
SEM2	4840	9.075

in decrease in average water level in the villages around Kanwar from 6.48 m bgl in 1970s to 6.93 m bgl in 1980 and 9.15 m bgl at present.

We assume price taking behavior in the farmers, and that there exists an inverse demand curve for crop output Q. It is also assumed that the reduction in groundwater level leads to adverse impact on household welfare, through an increase pumping cost. The impact of change in groundwater levels is reflected through an impact on water input W. For a non-marginal change in naturally recharged groundwater, the welfare change can be estimated as the resulting change in value of production less the increase in pumping cost. It is also assumed that the farmers supply to the same markets and source the inputs from the same market, and thereby face the same production and cost relationships. This also permits aggregation of welfare effects of change in groundwater levels for the individual farmer, across all farmers around the wetland. A single production function for wheat is assumed to be prevalent in the region.

The following production function has been specified for a single household:

$$Q = f(L, F, W)$$

$$\log Q = \alpha + \beta_1 \log L + \beta_2 \log F + \beta_3 \log W + C$$

Wherein, Y= annual crop output (in kgs.), L = total labour (person days) employed; F = total fertilizer

Table 36: Crop production function

Variable	Log-linear
Log (labour)	0.471 (5.321)**
Log (fertilizer)	0.367 (3.735)**
Log (Water)	-0.147 (-1.273)
Constant	0.084 (0.389)
Adjusted R2	0.644
F – Statistic	24.51**
Number of observations	40

Table 37: Economic value of groundwater recharge function

Scenario	Change in groundwater depth as compared to BAU (in m bgl)	Value lost due to reduced Groundwater levels (₹ Million)
SEM 1	-0.35	₹ 1.504
SEM 2	-2.67	₹ 9.658

Table 38: Ecosystem bundles outcomes

Ecosystem Service	Indicator	Scenario Outcome		
		BAU	SEM1	SEM2
Capture Fisheries	Annual Catch (MT)	50	230	360
	Economic Value at current prices (₹ Million)	5.621	33.728	53.439
Culture Fisheries	Annual Catch (MT)	76.82	217.42	347.88
	Economic Value at current prices (₹ Million)	7.473	21.153	33.844
Wetland agriculture	Total Produce (qtl)			
	Economic Value at current prices (₹ Million)	31.090	40.800	18.425
Aquatic plants for human use	Harvest (MT)	540	8075	4840
	Economic Value at current prices (₹ Million)	1.012	15.140	9.075
Groundwater recharge	Loss in economic value due to reduced groundwater level as compared with BAU (₹ Million)		1.504	9.658
Flood control		Low	Medium	High
Cultural and recreational value		Low		High
Value as biodiversity habitat		Low	High	High

application (kgs.); W = water level (below ground level in meters) and being the residual term. Ordinary Least Squares Regression estimates using logarithmic transformation were found to have the best fit on data on input and output parameters collected from 40 respondents. The regression coefficients are reported in table 36.

4.7. Distributional Impacts

The scenario analysis indicates the likely trends in ecosystem services as management is targeted for maintaining business as usual to restoration to 1980's conditions or to 1970s conditions. The net change in economic value over baseline for various ecosystem services is indicated in Figure 28. The analysis clearly indicates that maintaining BAU is an inefficient argument, and involves significant opportunity costs in terms of lost values if restoration of inundation regime is not targeted. Given the role of Kanwar in sustaining economy of communities living around Kanwar, it is important to assess the trends in terms of implications for livelihoods of different stakeholder groups. In particular, the likely livelihood outcomes for fisher and farmer groups will influence the degree of engagement and local support that can be expected for restoration. For this purpose, data on occupational structure and information from participatory appraisals was used to construct a stakeholder segmented distribution of economic values. Figure 29 presents the net changes in economic values in scenario SEM2 with respect to BAU as baseline. The analysis assumes no occupational transformation across scenarios and no change in production or consumption technologies. It can be inferred that the fishers are the group likely to gain the most through rejuvenation of capture and culture fisheries sources, albeit with a loss in agricultural production value. The costs of inaction (of not restoring the wetland towards SEM2) are the highest for fishers,

whereas, for the farmers, the current scenario works better.

Restoration of wetland complex towards SEM2 can be interpreted as a partial attempt to restore livelihoods for the fishers. The shrinkage of inundation regimes has led to near complete decimation of capture fisheries, which was the mainstay of livelihoods of the fisher community. While the culture fisheries have evolved in the *maun* and *chaur* areas around wetland complex, not all fishers have been able to switch over to this livelihood option primarily due to high capital requirements. The increase in wetland agriculture have accrued to those who own land, and in proportion of land ownership. The benefit per household to the marginal farmers and fishers has been the least on account of lowland-holding. Losses from reduced groundwater recharge are related to land holding.

The political economy of ecological restoration is also linked to the preferences for ecosystem services bundles. A qualitative preference analysis was therefore conducted to elucidate community preferences for various restoration scenarios. Following three village clusters representing the existing geomorphological, ecological and livelihood setup around the wetland complex were considered for analysis:

Cluster 1 – comprises villages located on marginally elevated areas along the southwest margin of wetland (Cheria Bariarpur, Karor, Manjhaul). Extensive shrinkage in inundation regime has been experienced in this region, leading to a predominance of farming activity. The region also has better infrastructure (markets and roads) as compared to other two.

Cluster 2 – comprises villages along northern and eastern margins of the wetland complex (Kanousi, Narayanpiper and Kumbhi). Wage labourers are the

Figure 28: Change in economic values of ecosystem services over scenario SEM2

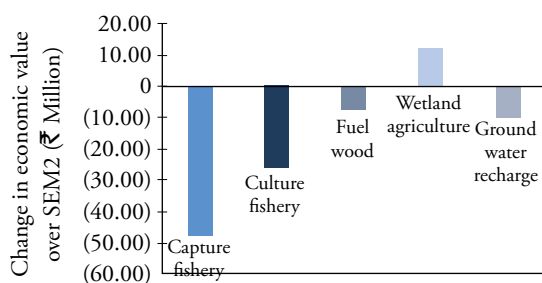
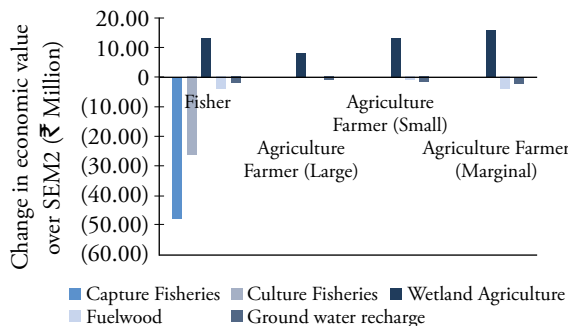


Figure 29: Stakeholder disaggregated change in economic values of ecosystem services over scenario SEM2



The distributional analysis of ecosystem services values indicates that ecological restoration is not a value neutral proposition. With changes in external environment, people have adapted to the changing land use conditions

predominant stakeholder group in the region. The villages are located in close proximity of permanently inundated areas of wetland complex, and have relatively higher abundance of groundwater.

Cluster 3 – comprises villages located in the downstream reaches (Akaha and Bagras) and are inhabited by small and marginal farmers and wage labourers. Being located at the outlet, communities routinely experience floods, which are perceived to have to have increased due to loss in flood buffering capacity of Kanwar.

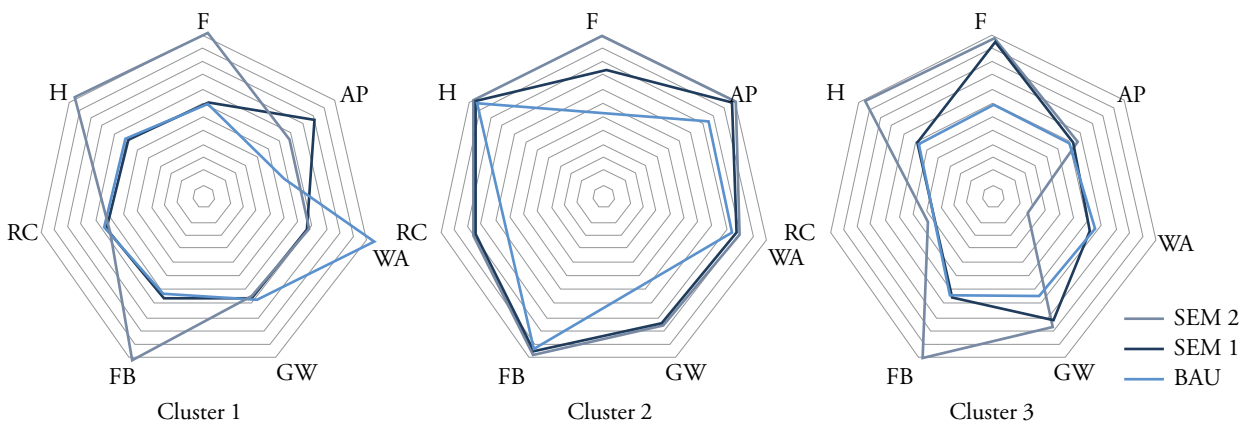
Communities in cluster 1 have indicated a higher preference for SEM2 (49%), followed by SEM1 (40%) and BAU (11%). Moving towards their preferred regime, a significant increase in fisheries, flood buffering capacity and habitat value is perceived, which exceeds the decline in value of Kanwar for wetland agriculture. Being a community comprising capture fishers and small farmers, the preference for restoration of fisheries is apparent in Figure 30.

For Cluster 2, which is a mix of farmers and wage labourers, there is an overall preference for BAU (43%), followed by SEM1 (31%) and SEM2 (26%). Moving from BAU towards SEM1 and SEM2, the communities indicate a decline in wetland

agriculture, for a relatively lesser increase in fisheries and groundwater recharge. Though an increase in recreational values is perceived, the gains do not stand to compensate for losses in wetland agriculture. Being predominantly a community of farmers, with relatively better availability of water and high crop productivity, the preference for BAU is self-evident. Within Cluster 3, the communities distinctly preference SEM 2 (91%). Moving to their preferred regime, the communities indicate preference for increase in flood buffering capacity, groundwater recharge and fisheries over value of Kanwar for wetland agriculture. Betterment of biodiversity habitat is also preferred.

The distributional analysis of ecosystem services values indicates that ecological restoration is not a value neutral proposition. With changes in external environment including production technologies and employment opportunities, people have adapted to the changing land use conditions. While the downstream communities prefer restoration to maximum inundation, communities living in the southwestern margins prefer a moderate increase in inundation regime to a situation as in 80s. Communities located on the upstream segment benefit from the current state, and thereby prefer no change.

Figure 30: Ecosystem services preferences of communities in different parts of wetland complex



The economic analysis indicates that there are significant costs of inaction associated with not restoring the inundation regimes. When an inundation scenario corresponding to the 70s is considered, the opportunity costs become significantly higher

4.8. Strategies for Integrated Management

Kanwar needs to be managed for its multiple ecosystem services and biodiversity values. Developmental programming till date has focused on enhancing production values of wetlands, specifically wetland agriculture, at the cost of other provisioning services (particularly fisheries), regulating services (groundwater recharge and flood buffering) and cultural services. Such a management has resulted in significant impacts on biodiversity habitat values as well.

Integrated management needs to be guided by a desired biophysical state and linked ecosystem services and biodiversity values. The current analysis has considered three such scenarios. The economic analysis indicates that there are significant costs of inaction associated with not restoring the inundation regimes. The opportunity costs are significantly higher when an inundation scenario corresponding to 70s is considered.

An analysis of scenario outcomes would be incomplete without consideration of their technical feasibility and associated costs. From the current analysis of wetland features, restoration of SEM1 scenario would require structural intervention for regulating outflows, and enhanced hydrological connectivity within the wetland complex. There is also a need to improve the water holding capacity of the complex through selective desilting of peripheral areas and *maun* and *chaur* areas. Restoration of inundation as in SEM2 is likely to require realignment of river embankments and connecting river flows through channels. There are implications for structural stability of the existing flood control structures on Burhi Gandak. For restoring wetland to a SEM1 scenario, a ball-park estimate of ₹1,500 million has been estimated over a period of five years, which would include investments in restoring water regimes, strengthening institutional arrangements, biodiversity conservation and improvement of livelihoods. For SEM2 scenario, the costs are likely to be at least two times the current estimate, and would require reclamation of land for construction of new channels.

Analysis of distributional consequences however highlights political complexities associated with

restoration choices. Communities have adapted to the transformed bundle of ecosystem services. There is a section of communities which prefers maintenance of the current state of wetland, which would permit agriculture values. Biophysical and hydrological assessments indicate that with increasing groundwater extraction, the water levels are expected to further decline leading to increased irrigation costs. Left on its own, these costs would crowd out the gains from agriculture.

Considering information from ecosystem services assessment and biophysical assessment, the management should intend to achieve a SEM1 scenario, as it is likely to increase habitat quality, improve capacity of wetland to moderate hydrological regimes, and support fisher livelihoods. The wetland may be managed on a zoning principle to accommodate production values along with conservation values.

A core area, to be inundated almost around the year may be managed for capture fisheries and maintenance of waterbird and fish habitats. The buffer zone, which includes *maun* and *chaur* areas surrounding Kanwar, are to be managed as sustainable production systems of culture based fishery and cultivation of aquatic plants. The land use in the entire complex needs to be regulated to prevent any adverse impact on ecosystem components and processes.

An important intervention would be create institutional arrangements for balancing cross sectoral interests, and include community perspectives on wetland management. The Government of Bihar has recently constituted Bihar Wetland Development Authority as the nodal policy and planning body for conservation and management of wetlands of the state. On the said lines, it is proposed to consider constitution of Kanwar Management Authority as a unified institutional mechanism for integrated management of Kanwar and associated *maun* and *chaur* areas. The existing regulatory regimes would also need to be reviewed to encourage stakeholder led management with due consideration of compatibility of land and water use practices with wetland regime.

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Acronyms

ANOVA	Analysis of Variance	PFCS	Primary Fishermen Cooperative Societies
BAU	Business as usual	PWD	Public Works Department
BOD	Biochemical Oxygen Demand	SDWRML	Sustainable Development and Water Resource Management of Loktak lake
BNHS	Bombay Natural History Society	SEM	Sustainable Ecosystem Management
CAFL	Chilika Aquatic Farms Limited	SSMPSS	Sri Sri Mahavir Pakshi Surakshya Samiti
CADA	Common Area Development Authority	STAP	Short Term Action Plan
CBO	Community Based Organization	SWAT	Soil and Water Assessment Tool
CDA	Chilika Development Authority	TA	Technical Assistance
CFCCS	Chilika Fishermen Central Cooperative Society Limited	TEEB	The Economics of Ecosystems and Biodiversity
CFCMS	Central Fishers Cooperative Marketing Society	TII	The Economics of Ecosystems and Biodiversity India Initiative
CIFRI	Central Inland Fisheries Research Institute	US\$	United States Dollar
CPCB	Central Pollution Control Board	UT	Union Territory
DO	Dissolved Oxygen	WAPCOS	Water and Power Consultancy Services
ES	Ecosystem Services	WISA	Wetlands International South Asia
ESRSPF	Environmental Social Reformation and Sangai Protection Forum	WTP	Willingness to Pay
FRMP	Fisheries Resource Management Plan	WWF	World Wide Fund for Nature
Gm	Gram	ZSI	Zoological Survey of India
GoB	Government of Bihar		
GOI	Government of India Ha Hectare		
HH	Household		
HRU	Hydrological Response Unit		
IFCD	Irrigation and Flood Control Department		
IMC	Indian Major Carps		
ITCM	Individual Travel Cost Method		
JICA	Japan International Cooperation Agency		
Km	Kilometre		
Kg	Kilogram		
KLNP	Keibul Lamjao National Park		
LDA	Loktak Development Authority		
LPG	Liquefied Petroleum Gas		
M AMSL	Meters Above Mean Sea Level		
MBGL	Meter Below Ground Level		
MCM	Million Cubic Meters		
mg/l	milligram per litre		
MoEFCC	Ministry of Environment, Forests and Climate Change		
MSY	Maximum Sustainable Yield		
MT	Metric Tons		
MU	Million units		
NGO	Non Governmental Organization		
NHPC	National Hydroelectric Power Corporation		
NSE	Nash-Sutcliffe Efficiency		

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