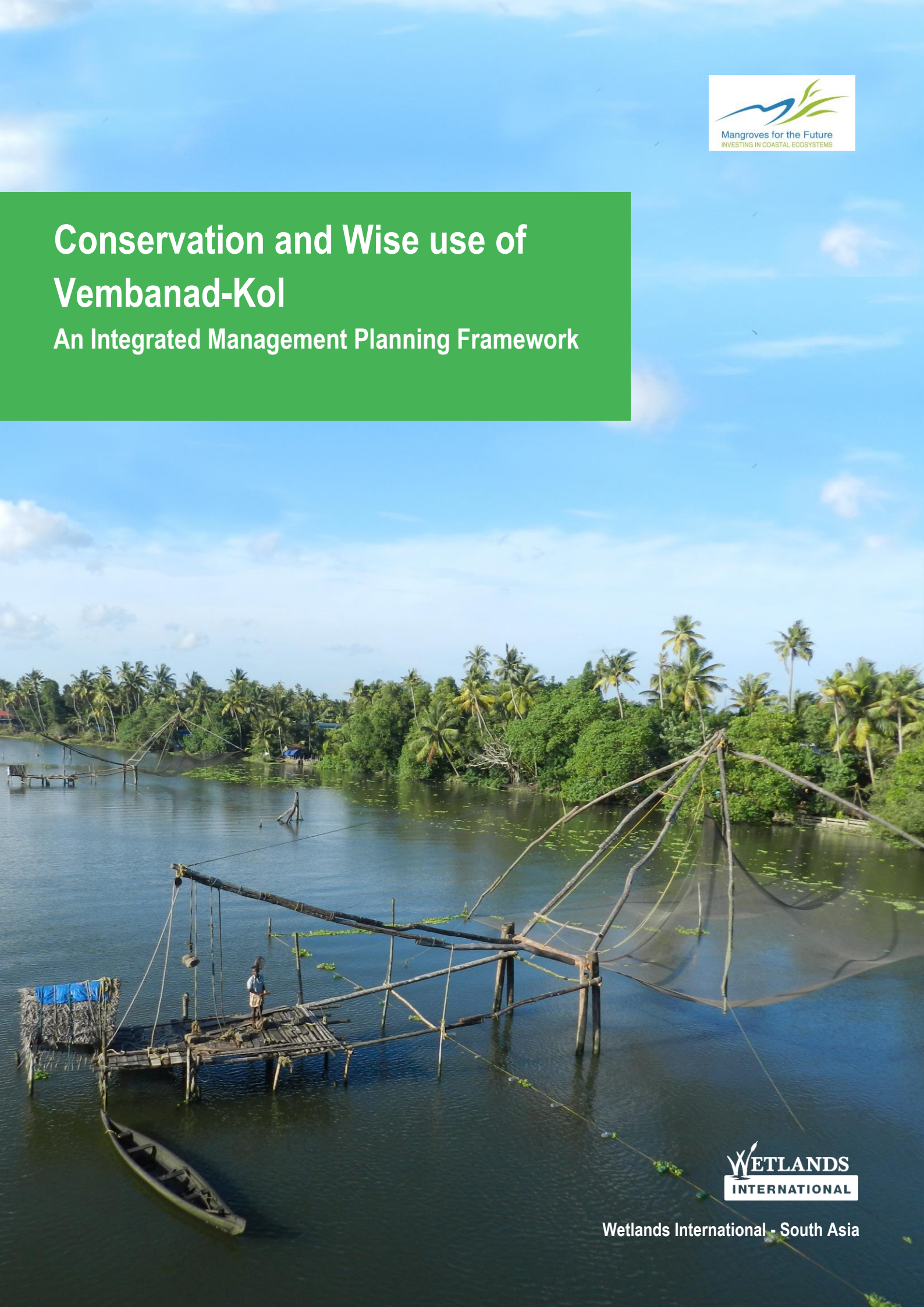
Mangroves for the Future
INVESTING IN COASTAL ECOSYSTEMS

Conservation and Wise use of Vembanad-Kol

An Integrated Management Planning Framework



WETLANDS INTERNATIONAL

Wetlands International - South Asia

Wetlands International – South Asia

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

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Mangroves for the Future

MFF is a unique partner- led initiative to promote investment in coastal ecosystem conservation for sustainable development. It provides a collaborative platform among the many different agencies, sectors and countries who are addressing challenges to coastal ecosystem and livelihood issues, to work towards a common goal.

MFF is led by IUCN and UNDP, with institutional partners : CARE, FAO, UNEP, and Wetlands International and financial support from Norad and SIDA

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December 2013

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Report prepared by **Wetlands International – South Asia** for **International Union for Conservation of Nature** and **Ministry of Environment and Forests, Government of India**under **Mangroves for the Future – India initiative**

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Acronyms

AC Road	Alappuzha-Changanassery Road
AD	Anno Domini
amsl	Above mean Sea level
BHC	Benzene hexachloride
BOD	Biological Oxygen Demand
BP	Before Present
CaO	Calcium oxide
CARE	Cooperative for Assistance and Relief Everywhere
Cell/l	Cells per liter
CMFRI	Central Marine Fisheries Research Institute
COD	Chemical Oxygen Demand
CR	Critically Endangered
CRZ	Coastal Regulation Zone
Cusec	Cubic feet per second
CWC	Central Water Commission
CWRA	Central Wetland Regulatory Authority
CWRDM	Centre for Water Resources Development and Management
^0C	Degree centigrade
DD	Data Deficient
DDT	Dichlorodiphenyltrichloroethane
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EN	Endangered
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
g/m^2	Gram per square meter
$gC/m^3/day$	Gram carbon per cubic meter per day
GI	Geographical Indication
GIS	Geographical Information System
GoK	Government of Kerala
GSDP	Gross State Domestic Product
Ha	Hectare
IADP	Intensive Agricultural District Programme
IBA	Important Bird Area
ICMAM	Integrated Coastal and Marine Area Management
IIT	Indian Institute of Technology
IPRD	Integrated Programme for Rice Development
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
K_2O	Potassium oxide
KFRI	Kerala Forest Research Institute
kg	Kilogram
km	Kilometer
km/hr	Kilometer per hour
km^2	Square kilometer
km^3	Cubic kilometer
KSCSTE	Kerala State Council for Science, Technology and Environment
KSSP	Kerala Sastra Sahitya Parishad
KTDC	Kerala Tourism Development Complex
KWMA	Kerala Wetland Management Authority
l	Liter
LC	Least Concern
LDA	Loktak Development Authority
m	Meter
m/km	Meter per kilometer
m^3/sec	Cubic meter per second
MCM	Million Cubic Meter
MFF	Mangrove for Future
mg/ kg	Milligram per Kilogram
mg/ l	Milligram per Liter
micromhos/cm	Micromhos per centimeter
mm	Millimeter
MoEF	Ministry of Environment and Forests
MPN/100ml	Most Probable Number per 100 milliliter
msl	Mean Sea level
MT	Metric Tonnes
µg/ l	Microgram per Liter
µS/cm	Micro-Siemens per centimeter
NE	Not Evaluated
NLCP	National Lake Conservation Plan
no/ l	Number per liter
NPCA	National Programme on Conservation of aquatic Ecosystems
NT	Near Threatened
NWCP	National Wetland Conservation Programme
P_2O_5	Phosphorus pentoxide
pH	Molar concentration of Hydrogen ion
ppm	Parts per million
ppt	Parts per thousand
PRIs	Panchayati Raj Institutions
%	Percent
SHGs	Self Help Groups
Sida	Swedish International Development Cooperation Agency
SoER	State of Environment Report
t	Tonnes
t/ha/ya	Tonnes per hectare per Year
TCL	Travancore Cements Limited
TM	Thaneermukom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VN	Vulnerable
WISA	Wetlands International - South Asia

Clam collectors returning with harvest

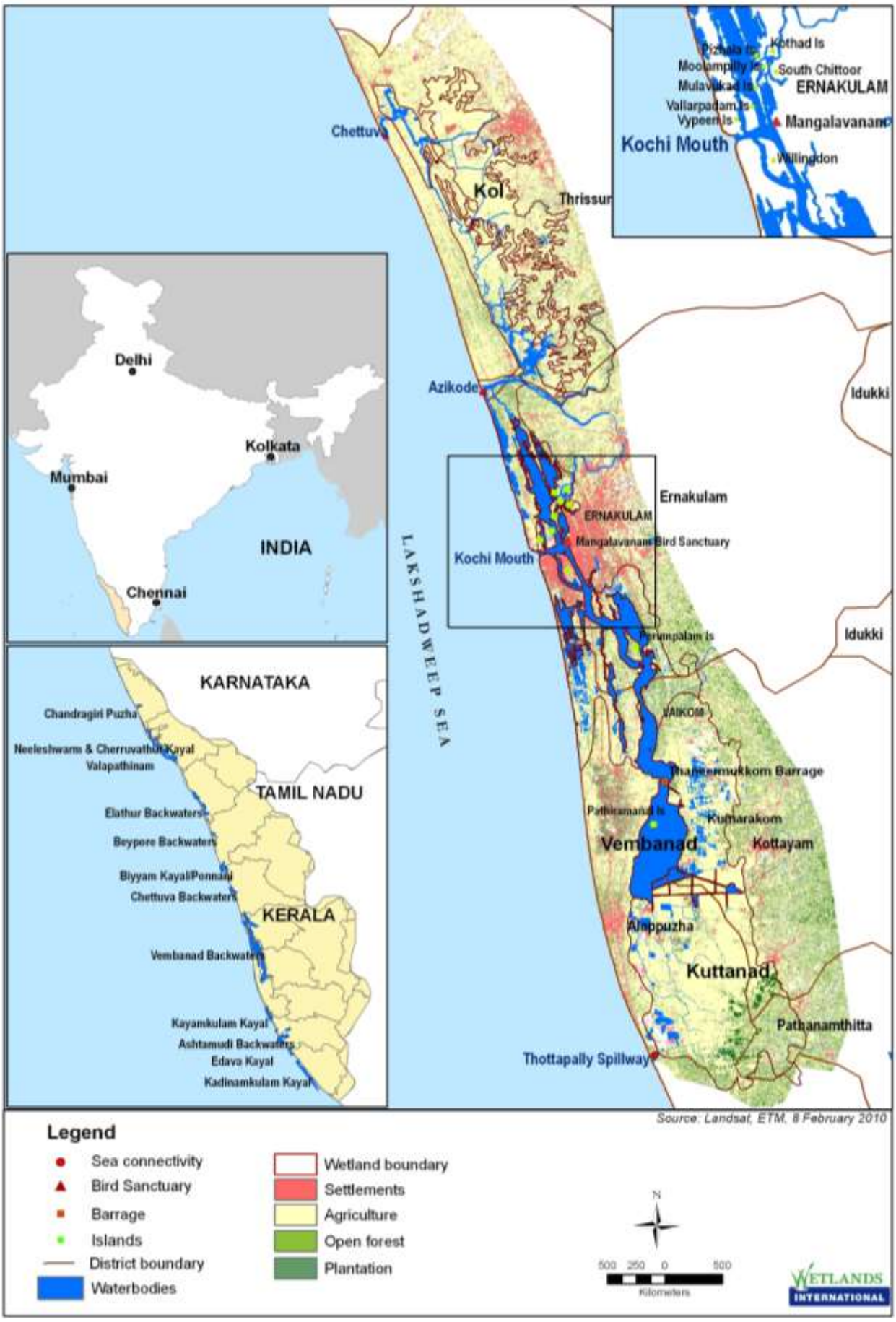
1 | Introduction

1.1 BACKGROUND

Vembanad-Kol constitutes one of the largest wetland regimes on the Malabar coastline. The wetland complex comprises Vembanad estuary flanked by river floodplains of Kuttanad and Kol, in south and north respectively interspersed by river estuaries and mangrove marshes which are interconnected by an intricate network of natural and manmade channels extending to over 1,780 km^2. Spanning around 145 km along the coastline of Alappuzha, Ernakulam and Thrissur Districts, Vembanad-Kol wetlands form a part of the extensive chain of backwaters which are characteristic features of the state (Map 1.1). The rich diversity supported by these wetlands is indicated by recorded presence of 147 plankton, 338 plant, 158 fish, and 225 bird species. Each year during winters, Vembanad-Kol harbours one of the highest populations of migrating waterbirds in the Central Asian Flyway within India. The wetland sustains livelihoods of nearly 0.2 million households through backwater tourism, inland navigation, and a range of resources as clams, shellfish and finfish. Located at the apex of the basin, Vembanad-Kol also regulates hydrological regimes, providing flood protection to large settlements as Cochin and Ernakulam as well as water for agriculture in the Kuttanad region – the Rice Bowl of Kerala. Vembanad – Kol was designated as a Wetland of International Importance (Ramsar Site) under the Ramsar Convention by the Ministry of Environment and Forests, Government of India in 2002. Vembanad Estuary and Kol Lands have been also identified as Important Bird Areas (IBA) of Kerala State. Mangalavanam, located on the eastern fringes of the wetland and a site of large waterbird congregation was declared as a Bird Sanctuary[1] under the Wildlife Protection Act in 2004.

Lack of consideration of wetland ecosystem processes and its full range of ecosystem services and biodiversity values in regional developmental planning has led to rapid transformation of Vembanad-Kol, creating several adverse ecological and socioeconomic impacts. Available historical evidences indicate that till the turn of 19th century, there was little anthropogenic pressure on the wetland complex. Development of Cochin Port in 1838 catalysed economic activities in the region. An all-weather natural port, it is located strategically close to the busiest international sea routes from the Gulf to Singapore and Europe to the Far East circuits and fastest growing maritime gateway to peninsular India. Large scale reclamation of naturally fertile floodplain marshes were encouraged since late 19th century and continued till the 1950s. Shallower wetland regions and marshes in the Kuttanad and Kol region were converted into polders, locally called *padashekharams*, to enable agriculture. A number of spillways, regulators and locks were constructed for regulating inflows and preventing salinity intrusion from the sea. In 1976, Thaneermukom Barrage was constructed across Vembanad to prevent saline water intrusion into Kuttanad and control tidal action within its polders. Incentives during

[1] Reference Kerala Forests and Wildlife Department Order: GO (MS) No.42/04/F&WLP dated 31 August 2004 extending to an area of 2.74 ha.



Map 1.1 | Location of Vembanad-Kol Wetland Complex

the 80s and 90s led to establishment of Udyogmandal, an industrial belt on the shorelines of River Periyar and within the vicinity of wetland complex.

During the 90s, backwater tourism emerged as one of the prominent features of Kerala tourism industry. There was an explosive surge in the number of tourist houseboats (kettuvallams, originally used as grain barges and presently the most sought after accommodation in the backwaters). The natural banks of the Vembanad estuary, once covered with thick mangrove forests, were cleared off to construct tourism facilities. Baker Estate at Kumarakom, which had the longest mangrove stretch in Kerala till the nineties, was extensively felled for construction of Kerala Tourism Development Center Complex.

The impacts of these developments on Vemaband backwaters are apparent. The area of the Vembanad Estuary has shrunk (from 365 km^2 in 1834 to 179.25 km^2 in 2010 and waterholding capacity drastically reduced (by over 77% during 1834 – 1984). Alteration of natural hydrological regimes has led to clogging of channels in Kuttanad area. Continued discharge of industrial effluents and sewage into the river and the backwaters has led to water quality deterioration and spread of freshwater invasives as water hyacinth. Diversion of upstream freshwater inflow to the sea for flood control in Kuttanad has led to reduction in water availability within Vembanad impacting flushing patterns. Changes induced in the natural salinity gradients of the Vembanad Estuary due to operation of Thaneermukom Barrage have led to decline in catch of brackish water and marine fisheries and live clams. Despite all hydrological interventions, rice production in Kuttanad has declined over the years, converting it from the coveted 'rice bowl of Kerala' to 'den of distress'.

Changing resource use patterns within the backwaters have made Vembanad-Kol wetlands a contested landscape, with wetland values and functions made subservient to economic exploitation. The operation of Thaneermukom Barrage is a perennial conflict between fishers (preferring natural salinity regime) and farmers (preferring freshwater conditions all the year round). Local clam collectors' societies are highly impacted by commercial clam trawling operations (major being Travancore Cements) which lead to shifting of beds and reduced natural recruitment. Tour operators are in conflict with environmental groups which have for long rallied against increasing tourism operations in biodiversity hotspots as Kumarakom and Patheramanal islands. Declining aesthetics due to spread of invasives and degrading water quality put tour operators in conflict with industrial operations in Udyogmandal region.

Degradation of Vembanad-Kol has significant implications for ecological and economic security of the entire coastal zone of Kerala State. Yet, coordinated actions for sustainable management of the wetland system are yet to the undertaken. Designation of a site as Wetland of International Importance commits the national government to its wise use, and putting in place an integrated management plan for safeguarding wetland features balancing conservation of biodiversity values with livelihoods. Despite implementation of a range of research programmes, notably by Center for Water Resources Development and Management (CWRDM), Cochin University, Kerala Sastra Sahitya Parishad (KSSP), Kerala State Forest and Wildlife Department, local research agencies and civil society, such a plan fails to exist. Meanwhile, sectoral management plans continue to be promoted for agriculture and tourism, without taking into cognizance wetland functioning. While the national and state level regulatory frameworks (Wetlands Conservation and Management Rules, 2010 and Kerala Conservation of Paddy Land and Wetland Act, 2008) provide legislative basis for regulating activities detrimental to wetland ecosystem, their enforcement remains a challenge.

The current project, supported under Mangroves for the Future (MFF) Programme and implemented by Wetlands International – South Asia, was designed in response to the request made by State Wetland Technical Unit of Kerala State Council for Science,

Technology and Environment for a management planning framework for Vembanad-Kol backwaters. Mangroves for the Future (MFF) is a partnership-based initiative promoting investment in coastal ecosystems for sustainable development.

1.2 OBJECTIVES

The project is aimed at developing a management planning framework for conservation and wise use of Vembanad-Kol backwaters as a means to support mainstreaming wetland ecosystem services and biological diversity into developmental planning and decision making processes.

Vembanad-Kol wetland is a multi-functional ecosystem supporting rich biodiversity as well as livelihoods of dependent communities. The need for maintaining wetland values and functions, while at the same time delivering services and benefits now and into the future, for human well-being necessitates adoption of management approaches which recognize linkages between livelihoods, wetland functioning and biological diversity. India, as a Contracting Party to Ramsar Convention on Wetlands is committed to ensuring wise use of all wetlands in her territory. The wise use principle encourages stakeholder engagement and transparency in negotiating trade-offs and determining equitable outcomes for wetland conservation while promoting maintenance of environmental, economic and social sustainability. Management planning is an instrument to outline the strategies, mechanisms and actions through which wise use of wetlands is to be achieved.

Wise use of wetlands, defined within the Ramsar Convention text as 'maintenance of their ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development' forms the overarching principle for management planning. 'Wise Use' has been also highlighted as the guiding approach for wetland conservation in the National Environment Policy (2006), National Biodiversity Action Plan (2008) and as the primary objective of the National Wetland Conservation Programme of the Ministry of Environment and Forests, Government of India (presently merged into National Plan for Conservation of Aquatic Ecosystems. Site-based management planning is recognized as one element of a multi-scalar approach providing a basis for linking with broad-scale landscape and ecosystem planning, including at the integrated river basin and coastal zone scales.

Management planning is aimed at the long term objective of ensuring conservation and wise use of Vembanad-Kol for securing biodiversity as well as well-being of dependent communities. The purpose is to put in place effective management practices which enable integration of biological diversity and ecosystem service values of Vembanad-Kol wetlands in river basin and coastal zone level conservation and development planning. The management planning framework is specifically aimed at:

- outlining a strategy for identification of site management objectives
- describing the management actions required to achieve objectives
- determining the factors that affect, or may affect, the various site features and functions
- defining monitoring requirements for detecting changes in ecological character
- supporting resource mobilization
- enabling communication within and between sites, organization and stakeholders
- ensuring compliance with local, national and international policies and regulatory frameworks

1.3 APPROACH AND METHODOLOGY

The ecological components, processes and services of Vembanad-Kol wetlands are influenced by land and water management practices within the immediate as well as indirect catchments of the wetland complex and the coastal zone. Management planning for Vembanad-Kol therefore calls for an approach which recognizes the interconnectedness of wetland biological diversity and ecosystem services with river basins and coastal zone taking into account the external, natural and induced factors. The approach also needs to address climate change which has direct as well as indirect implications for wetland features and their governing factors. There is an underlying need to maintain ecological character while providing for sustainable utilization of wetland resources for the benefit of stakeholders, particularly local communities.

Wetland ecosystems evolve and function within particular physical templates, the characteristics of which are determined primarily by interaction between water and sediments. Water apart from being an integral part of an ecosystem, is a natural resource, and social and economic good, whose quantity and quality determined the nature of its use. Considering these interactions, an Integrated Water Resource Management (IWRM) has been adopted as the guiding approach for management planning. The framework brings together stakeholders at all levels considering their needs and aspirations while ensuring conservation of the wetland ecosystem within the river basin. A critical requirement for IWRM is introduction of land use and water planning and management mechanisms which are aligned with ecological character of wetland complex. IWRM at river basin and coastal zone scale is also underlined in the New Guidelines for Management Planning endorsed by the Eighth Meeting of Contracting Parties to the Ramsar Convention[2]. In order to safeguard site and their features, the planning process recommends adoption of an adaptable management process which allows wetland managers to respond to the legitimate interest of others, adapt to ever-changing political climate, accommodate uncertain and variable resources, and survive the vagaries of the natural resources.

The National Environment Policy (2006) of Government of India recommends integration of conservation and wise use of wetlands into river basin and coastal zone management involving all relevant stakeholders, in particular local communities, to ensure maintenance of hydrological regimes and conservation of biodiversity. It further recommends integration of wetland conservation into sectoral development plans for poverty alleviation and livelihood improvement. The Wetland Conservation and Management Rules (2010) provide an institutional mechanism to prevent any fragmentation of hydrological regimes, pollution or conversion for non-wetland uses.

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

- Setting management objectives and targets based on interactions of wetland ecological character at river basin and coastal zone scale
- Integrating wetland management within sectoral planning for conservation and development
- Balancing the needs of biodiversity conservation with securing livelihoods of dependent communities
- Promoting cross-sectoral institutional arrangements, particularly involvement of local communities and stakeholders in wetland management
- Integrated wetland inventory, assessment and monitoring system to support planning and decision making

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

- Integrating traditional knowledge and practices with assessments and management planning procedures
- Periodic monitoring and evaluation with focus on achieving goals and objectives rather than merely activities

The methodology adopted for management planning follows largely the Ramsar guidelines, which recommend a diagnostic approach based on a critical evaluation of ecological, economic and socio-cultural features to identify objectives and operational limits including factors for effective restoration and management of wetland ecosystem (Fig. 1.1). The management planning framework includes the following components:

- establishment of preamble
- evaluation of wetland features and governing factors for describing status and trends in wetland ecological character and identification of threats
- review of current institutional arrangements in terms of ability to maintain ecological character and respond to drivers and pressures likely to have adverse impact
- identification of management planning components, outcomes, performance indicators, activities and implementation strategy.

Status and trends in hydrological, geological, ecological and socio-economic features of Vembanad-Kol and their governing factors were derived based on field visits, stakeholder consultations and review of published information. Evaluation of features formed the basis of description of ecological character and assessment of risk of adverse change. The existing institutional arrangements were reviewed in terms of their fit with the needs of integrated management. The planning framework was designed as a response to the existing as well as likely risks of adverse changes in wetland ecological character.

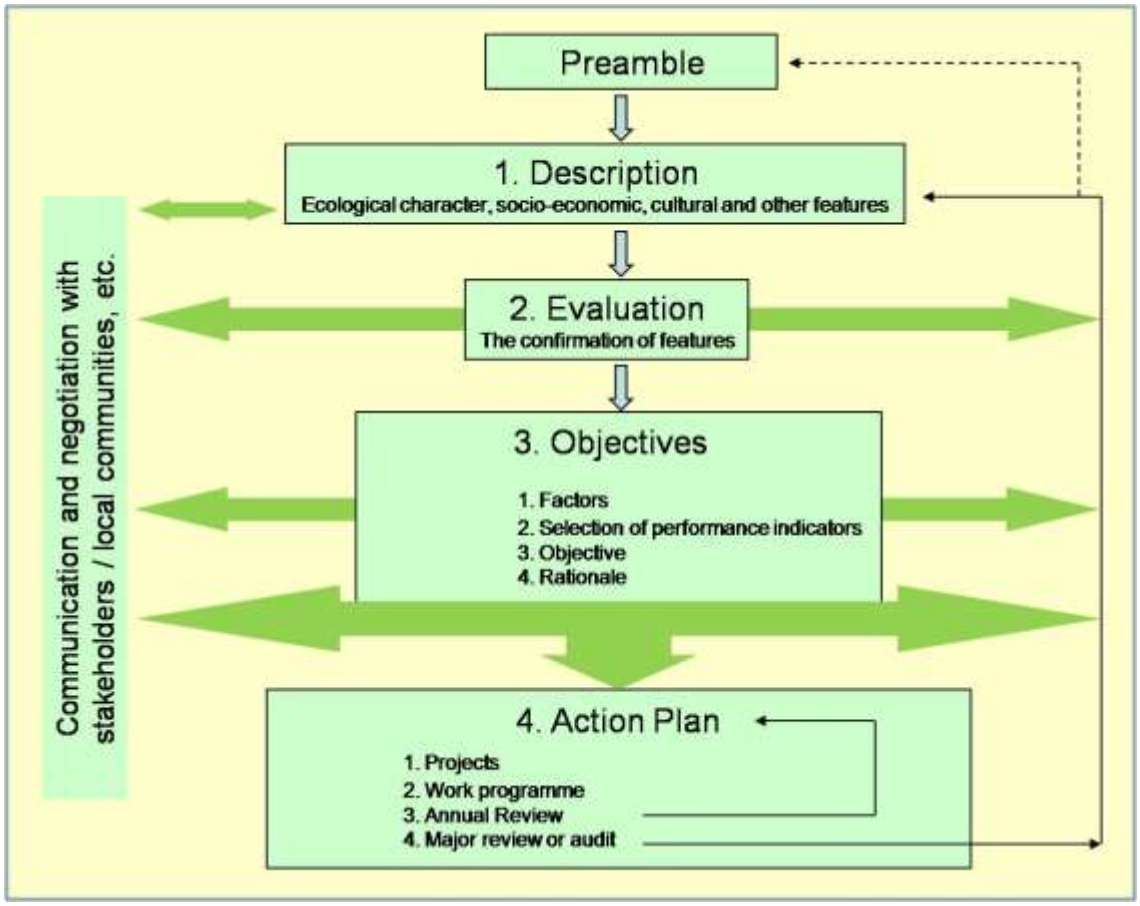


Fig. 1.1 | Management Planning Framework for Wetlands (Source : Ramsar Handbook 14)

1.4 REPORT STRUCTURE

The management planning framework is presented in five sections. The purpose, approach and methodology have been outlined in the introductory chapter. This is followed by evaluation of wetland features in Chapter 2. Chapter 3 contains description of ecological character and assessment of risks of adverse change. Knowledge gaps have also been identified. Chapter 4 contains a review of existing institutional arrangements and a proposal for revision of the same. The management planning framework is presented in Chapter 5. An implementation strategy, including institutional arrangement, monitoring and evaluation and possible funding options are also included in the chapter.

Clam collector with his iron rake

2 Description and evaluation of wetland features

2.1 Location and Extent

The Vembanad-Kol wetland complex extends between 9°16' to 10°36' latitudes and 76°01' and 76° 35' longitudes in a shallow, and for most parts, below sea level depression along the Malabar coastline within Ernakulam, Alapuzzha and Thrissur districts. Vembanad estuary, Kuttanad and Kol lands are its three major physiographic divisions which are interconnected by an intricate network of natural and man-made channels.

Vembanad is a bar built estuary[1] which receives inflows from seven major rivers[2] and has two major openings into the Lakshadweep Sea. The mouth at Cochin which houses the Cochin port and harbour is its most prominent connection to the sea. The opening of River Periyar at Azikode marks the northern tip of the estuary. The stretch between Vaikom and Cochin is dotted by a number of islands. Wellingdon, located adjacent to Cochin City, has been developed on a natural island by dumping dredged material from the Cochin port and harbor. Vypeen is largest of a series of seven islands between Azikode – Cochin. Pathiramanal is a 68 ha natural island located between Muhamma and Kumarakom harbouring significant biological diversity, especially of waterbirds. Patches of mangroves exist along the inner shorelines of the estuary, the largest existing chunk being around Kumarakom.

The Vembanad estuary is flanked by river floodplains in north (Kol lands) as well as south (Kuttanad). Kuttanad is a floodplain of Rivers Achencoil, Pamba, Manimala and Meenachil which have been converted over a period of time into permanent agricultural lands for cultivation of rice and coconut. These include a substantial portion of Vembanad estuary reclaimed through construction of polders (locally called *padashekharam*) and modification of natural hydrological regimes. Kuttanad is also known as the 'Rice Bowl of Kerala' owing to high agricultural productivity. There are presently around 1,200 polders in this region. The Kol lands are floodplains of Rivers Keechari, Puzakkal and Karuvannur, reclaimed for agriculture. Both Kuttanad and Kol lands have major portions located below sea level and are flooded for prolonged periods after monsoon. Brackish marshes

[1] An estuary is a semi enclosed coastal body of water which has a free connection with open sea and within which sea-water is measurably diluted with freshwater derived from land drainage (Pritchard, 1967). From a geo-morphological perspective, estuaries can be classified into four categories: (1) drowned river valleys, (2) fjord type estuaries, (3) bar-built estuaries, and (4) estuaries produced by tectonic processes. Bar-built estuaries are formed when offshore barrier sand islands and sand spits build above sea level and extend between headlands in a chain, broken by one or more inlets.

[2] Rivers Pamba, Achencoil, Manimala, Meenachil and Muvattupuzha flow into Vembanad through Kuttanad, whereas Chalkudy and Periyar flow directly into the estuary. Three rivers, namely Keechari, Puzakkal and Karuvannur flow into Kol lands.

around Cochin have traditionally been used for rice-shrimp aquaculture, locally known as *pokkali*.

The present extent of Vembanad-Kol wetlands is fragment of an extensive regime of estuaries and interconnected river floodplains extending between Thrissur and Arattupuzha which existed till the beginning of the 19th century[3]. Conversion of wetlands for agriculture, settlements and infrastructure development as ports particularly in the last century has fragmented the entire regime, with several areas losing wetland characteristics.

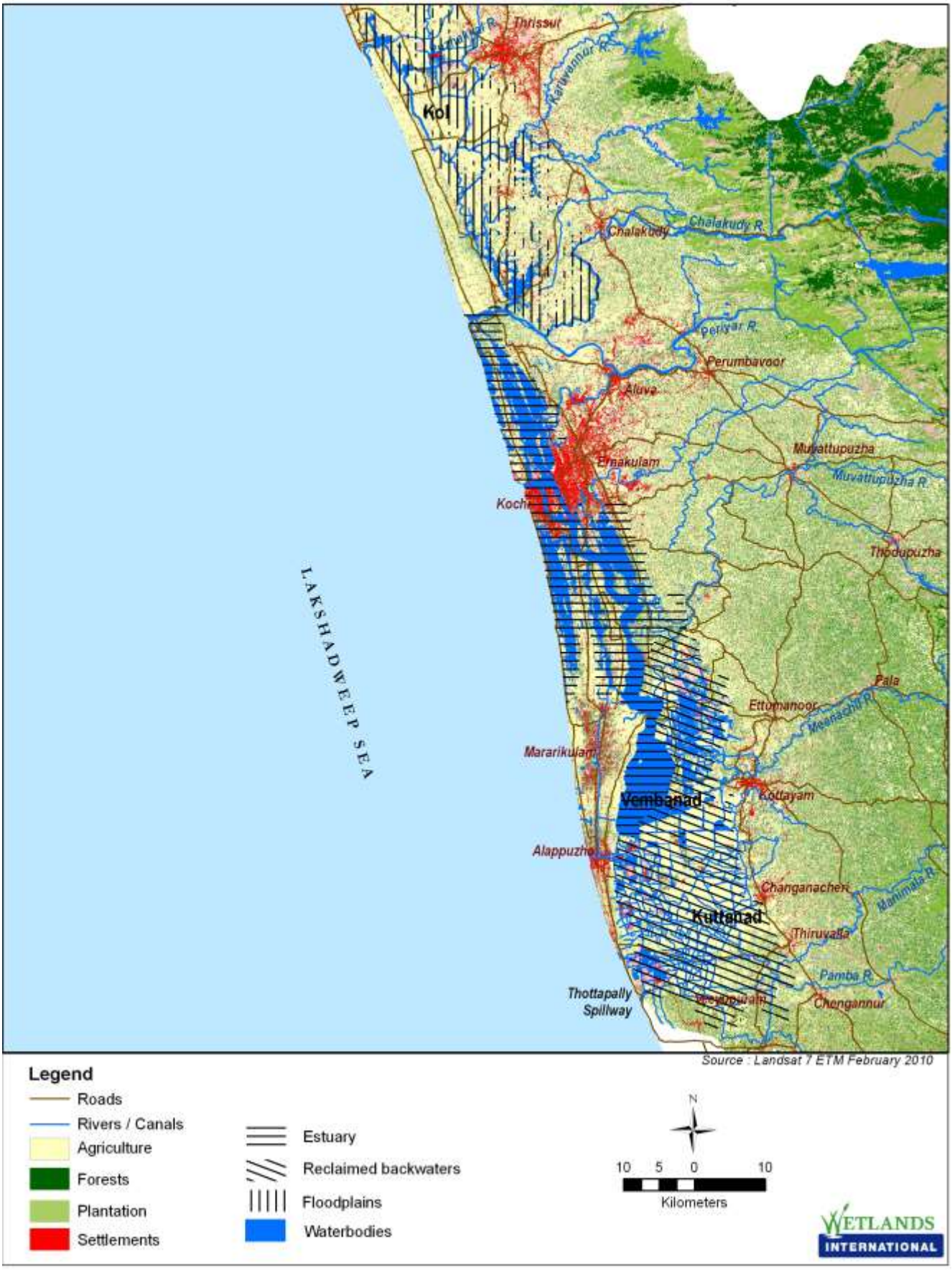
For the purpose of management planning, it is imperative to delineate the present extent of wetlands so as to enable review of various features and governing factors. Typically, wetlands can be delineated using three broad characteristics, namely inundation (presence of water, permanently or seasonally), hydrophytic vegetation (vegetation adapted to wet conditions) and hydric soils (soil that is saturated, flooded or ponded long enough favouring anaerobic condition). Natural variability in environmental conditions also needs to be taken into account while determining the wetland boundaries. A comprehensive delineation of wetland complex is yet to be carried out, and therefore a range of estimates have been mentioned in various reports[4].

The present extent of Vembanad–Kol wetland complex, derived from analysis of remote sensing imageries, and data on soil and vegetation types is presented in Map 2.1. The total extent of the wetland complex is estimated to be 1,780 km^2. The Vembanad estuary complex extends to 630 km^2, which includes 243 km^2 open water area and additional 387 km^2 as islands, marshes and coastlines. Wetland areas in Kuttanad[5] extend to 725 km^2, and are essentially land reclaimed from Vembanad estuary and floodplain marshes. The area is characterized by presence of peaty acidic and alluvial soils having elevation at or below sea level, and congested drainage patterns leading to prolonged inundation during post monsoon period. Kol lands extend to 425 km^2 and have features similar to that of Kuttanad.

[3] A useful reference is the SOI toposheet of 1917-18 (Map 2.8)

[4] James (1997) estimate the wetland extent to be around 3,000 km^2, with Vembanad (including Kuttanad) and Kol lands extending to 2,195 km^2 and 521 km^2 respectively, the rest being the area under rivers, channels and estuaries. A broad hydrological connectivity principle has been used for mapping, wherein all inflowing river channels, estuaries, wetland areas converted for agriculture and settlements have been included within the boundary. The Ramsar Information Sheet (RIS) submitted to the Ramsar Convention Secretariat refers the wetland area to be 1,512.50 km^2, but the boundaries include large settlement areas as Ernakulam township and exclude part of Kol lands. A more recent satellite imagery based mapping of Ramsar sites of India published by Space Application Center indicates area of Vembanad-Kol to be only 175.89 km^2 (Murthy et al, 2013). Apparently, the intermittently flooded agricultural lands adjoining the estuary have not been included.

[5] The overall area of Kuttanad has been reported to be 900 km^2 of which 550 km^2 is land reclaimed from Vembanad estuary and floodplain marshes of Pamba, Achenkoil, Manimala and Menachil Rivers. The rest is constituted by highlands, which are mainly used for settlements. The reclaimed area is classified into six agro-ecological zones. Land reclaimed from estuary is characterized by polders and is classified as Kayal and Lower Kuttanad, with total extent of 257 km^2. Upper Kuttanad, North Kuttanad, Purrakad Kari and Vaikom Kari are land reclaimed from floodplain marshes and extend to 293 km^2.



Map 2.1 | The Vembanad-Kol wetland complex

Kochi Mouth

2.2. GEOLOGY AND GEOMORPHOLOGY

The Kerala coast is characterised by occurrence of tertiary and recent sediments. The rivers and streams flow mostly parallel to the coastal plain and their courses have evolved in response to the depositional history of the lagoon systems that prevailed during the Quaternary. The Alappuzha - Ponnani stretch is composed purely of alluvium of recent deposits with prominent palaeo strandlines. Palaeo beach ridges or regression-transgression features are prominent in the landmass between Cochin mouth to the south. One of these sets of features run parallel to Alappuzha - Cochin coast line and separates the Vembanad- Kuttanad area from the Lakshadweep Sea (Chattopadhyay 2010). The sand in the beach zone of Kerala contains significant quantities of heavy minerals (Jayalakshmi et al. 2003).

Vembanad is one of the largest tropical estuaries of India and a major burial ground for Quaternary deposits (Narayan et al., 2002) (Map 2.2). The wetland complex formed a part of marine environment in the geological past, with an alluvial bar boundary running parallel to the coast and interrupted at places by Arabian Sea. In AD 1341, a catastrophic cyclone is believed to have induced change in course of River Periyar resulting in formation of islands and separating a distinct waterbody that yet maintained connection with the sea (Menon, 1913). Peat deposits, with a radiocarbon age of 40,000 years BP have been identified at different depths in the boreholes between sandy clay and clayey sand sedimentary facies. Pollen analyses of peat reveal the existence of mangrove vegetation and evergreen forest (Narayan et al., 2002).

Mostly coastal alluvium soils are found within the wetland complex (Map 2.3). The predominant role of fluvio-estuarine deposition is indicated by the presence of black carbonaceous clay, high organic content, acidic soils and a peaty substratum in major parts. The soils of Kuttanad exhibit the effect of anaerobic decomposition and are acidic in reaction due to microbial oxidation of organic matter.

Soils in Kol land are of piedmont type, silted up with alluvium brought down by Rivers Karuvannur and Keechery. Texturally the material ranges from fine to coarse clastic particles derived from the surrounding lateritic hills. Based on textural analysis, soil in the region has been classified into clay, sandy loam, sandy clay loam, and clay loam (Sheela, 1988). Organic matter content of the soil is high varying from 2.07-4.16 % in the surface and 1.37-9.7 % in sub-surface (Hameed, 1975). The presence of organic peat layer in the sub-surface makes soils extremely acidic (pH ranging between 2.6 to 6.3). The total

nutrient content of the soil throughout the Kol land is 0.14-0.57% nitrogen, 0.2-0.24 % P_2O_5, and 0.09-0.6 % of K_2O. CaO levels are also reported to be very high (ibid).

Crystalline and sedimentary rocks of tertiary ages are prominent in the Western Ghats from where the rivers flowing into the wetland complex originate. An intervening narrow stretch of the midlands are lateritised to various depths whereas the recent and sub recent sediments form the low lying and river valley bottoms. Forest loam soils occur in the upper reaches. The middle reaches are characterized by lateritic formations interspersed with brown hydromorphic soils, whilst riverine alluvium is found in the river floodplains.

2.3. WETLAND CATCHMENTS

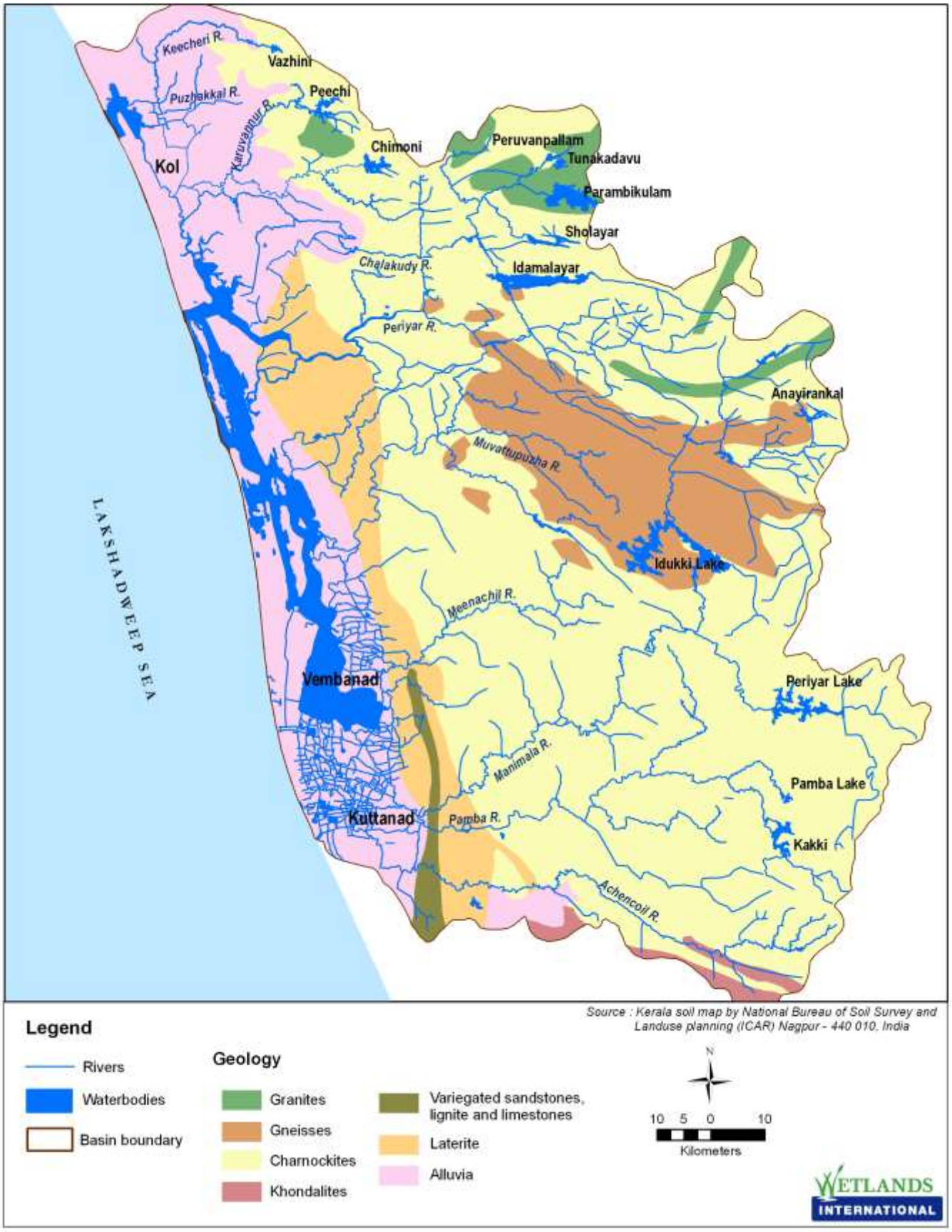
The Vemabanad-Kol wetlands receive inflows of ten rivers (Keecheri, Puzhakkal, Karuvannur, Chalakudy, Periyar, Muvattupuzha, Meenachil, Manimala, Pamba and Achencoil) all of which originate in Western Ghats. The drainage basins of these rivers span 15,554 km^2 area (between 9° 17' and 10° 43' latitude and 75° 58' and 77° 24' longitude) in seven districts of the state (Alappuzha, Idukki, Ernakulam, and parts of Kottayyam, Thrissur, Palakkad, and Pathanamthitta) (Map 2.4).

The catchment of Vembanad-Kol is dominated by undulating, subdued hills and steep scarp slopes with altitude ranging between below msl to around 2, 700m amsl (Map 2.6). Based on topography and elevation profile, the catchment has been classified into three broad categories: highlands, midlands and lowlands. The highland region has elevation ranging between 75 to 2,700m amsl and is largely covered by forests and plantations. The midlands have altitudes between 7.5 to 75m amsl and are largely dominated by agriculture and plantation. The lowland region wherein the Vembanad-Kol wetland complex is located is a narrow coastal strip bordering the Arabian Sea marked by presence of wetlands interspersed with agriculture and settlement areas. The highlands and midlands cover 49% and 22% of the basin area respectively.

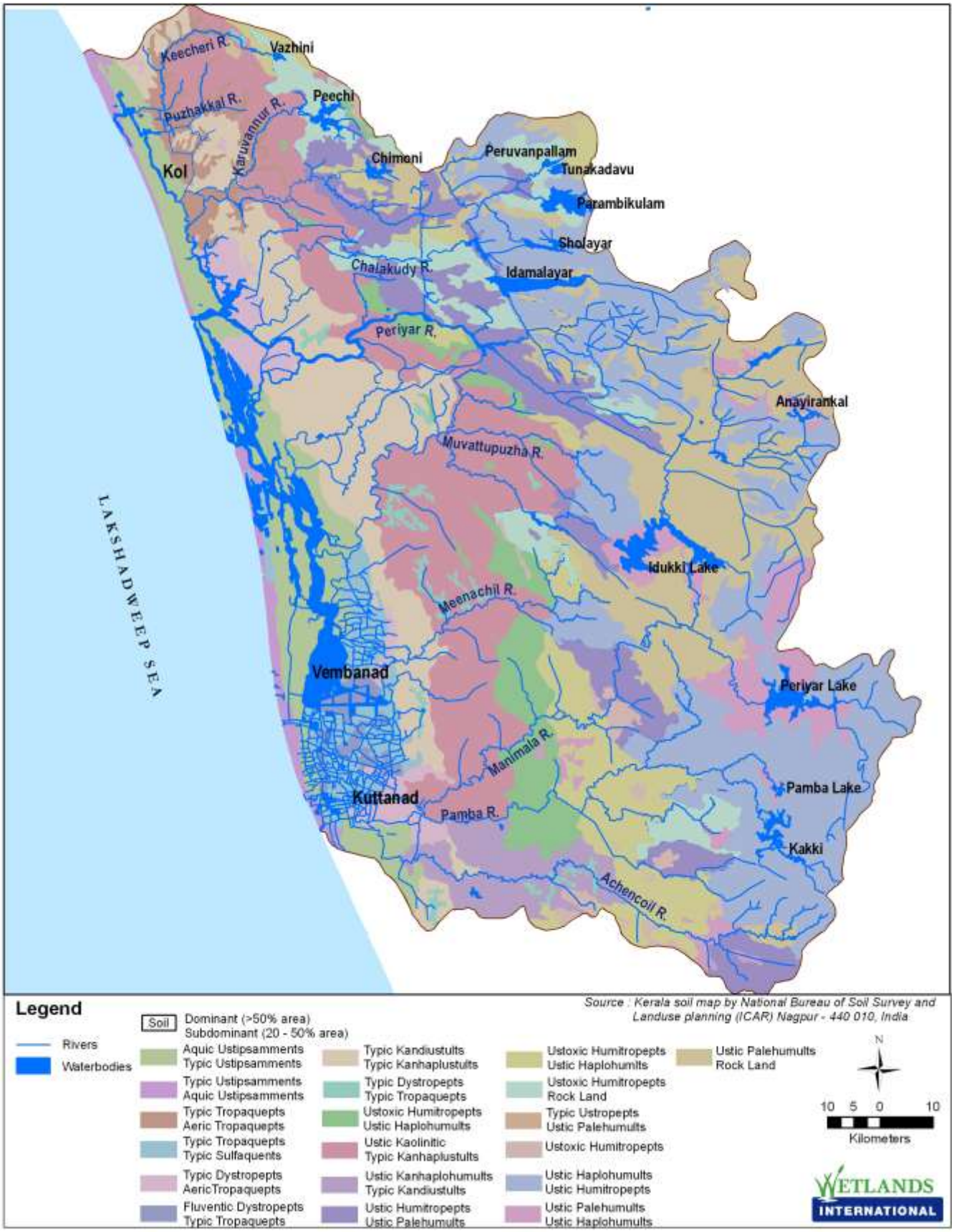
The rivers of the Vembanad-Kol catchment are steep, fast flowing and monsoon fed. The rivers flow down the highlands over steep slopes of almost 60 m/km or more to midland and lowland stretches with much flatter slopes of 1m/km. Periyar with a basin area of 5,284 km^2 is the largest river draining into the wetland complex (Table 2.1). Assessment of land use and land cover of the basin using satellite imageries of 2010 indicate forests to be the predominant category followed by agriculture and plantations (Table 2.2).

Dense forests are present in 3,375 km^2 of the catchments mostly restricted within its highlands (Map 2.6). Almost entire forest area is interspersed with plantations of rubber, tea, coffee, cardamom and other economically important species. Temperate *shola*[6] forests are found on the crest. Occurring at an altitude of 1800 m amsl, these forests are characterized by dense growth of trees in the depressions and folds of the Western Ghats surrounded by extensive areas of grasslands. The forests in the lower reaches belong to moist deciduous category, and followed by wet evergreen forests. The evergreen and semi evergreen forests have generally three tiered vegetation with *Acrocarpus fraxinifolious, Antiaris toxicaria, Calophyllum, Cullenia exarillata, Dichopsis elliptica, Dipterocarpus indicus* and other species forming the top canopy. The middle storey comprises *Actinodaphne hookeri, Baccaurea courtallensis, Canarium strictum, Cinnamomum zeylancium, Elaeocarpus* and the third storey of *Euonymus* sp., *Leea sambucina* etc. The moist deciduous species found within the catchment area include *Tectona grandis, Dalbergia latifolia, Pterocarpus marsupium, Adina* sp. and related species.

[6] Sholas are local names for patches of stunted tropical montane forests found in valleys amid rolling grasslands in the higher montane regions.



Map 2.2 | Geological formations in Vembanad-Kol catchment



Map 2.3 | Soil types in Vembanad-Kol catchment

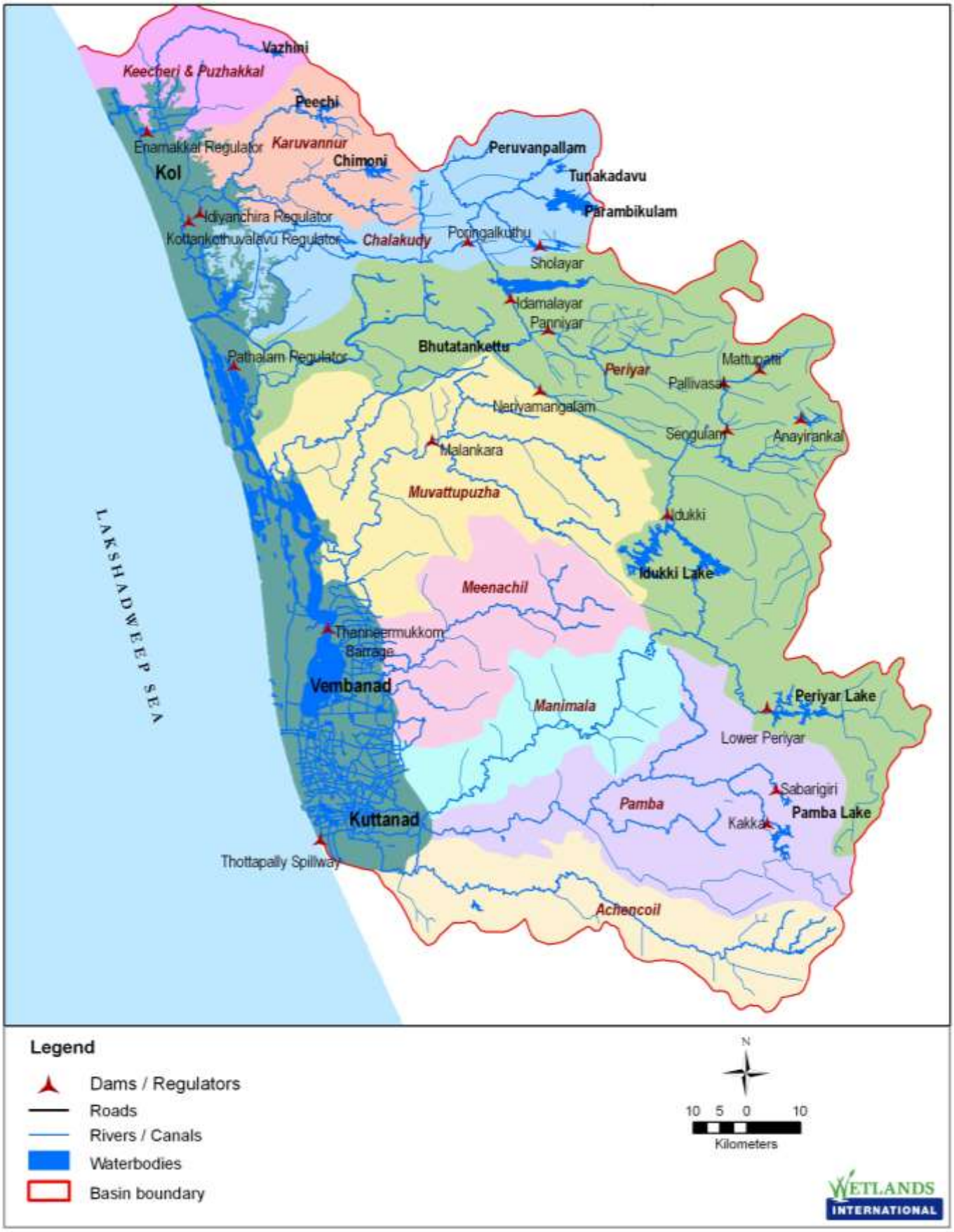
Table 2.1 | River Basins of Vembanad-Kol Catchment

River Basin	Drainage Area (km^2)	Elevation zone		
		High Land	Mid Lands	Low Lands
Keechari – Puzakkakal#	635	-	414	221
Karuvannur#	1,054	433	382	239
Chalakudy#	1,404	834	332	238
Periyar#	5,284	4,502	402	380
Muvattupuzha†	1,208	146	806	255
Meenachil†	603	74	338	191
Manimala†	706	168	365	174
Pamba†	1,644	1,100	182	362
Achencoil†	796	420	241	135
	13,334	**7,677**	**3,461**	**2,195**
Wetland complex and adjoining coastal areas‡	2,220			2,220
	15,554	**7,677**	**3,461**	**4,415**

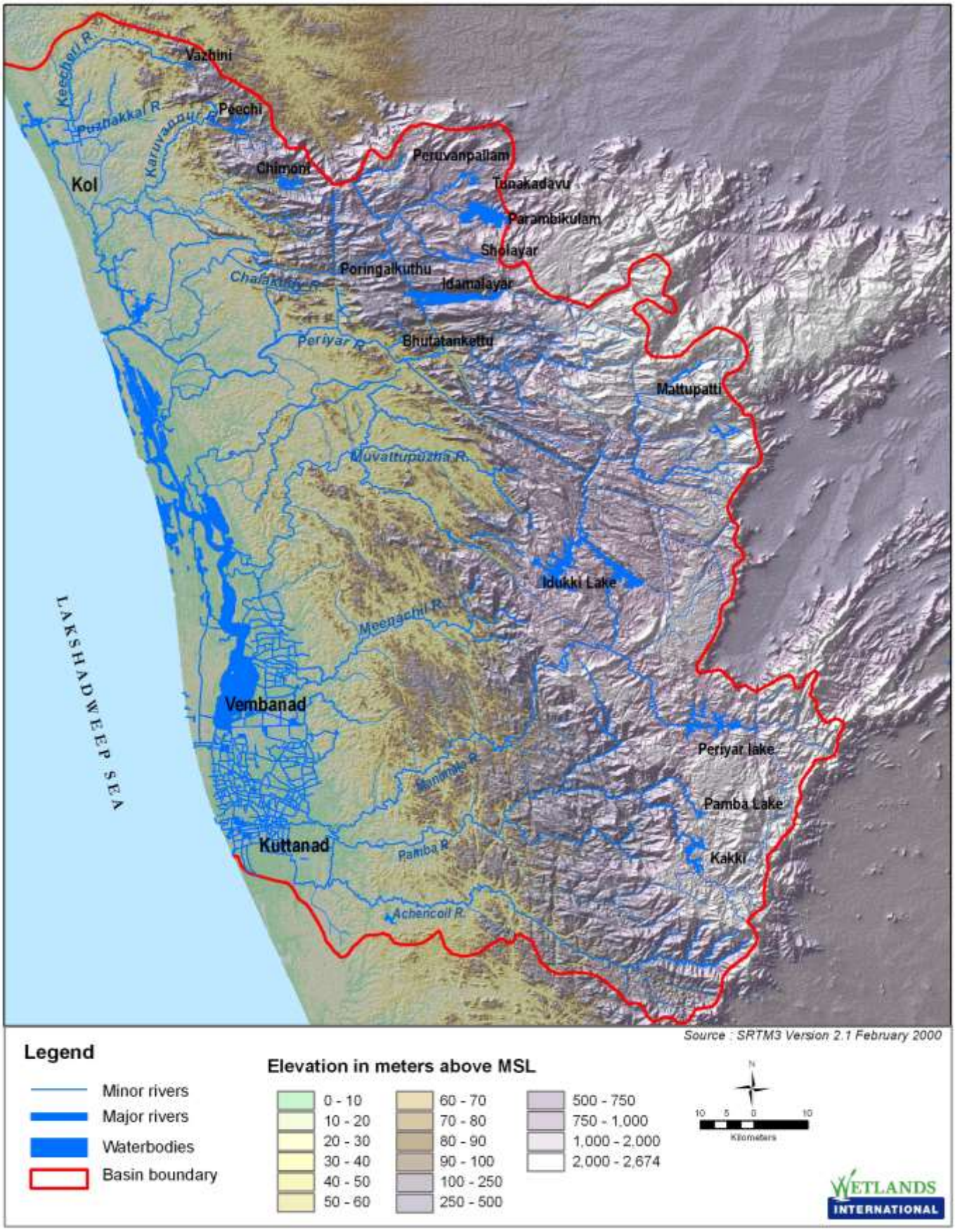
(Data Source: # =CWRDM 2006, † = IIT and CWRDM, 2012, ‡ = includes area of wetland complex – 1780 km^2 and adjoining coastal areas = 440 km^2 , all estimates have been rounded off to nearest km^2)

Table 2.2 | Land use Land cover of Vembanad-Kol Catchment (2010)

Land Use Land cover Class	Area (in km^2)	Percent to total area
Forests	**6,655**	**44**
Dense	3,375	22
Open	3,280	22
Grasslands	**813**	**5**
Agriculture and Plantation	**5,537**	**37**
Settlements	**329**	**2**
Wetlands	**1,780**	**12**
Open water area	457	3
Rice paddies and plantation	1,216	8
Built up area	107	1
Total	**15,114**	**100**



Map 2.4 | Drainage basins within Vembanad-Kol catchment



Map 2.5 | Elevation profile of Vembanad-Kol catchment

A typical home garden with coconut on the fringes and banana in middle. As the latter grows in height, the intervening spaces are cropped with spices and vegetables

Agriculture and plantations account for 45 % of the catchment covering an area of 6753 km^2. Plantations in the highlands have been mostly developed through clearing of the forest. Major crops grown are rubber, tea, coffee and cardamom. Food crops as well as cash crops are cultivated in the mid lands. Rice and tapioca are the main food crops while rubber, coconut and pepper are the main cash crops. Annual crops like plantain and pineapple, seasonal crops like ginger, tubers, vegetables and a wide range of perennial crops like jack fruit, and mango are also grown. Home gardens are the characteristic feature of farming systems in the midlands. The selection and inclusion of crops are influenced by the climate and by household preferences, requirements, and dietary habits. Coconut is the base crop in most of the agro climatic areas, except in the high ranges. The spaces between coconut plants are used to raise an array of intercrops, resulting in a multi-storey cropping pattern with distinct canopy stratification. Perennial crops such as coconut, areca nut, jackfruit, mango, cashew, tamarind, and forest tree species occupy the upper layer; pepper, clove, nutmeg, and cinnamon occupy the second layer; banana, cassava, yam, and the like occupy the third layer; and ginger, turmeric, pineapple, vegetables, and guinea grass occupy the ground layer.

Agriculture in lowlands is mostly concentrated in Kuttanad and Kol lands (Box 1: Rice paddies of Kuttanad). Marshes within Ernakulam and Alapuzzha districts are also used for brakishwater aquaculture. Rice fields, after harvests are fitted with locally made gates and water from the high tides is allowed to be retained within the fields. This locally evolved technology is called *pokkali* (details in Box 5).

Settlements account for around 2.69 % of the catchment area. As per 2011 census, the basin is inhabited by 8.8 million people, mostly concentrated in 84 urban centers. Physiography of the area has distinct influence on the settlement patterns. The coastal lowlands and midlands, which provide congenial grounds for development of transportation networks, commercial activities and access to other social infrastructure have comparatively higher population densities as compared to the highlands. The catchment is dominated by small, well-distributed urban centers rather than one large megacity.

Change in land use and land cover has significant direct and indirect bearing on wetland processes. The Survey of India toposheets of 1917-18 (scale 1: 250,000) and remote sensing imagery of 1973 (Landsat 3, February 1973) were analysed to assess these changes (Map 2.7 and 2.8). The lowland area in 1917-18 is characterized by a vast backwater area spanning 398 km^2 surrounded by a large patch of marshes in Kuttanad and Kol areas extending to 767 km^2 .By 1973, an extensive conversion of backwater area for agriculture is evident. Within the midlands, expansion of areas under agriculture is indicated. Further changes following 1973 are mainly in the lowland area wherein rapid expansion of settlements is indicated.

Box 1: Rice paddies of Kuttanad

Inundated polders in Kuttanad

Rice based production systems within wetlands have traditionally served as staple source of food worldwide. However, management of wetlands for food production is often at the expense of their regulating services (e.g., ability to influence hydrological regimes, moderate floods etc.), creating policy trade-offs. The Ramsar Convention classification of wetland types includes rice fields in the category of human made wetlands. The Contracting Parties of the Convention in their 10th meeting held at Changwon, South Korea adopted a resolution on enhancing biodiversity in rice paddies as wetland systems[7]. The rice paddies of Kuttanad form an integral part of the Vembanad-Kol wetland complex, and thereby their sustainable management is an important precondition for achieving the goal of 'wise use'.

Rice is the staple food of Kerala. The aim of developmental policy in the state has been to ensure self-sufficiency in rice production so as to reduce dependence on imports and inflows through trade. Till the Second World War, rice was procured by the rulers of Kerala from areas as far as Myanmar. Thereby, the state government looked into mechanism for increasing local production, and developing Kuttanad as 'Rice Bowl of Kerala' formed an integral part of these efforts.

Kuttanad is a floodplain formation of Rivers Pamba, Achencoil, Manimala and Meenachil Rivers at the southern end of Vembanad estuary. Geological evidences indicate that the region once formed part of an extensive bay of Arabian Sea which gradually filled up with sediments brought in by the inflowing rivers. Its areal extent is around 900 km^2, covering 79 villages within Alappuzha, Pathanamthitta and

[7] Resolution X.31 emphasizes on maintenance and enhancement of ecological and cultural role of rice paddies, and inter alia stresses maintaining connectivity with surrounding natural and semi-natural habitats.

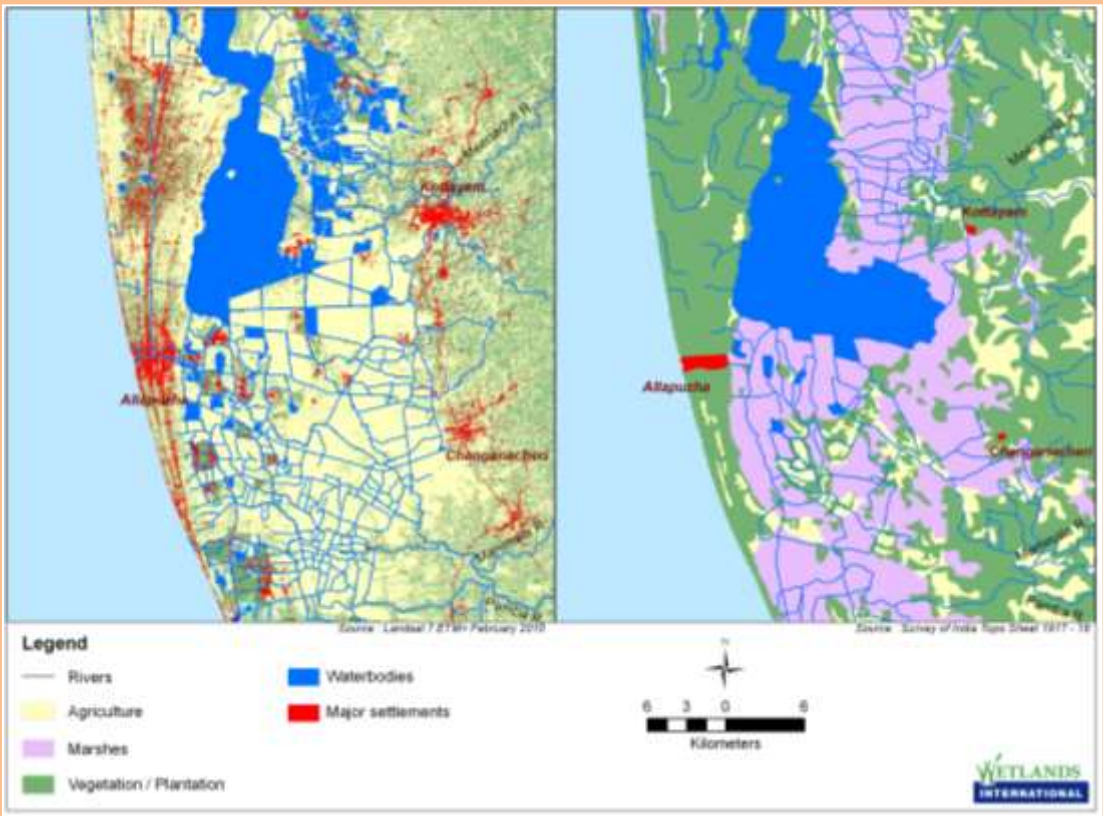
Kottayam Districts. Barring a small patch in the south, the entire Kuttanad was at or below sea level and thereby remained waterlogged and marshy for large parts of the year. This raised portion was known as 'Old Kuttanad' or 'garden land' mostly used for settlements and coconut cultivation.

The erstwhile rulers of Travancore District felt the need to develop the waterlogged areas for rice cultivation so as to feed the rice requirement for a growing population. Private entrepreneurs initiated reclamation of marshes, however, with very limited success. Early 1880s, the state got actively engaged into promoting reclamation of marshes, offering loans at concessional rates and exempting land taxes for the first five years of cultivation. However, in 1903, reclamation was temporarily banned on the apprehension that silt was being mobilized on the mouth of Cochin port. In 1912, the ban was again lifted, and Rani, Chithra and Marthandam kayal emerged. Reclamation projects continued till post-independence. In 1942, an agricultural workers' union was formed to improve working conditions of wage labourers. The Land Reforms in the 70s led to reclaimed land being allocated to cultivators. The reclaimed land was classified under 20 sub-divisions and numbered alphabetically from A to T. 'New Kuttanad' emerged by 1960s including 550 km^2 of land reclaimed from marshes and Vembanad estuary.

Reclamation was usually taken up during summers when river flows were at the leanest. Water wheels were used to drain water from temporary embankments (made from double lined coconut stems filled with sand, clay and garbage). Introduction of mechanical pump sets during the last decade of 19th century greatly enhanced the pace of reclamation. By the early 20th century mechanized pump sets imported from Great Britain and run by kerosene and crude oil started to be used.

These reclaimed lands exist in clusters called polders or *padashekharam*, bound by outer embankments. There are presently over 1200 polders with an area of 593.75 km^2 varying in size from 1 to over 900 ha. Gradually, collectivization of operations took place with *padashekharam* management committees being constituted and dewatering operation schedules streamlined.

Despite Kuttanad being naturally fertile, prolonged inundation and salinity constrained intensification of agriculture. As the flow of rivers dwindled from December, the salinity in surface waters increased, and



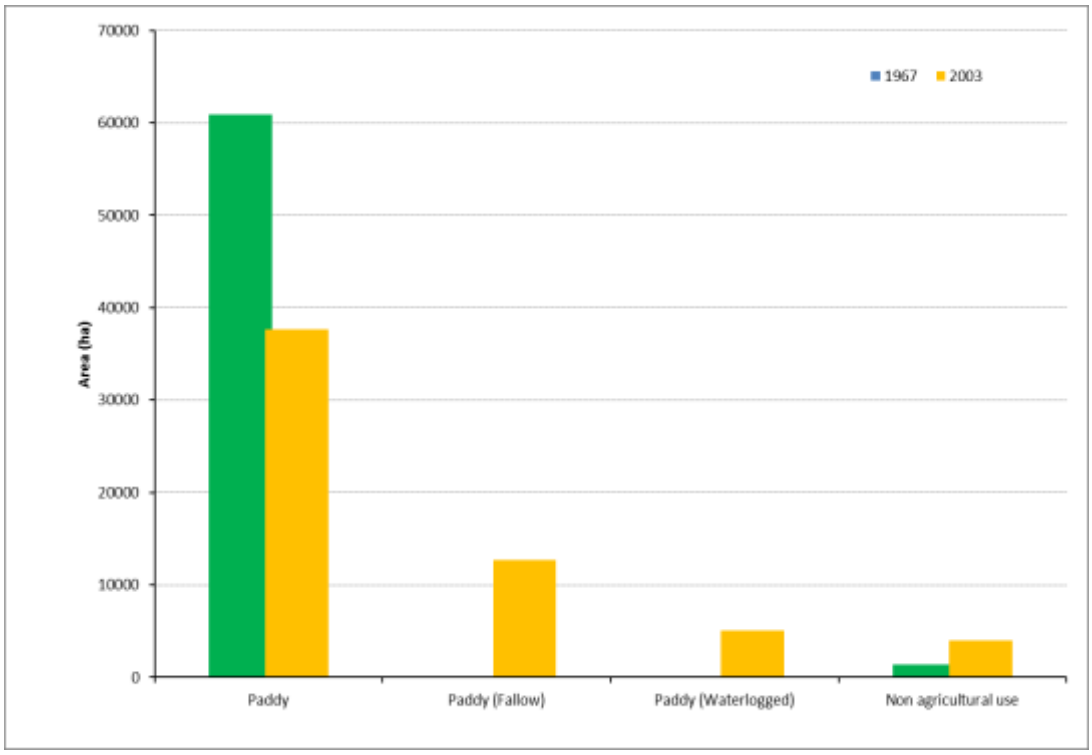
Conversion of marshes for agriculture in Kuttanad

Kuttanad remained brackish till May. Rice cultivation was possible only once in three years during the punja season, sown after southwest monsoon and harvested before tidal intrusion of seawater during summer. Crop varieties matured within 100 days with an average productivity of around 1,200 kilogrammes per hectare. A post second World-War food scarcity induced the state government to order annual cropping. Pumping subsidies were announced. Rice Research Station was set up in 1940 to develop crop varieties ideal for Kuttanad. The practice of an additional crop, with a cropping cycle of May to August was promoted in around 10,000 ha.

Rice cultivation in Kuttanad is based on meticulous manoeuvring of water levels. Preparations begin in March-April with ploughing, application of lime to reduce acidity of soil and then letting in waters from the canals to inundate the fields throughout the southwest monsoon period. This suppresses capillary rise of salts from below the soil. In August – September, when water levels decrease to manageable levels, outer bunds encircling the fields are repaired. Second round of ploughing begins as the south-west monsoon subsides. The ploughing is done in waist deep-water. Dewatering commences soon after, following which inner bunds are repaired. Weeding is done prior to sowing. For transplantation, seeds are packed in screw-pine bags and soaked to induce sprouting. The sprouted seeds are transplanted and fertilizers are applied. Twenty-five to thirty days after sowing, the overcrowded portions are thinned out. Harvesting is done by cutting the ear heads, which is then thrashed, paddy separated and transported in storage barns.

As agriculture within the reclaimed lands was not possible without regulation of flooding and salinity, two major hydrological interventions were commissioned. In 1955, Thotapally spillway was constructed to divert the monsoon inflows of Pamba- Achencoil and Meenachil Rivers, through a lead channel from Veeyupuram to Thotapally. It was designed to discharge 64,000 cusecs (cubic feet per second) flow, which was approximately one third of the monsoon flow of the river systems at Veeyupuram. In 1968, construction of Thaneermukom Barrage was initiated across Vembanad estuary to prevent salinity intrusion from the Cochin mouth. A road between Alapuzza and Changanassery was constructed to facilitate communication and transport. The Kuttanad Development Project launched by the government in 1972 projected that with making the bunds permanent, it would be possible to ensure double cropping in 520 km^2.

However, the benefits of these hydrological regulations were crowded out within a span of three to four decades. The introduction of high yielding rice crop varieties (having longer maturity period, 120 – 130 days as compared to around 100 days for the traditional variety) led to changes in cropping schedules, forcing closure of the Thaneermukom Barrage for longer period. In actual practice, barrage closure extended from three month period of December – March to even May and June. Instances of pest and



Changes in land use pattern in Kuttanad (1967-2003)

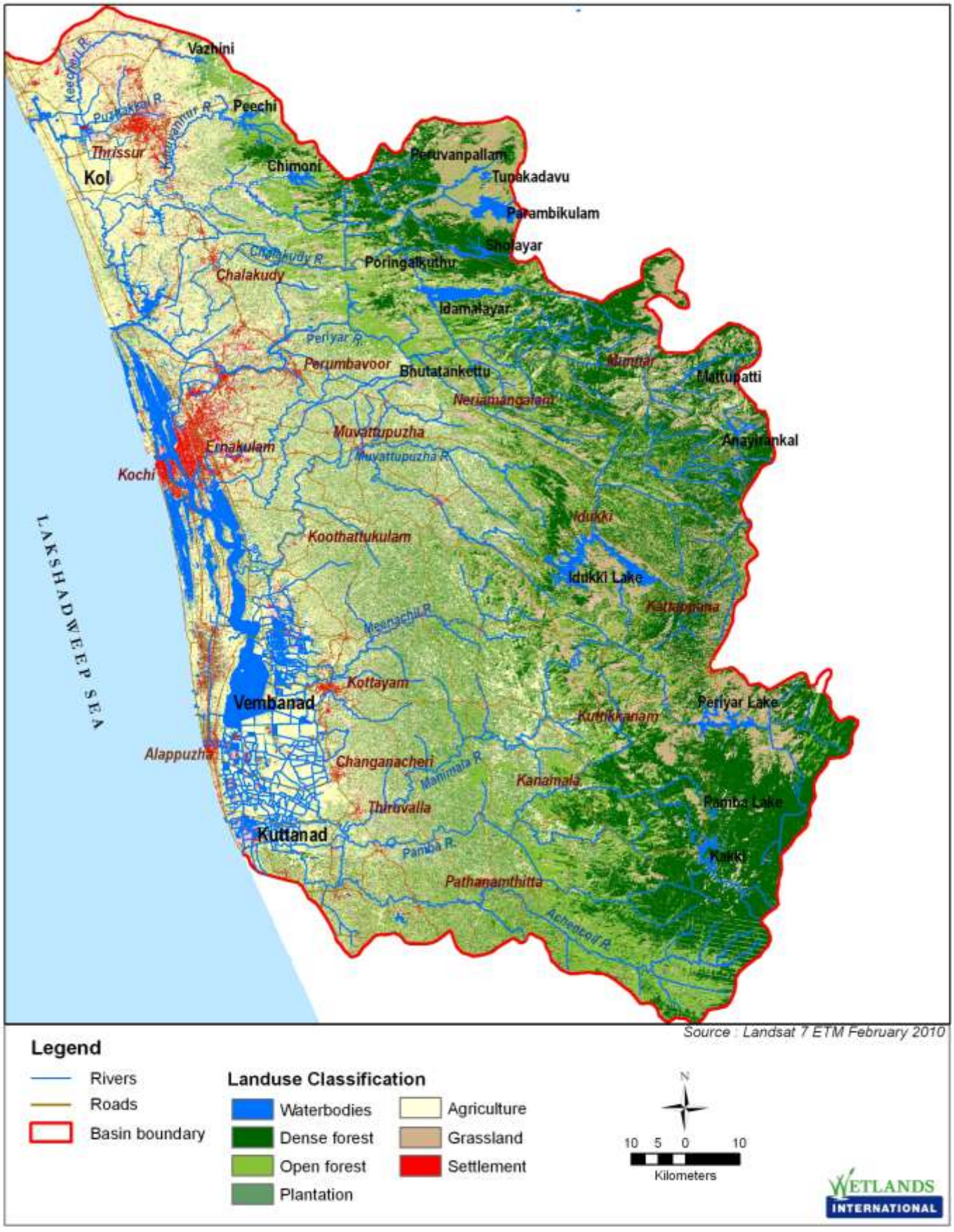
crop diseases led to increased use of chemical pesticides and fungicides. Extended closure of barrage also brought the farmers in conflict with fishers who reported interference in migratory pathways and decline in catch. Not all the reclaimed polders could be used for agriculture, as waterlogging continued in the blocks adjoining the estuary. Economically, high costs of labour and recurring costs of maintenance of embankments, water pumps and allied infrastructure affected profitability. As per assessments of remote sensing imageries by the Kerala Land Use Board, the area under paddy in Kuttanad reduced from 609 km^2 to 376 km^2 during 1963 – 2003, coupled with increase in area left fallow and converted for non-agricultural uses. The canals are choked by invasives as water hyacinth which further aggravates waterlogging. AC road, constructed across the floodplains has turned out to be a major flow obstruction.

Kuttanad was identified as one of the 31 farm- distressed districts by the Ministry of Agriculture in 2006. An assessment of ecological and livelihood status of Kuttanad wetland was conducted by M S Swaminathan Research Foundation, based on which a Kuttanad Rehabilitation Package amounting to Rs. 1,300 crore is under implementation. Activities under the aegis of the plan include reorganizing crop production, improved management of Thaneermukom Barrage, reduction in freshwater invasives and improvement of fisheries.

The current condition of Kuttanad requires a serious examination of ecological and economic viability of intensification of wetland-agriculture. The extent of infrastructure developed in the region is way beyond what a wetland can sustain. The tradeoffs in terms of impacts on biodiversity and foregone wetland functions as ability of regulating floods are apparent. Addressing these issues in a meaningful way is pertinent in order to develop wise use strategies for Vembanad-Kol.

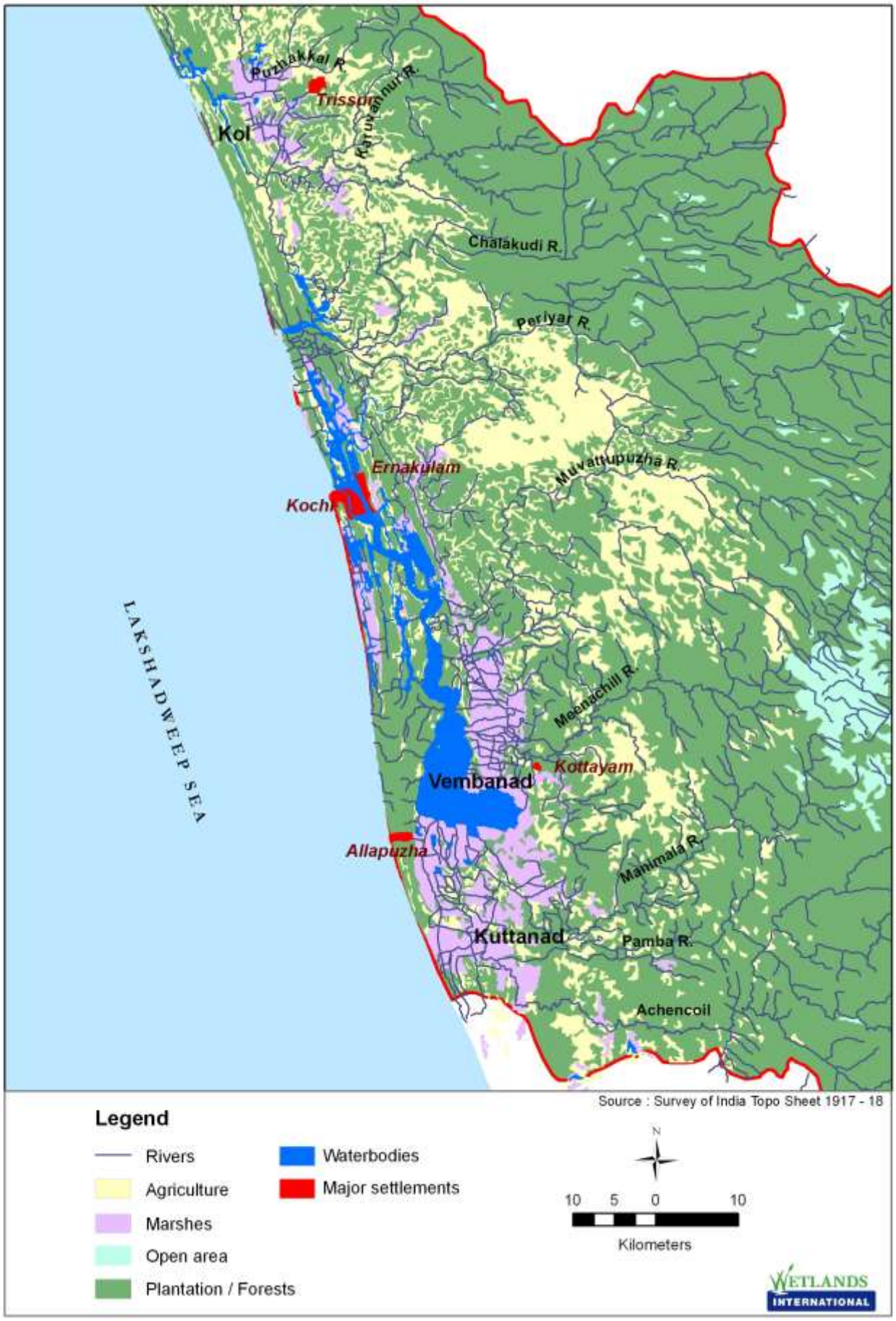
Source: Based on information contained in Kuttanad Project Development Report (1971); Report on Measures to Mitigate Agrarian Distress in Alapuzza and Kuttanad Wetland Ecosystem by M. S. Swaminathan Research Foundation (2007) ; and information contained on website of Kuttanad Package official Website (www.kuttanadpackage.in visited on November 11, 2013)

AC channel choked with water hyacinth. This channel is connected with Pamba River



Map 2.6 | Landuse of Vembanad-Kol catchment 2010

Map 2.7 | Landuse of Vembanad-Kol catchment 1973



Map 2.8 | Landuse of Vembanad-Kol catchment 1917-18

2. 4. HYDROLOGICAL REGIMES

The hydrological regimes of Vembanad-Kol are influenced by the riverine as well as coastal processes. A complete and systematic regime characterization of the wetland complex is yet to be carried out in absence of a well-defined and established monitoring system, however, periodic assessments carried out in Kuttanad and inflowing rivers provide useful information based on which key management issues can be identified. Notable of these assessments is Kuttanad Water Balance Study carried out in 1989 to identify water management and hydraulic engineering measures to mitigate water related problems in Kuttanad area. Center for Water Resources Development and Management has also carried out studies on various hydrological aspects of the Vembanad estuary and the inflowing river basin. Studies by National Institute of Oceanography provide information related to coastal processes. Kerala Sastra Sahitya Parishad (KSSP), a Forum for Science Writers of Kerala has also documented several historical changes in land use within the estuarine area, which help in understanding regime baselines.

Water Inflows and Outflows

Vembanad-Kol wetlands receive freshwater inflows from nine drainage basins (Map 2.5). Rainfall is an important variable governing freshwater inflows into the wetland complex, as all the inflowing rivers are rainfed. The basin experiences two distinct rainy seasons - the Southwest monsoon (June to August) and the Northeast monsoon (September to December). About 60% of the rainfall occurs during the Southwest monsoon, 30% during Northeast monsoon and the remaining in the summer months. Significant spatial and temporal variation exists within the basin, with the highlands generally receiving more rainfall than the midlands and lowlands. Average annual rainfall within the upstream catchment area varies from 2,970 mm in the Meenachil Basin to 4,360 mm in the Manimala Basin (Gopakumar and Takara 2009). The average relative humidity is 80% as this area is situated in humid tropics and experiences fairly uniform temperatures throughout the year, ranging from a minimum of 21^0C to a maximum of 36^0C.

Rivers Pamba, Achencoil, Manimala and Meenachil and Muvattupuzha flow into Vembanad through Kuttanad, whereas Chalkudy and Periyar flow directly into the estuary. Rivers Keechari, Puzzakal and Karuvannur flow into the Kol lands. The total flow of these rivers has been estimated to be 22,568 MCM[8], of which 84% is during monsoons. Over 60% (13,833 MCM) of inflow is received in Vembanad through the rivers draining Kuttanad, 67% of which is during southwest monsoon and 12% during the northeast monsoon (Fig 2.1 and Fig 2.2).

Inflows from the sea govern the salinity regimes in the estuary. During June to November, high inflows lead to development of freshwater conditions in large parts of estuary and associated floodplains. However, as the flow recedes during the period December – May, water is received from the sea creating brackish water conditions.

An indication of the net exchange of flows with Arabian Sea is made based on computation of water balance for Vembanad-Kol wetland. Using the assumption that the water volume in the wetland stays constant in a given year, it is estimated that 24,574 MCM of water volume is drained into the sea through the wetland (Fig 2.3). Further assessments are required to characterize the tidal flux as it plays an important role in determining the salinity.

[8] Source of Data: CWC daily flow data from the following stations : Kidangoor (Meenachil) – Jun 1986 – May 2000; Malakkara (Pamba) – June 1986 – May 2000; Kaiurpara (Manimala) - June 1986 – May 2000; Thumpamin (Achenkoil) – June 1978 – May 2000; Ramamangalam (Muvatupuzha) – June 1978 – May 2000. Data for Periyar, Chalkudy, Karuvannur and Keechari-Puzzakakal are from CMRDM, 2006, converted into monthly flow volumes based on rainfall data.

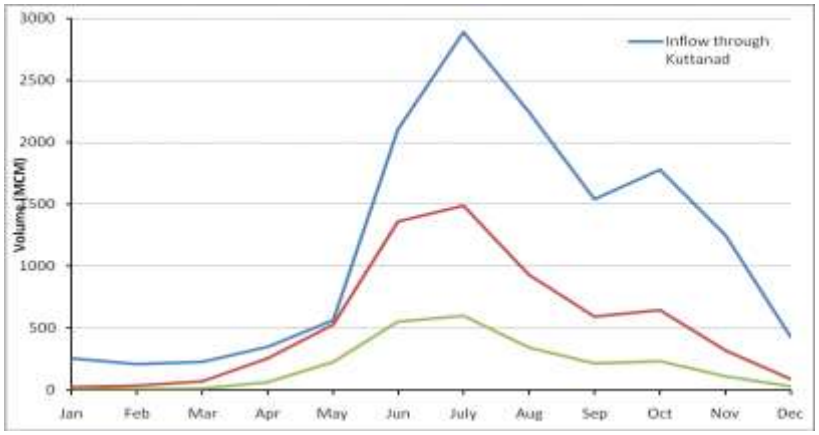


Fig 2.1 | **River inflow volumes into Vembanad-Kol wetlands**

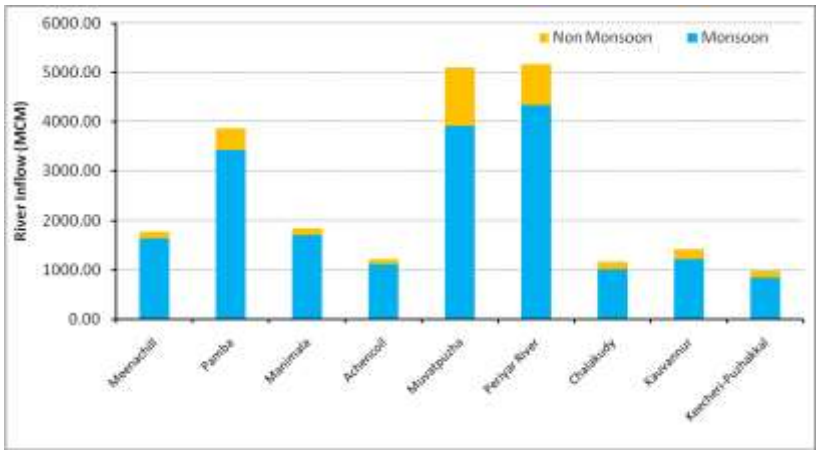


Fig 2.2 | **Inflows from drainage basins into Vembanad-Kol wetlands**

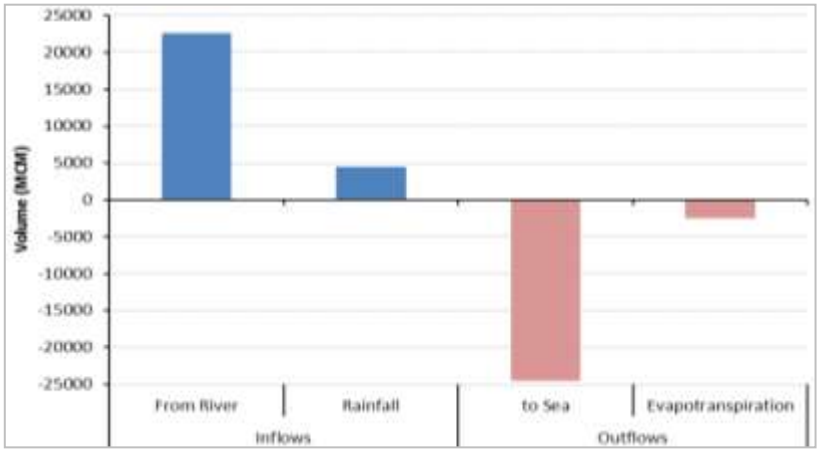


Fig 2.3 | **Annual water balance for Vembanad-Kol wetlands**[9]

[9] Assessment based on Gopakumar and Takara (2010). Assuming that during a year there is no net gain or loss of water in the wetland complex, and no tidal and groundwater exchange, water balance can be derived from the following equation: River inflow + Precipitation on wetland = Evapotranspiration from wetland + Water outflow to Sea. Mean annual precipitation for the wetland complex has been taken to be 2517 mm / year. Mean crop reference evapotranspiration is 1430 mm / year. An average evaporation factor of 1.125 has been used to derive evaporation from water surface (1609 mm / year). Areas of water and wetland complex are from remote sensing imagery of February 2010.

Hydrological connectivity of the wetland with the rivers and sea is regulated by a series of hydraulic structures. Within the lowlands, the natural hydrological regimes have been modified to meet the freshwater requirements for agriculture in the reclaimed backwaters and floodplains of Kuttanad and Kol regions. Thottampally spillway was constructed in 1955 to divert monsoon flows of Achencoil, Pamba, Manimala and Meenachil away from Kuttanad in order to reduce flooding in agricultural lands. A bridge-cum regulator with 40 vents each with 7.6 m clear span has been constructed at Veeyupuram which connects to the sea at Thotapally through a 9 km long lead channel. The design width was assessed to be 1,200 m; however, the specifications were maintained only for the 1 km and for the rest construction was done at nearly half the design width. A sand bar is formed at the mouth each year, which is cut when the water levels reach 0.70 m amsl, the profile being maintained by the flood-flows in the following periods. The spillway is opened during June to December, and closed during rest of the year to prevent saline water intrusion. With insufficient capacity to divert floodwaters, floods persist as a threat to agriculture operations in Kuttanad. Similarly, regulators at Ennamekulam and Kottenkottuvalavu serve as a spillway for the floodwaters as well as regulators to control entry of saline water into the Kol lands. In 1974, the Thaneermukom barrier was constructed across the estuary to prevent salinity intrusion into paddy fields of Kuttanad, operation of which has been a major source of conflict between farmers and fishers (Box 2: Operational regime of Thaneermukom Barrage) .

In the upstream reaches, the rivers have been regulated to provide water for drinking water supply, irrigation and hydropower. Rivers flowing into Vembanad-Kol wetlands are comparatively longer (165 km), with 67% area under the highlands with steep slopes of over 60 m / km, and therefore have a high potential for hydropower and irrigation development. Fourteen of the 26 power projects in Kerala are located within the Vembanad-Kol Basin, accounting for more than 80% of the total installed thermal power capacity and 64% of the total installed capacity of the state from all sources. Periyar River, which contributes 25% of the overall inflow to the wetland, has been the focus of water resources development with 7 projects located within its basin.

View of Thaneermukkom Barrage from southern end

Box 2: Operational regime of Thaneermukom Barrage

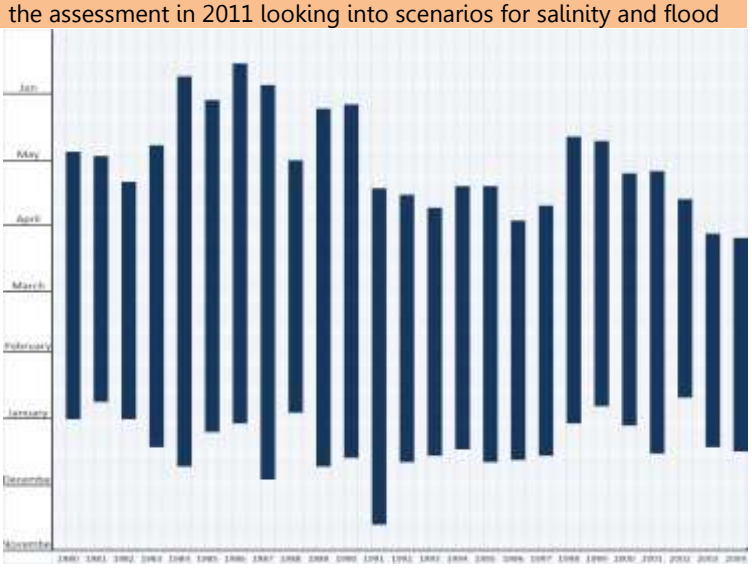
The Thaneermukom Barrage was designed to prevent salinity ingress in the dry season and retain freshwater from the inflowing rivers into Kuttanad region so as to enable safe *punja* crop and intensify *viruppu* crop of rice. It has been constructed at a narrow segment of the estuary, between Thaneermukom on the west and Vechoor in the east. The design of the 1252 m long structure included 92 vents and locks at each end for navigation, to be constructed in three phases. The first phase at Muhamma end with 31 shutters and two locks for navigation was completed in 1968. The second phase at Vechoor end with 31 shutters and one lock was completed in 1974. Construction of remaining shutters connecting the two ends never materialized, and a cofferdam was constructed instead.

The barrage has been relatively successful in ensuring freshwater conditions in Kuttanad and enabling cropping additional areas during dry seasons. However, there have been several ecological consequences triggered by changes in salinity regimes and impeded circulation and mixing patterns. There has been a decline in brackishwater fisheries. Elimination of tidal flushing has impacted pollution levels in Kuttanad, further aggravated by increased use of fertilizers and pesticides which also contribute to proliferation of invasives as water hyacinth. The shutters have remained closed for a period upto six months, invariably creating conflicts between farmers and fishers.

Concerned on the rising conflicts between stakeholders, the Government of Kerala constituted an Advisory Committee in 2001 to look into the opening and closing of shutters of the barrage. The Committee further constituted a Technical Expert Committee in 2002 headed by Dr. E.J.James (Former Director, CWRDM) to assess the environmental, ecological and socio-economic imbalances arising out of barrage operations. Members were drawn from School of Environmental Studies, Rice Research Station, Kerala Water Authority and representatives of the departments of agriculture, fisheries and health. Following hydrological assessments and stakeholder consultations, the committee recommended minimizing the annual period of closure of barrage to mid-December and mid-March. Other important recommendations included implementing a detailed environmental monitoring programme and a participatory structure for barrage operations. The recommendations were adopted, and to a large extent followed.

Declining state of agriculture in Kuttanad forced a relook into Barrage operations and flood management. The M.S. Swaminathan Committee report endorsed the recommendations made by James Committee but highlighted the issues of lack of interdepartmental coordination, and need to improvise the technology used for managing the gates. Detailed studies on modernization of Thaneermukom Barrage and Thottapally spillway were inbuilt into the Kuttanad Package implementation plan. A team of CWRDM and IIT Madras concluded the assessment in 2011 looking into scenarios for salinity and flood control using the current state of the two structures[10]. The study concluded that the Thottappally spillway and the channel were able to alleviate floods only for the normal years. The assessments also concluded that it was possible to keep the gates of the Thaneermukom Barrage open each day for a stipulated period to allow for circulation and mixing as well as reduce pollution.

The barrage operation arrived at included closing the gates when the salinity in the south of barrage fell below 1.8 ppt has been recommended. The report is currently being considered for implementation.



Closure period of Thaneermukom Barrage over the years

[10] IIT and CWRDM (2011). Study for modernizing the Thaneermukom Bund and Thottappally spillway for efficient water management in Kuttanad Region, Kerala. Final Report submitted to Government of Kerala.

Sedimentation

Wetlands act as sediment traps. The floodplain systems in Kuttanad and Kol regions have developed as a result of riverine sediment accumulation over geological timelines. While some natural sedimentation is bound to take place in wetland, continued accumulation due to human disturbances needs careful management.

The rivers associated within the Vembanand-Kol wetland system, as in general in Western Ghats, are steep and fast flowing. The wetlands function as a sink for the monsoon flood flows. Flood frequency analysis for the period 1964 – 86 indicated that floods with return period of 10 to 25 years have only marginal effect on the water level at Cochin mouth, thereby indicating the capacity of the wetland to contain floods. Computations also indicated that in absence of the lagoon and the nearby low lying areas, the entire area to the west of the wetland should have been flooded leading to considerable damages. However, conversion of wetlands for agricultural purposes has reduced the flood retention capacity and consequent inundation of the peripheral areas. The situation is more critical in Kuttanad and Kol lands. Based on the reservoir sedimentation surveys carried in seven reservoirs of the river basin draining the wetland, the average sediment yield was observed to be 26t/ha/yr. The total sediment yield from all the river basins draining into Vembanad lagoon and Kol lands has been estimated to be 32 million tonnes and 4 million tonnes respectively.

The most recent assessment of waterholding capacity of Vembanad estuary is based on the 1987 bathymetric survey by Water Resources Department of Kerala State (Gopakumar and Takara, 2009). The bottom elevation was found to vary from -9.9m amsl to 2m amsl, with a mean of -1.725m amsl. The southern portion is comparatively shallower as compared to northern parts of Cochin estuary, which could be attributed to periodic dredging carried out at the mouth to maintain the port. At 1m amsl the estuary has an area of 216.53 km^2 and a volume of 611.47 MCM (Fig. 2.4). Reclamation of estuarine areas for agriculture has led to drastic decline in water holding capacity from 2.4 km^3 to 0.6 km^3 during the last 50 years changes in depth of estuary at various locations during 1940 to 1992 is presented in Fig. 2.5.

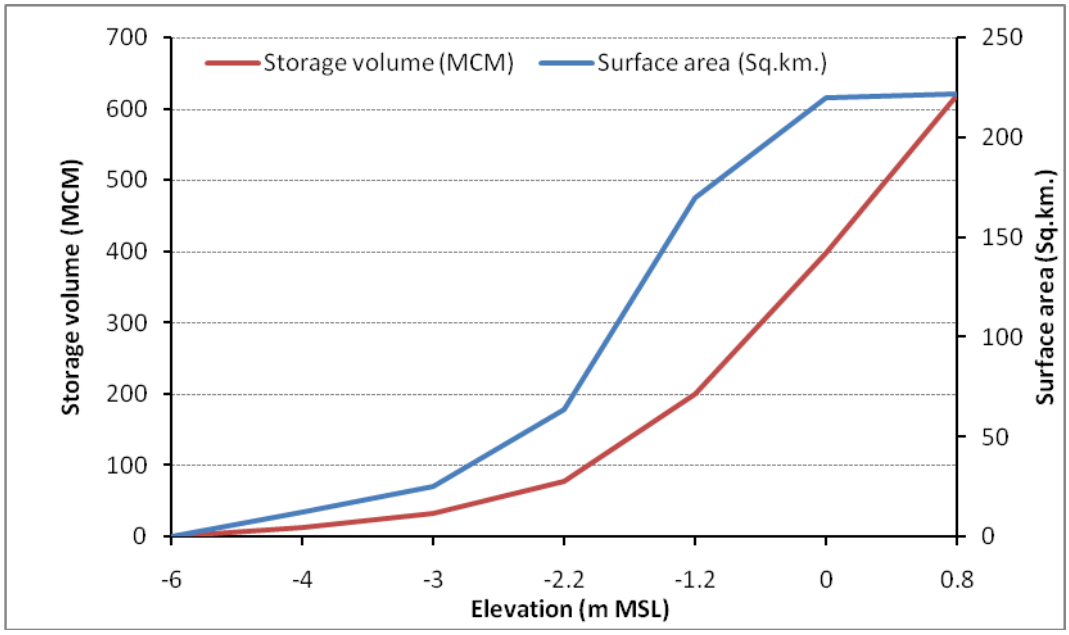


Fig. 2.4 | Elevation area capacity curves of Vembanad Estuary (Source: GopaKumar and Takara, 2009)

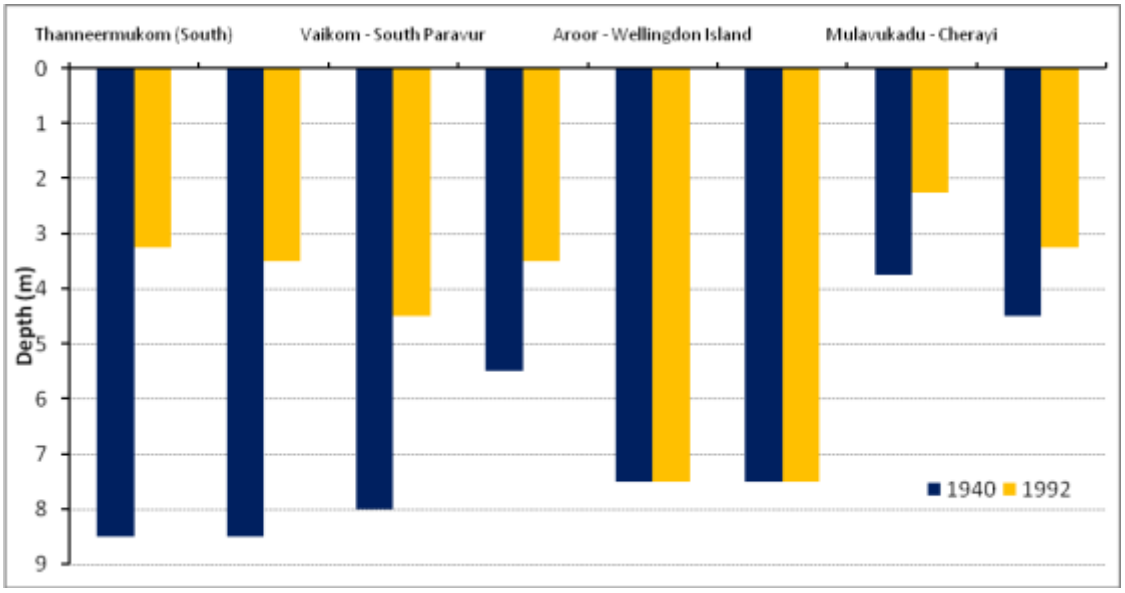


Fig. 2.5 | Change in depth of Vembanad estuary (1940 and 1992) (Source : KSSP, 1992)

Geologically, evolution of Kuttanad and Kol lands is linked with sediment inflows from the rivers. Extensive channelization in the two stretches has impeded the natural process of fanning of sediments, constricting inflows into channels. Construction of hydrological structures in the heads of the rivers is also likely to impact floodplain evolution in the longer terms. Further assessments are however required to establish the impact of changes in fluvial dynamics on the wetland complex.

Water Quality

Water of Vembanad estuary is alkaline, well oxygenated and brackish. Its salinity varies from 4.5- 33.1 ppt (Sujatha et al., 2009). At Kochi mouth, salinity is highest (23-30 ppt) which progressively reduces inwards. The salinity in the Kol wetland and a part of Vembanad north of Thaneermukom Barrage was observed to range between 10 – 15 ppt during 1990s. Inter basin transfer of water from Periyar to Muthapuzha and discharge of water from tail races of hydropower projects have changed salinity gradient in the central part of estuary which presently tends towards freshwater conditions.

The Thaneermukom Barrage plays a critical role in influencing salinity. During December to March when barrage gates are closed, salinity towards the north of Thaneermukom is reported to be higher (10 ppt) which favours integrated prawn farming in *Pokkali* and *Kaipad* areas. Freshwater conditions prevail south of Thaneermukom (0.00 ppt recorded at Pathiramanal) favour the *Punja* crop in Kuttanad areas during the period. The barrage gates are opened from April to December and a gradual increase in salinity is observed in southern part (7.1 ppt) (IIT and CWRDM, 2011). Lower salinity levels are recorded between June to September in monsoon with a gradual increase during October to January. The entire backwater becomes freshwater during monsoon barring bar mouths. From November to January partially mixed conditions prevail.

The lake is nutrient rich with nitrate-nitrogen and phosphate-phosphorus concentrations ranging between 0.01-1.06 mg/l and trace to 0.45 mg/l respectively (Sujatha et al., 2009). High electrical conductivity values have been reported from surface water (167-313 micromhos/cm and north of Thaneermukom (14960 micromhos/cm) which is correlated with direct discharge of industrial effluents at these locations (Vincy et al., 2012, IIT and CWRDM, 2011). Silica, a product of weathering, is in the range of 0.16-19.9 mg/l (Sujatha et al., 2009) (Table 2.3).

Impact of developmental activities on water quality of wetland is apparent. The Vembanad estuary serves as a sink for the effluents of several industrial and manufacturing units. Agricultural runoff and sewage generated in Alappuzha and other urban areas nearby also join the backwater. Kochi city alone generates 2,550 million l/day of urban sewage that directly enters Vembanad estuary largely untreated. The total dissolved solid content of water is as high as 53,750 mg/l during summer, gets reduced to 160 mg/l during rainy season. In Kochi, the existing sewage facilities process water from only 1% of the population. Though a septic tank sewage system is used in most parts, large number of toilets located on the banks of the estuary lead to direct faecal contamination. Faecal coliform counts of up to >2500 MPN/100 ml have been recorded. Kochi Corporation sewage collection system empties its municipal wastes containing high particulate organic matter into the estuary through the Padiyathupalam, Kalvathi, Rameswaram, Pulimuttu and Thevara canals.

There is a high concentration of major industries on the banks of the Periyar River in the Udyogamandal area, 10 km north of Kochi harbor (Map 2.9). It is estimated that nearly 260 million liters of untreated effluents reach the Periyar estuary daily from the Kochi industrial belt (Priju and Narayana, 2007). These discharges contain hazardous concentrations of a range of chemical contaminants such as phosphates, sulphides, ammoniacal nnitrogen, fluorides, heavy metals (mercury, chromium, lead, copper, zinc and insecticides (DDT, BHC etc). The presence of radioactive waste materials has also been reported from these areas.

Table 2.3 | Surface water quality of Vembanad

Parameters	**1995-96**[1]	**1998**[2]	**2008-2012**[3]
pH	6.1-7.2	-	7.1-8.5
Temperature (^{0}C)	28.6-31.9	23.3-31.0	29-33
Dissolved oxygen (mg/l))	5.9-8.1	3.44-5.59	2.81-5.64
Salinity (ppt)	-	0.04-33	4.5-33.1
Transparency (m)	1.10-1.86	-	-
Conductivity (micromhos/cm)	-	-	167-313
Calcium (mg/l)	-	-	17.6-160
Magnesium (mg/l)	-	-	1.9-413
Sulphate (mg/l)	39.2-116.9	-	5-357
Chloride (mg/l)	-	-	150-6350
Nitrate-Nitrogen (mg/l)	0.04-0.5	-	0.01-1.06
Phosphate-Phosphorus (mg/l)	Trace- 0.03	-	Trace- 0.45
Silicate (mg/l)	0.7-11	-	0.16-19.9
BOD (mg/l)*	0.5-3	-	3.45-5.9
Faecal coliform (MPN/100ml)	Nil- >2400	-	-

Data Source: *Balchand and Nambisan, 1986; [1]James et al, 1997; [1]CWRDM, 2006; [2]ICMAM, 2002; [3] CWRDM, 2011; [3]Sujatha et al., 2009; [3]Nasir, 2010; [3]Vincy et al., 2012

Map 2.9 | Major industries within Vembanad-Kol catchment

The region of Vembanad estuary, near confluence of Periyar River is influenced by large influx of chemical and metal processing industries. High concentrations of lead (32.5 µg/l), copper (13.065µg/l), zinc (40µg/l) and cadmium (2.22 µg/l) have been reported during pre-monsoon (Anju et al., 2011). Increase in accumulation of copper, nickel, cobalt, zinc and cadmium have also been reported in lake sediment (Priju and Narayana, 2007).

Coconut coir retting and associated operations, though small scale, are extensively distributed along the coastal stretches and contribute heavily to the organic pollution load of the open water bodies. Large quantities of polyphenols along with hydrogen sulphide are released from the coconut husks during the retting process, creating anoxic conditions. Untreated retting effluents which contain high concentrations of biodegradable organic matter along with sulphides, nitrate and phosphates exert heavy BOD and COD stress on the surrounding aquatic environment. The BOD values of lake during 2008-12 range from 3.49-5.9 mg/l (Vincy et al.,2012) which is beyond the permissible limit for inland surface water (3 mg/l BOD as per IS:2490-1974).

Intense rainfall coupled with steep topography retards infiltration and causes the mineral products of weathering to flush down through the surface runoff. Consequently, the groundwater is less mineralized and its quality is better. The shallow groundwater in the upper reaches is slightly acidic or near neutral showing that the hydrogen ions have not reacted completely with the minerals of the parent rock. The distribution of electrical conductivity, which is an index of mineralisation, is about 50µS/cm to 2850 µS/cm 250C (Nasir, 2010). The middle reaches of the basins show slightly greater values for electrical conductivity. The lower reaches are composed of fine, dark coloured deltaic sediments and exhibit alkaline conditions. The dissolved solids content is also higher, as compared to the upper reaches of the basin. Fluoride concentration is below 0.2 mg/l in the shallow groundwater zone. Ground water can be classified as C1S1, C2S1 and C3S1 group with higher salinity hazard (ibid).

Coir submerged for softening in a channel near Vaikom

Box 3: Sand Mining in Vembanad-Kol catchment

River sand and gravel are mined extensively from the rivers of the Vembanad catchments. The intensity of the mining is high in the alluvial reaches of the main channels. It has been estimated that around 12.13 million tonnes of sand and gravel are being extracted annually from the seven rivers draining the Vembanad estuary (Padmalal et al., 2008). Half of this is from River Periyar which flows through the Kochi city. River Muvattupuzha is also mined for sand owing to its proximity to the city. Apart from instream mining a substantial amount of sand is also being extracted from the floodplain areas of these rivers. Instream mining operations employ about 22300 registered labourers. The number of indirect workers depending on the quarried sand in the construction sector would be over 0.1 million (ibid).

The rate of sand mining is around forty times higher than natural replenishment. As a result, the rivers and associated wetlands are being adversely affected. Indiscriminate sand mining has resulted in the development of pits of various dimensions in river beds. Frequent movement of heavily loaded vehicles across the river banks emitting oil and gasoline pollutes the river and stirs up clouds of fine organic and inorganic particulates, in the overlying waters. Lowering of water table in the wells adjacent to sand mining sites is noticed in the lower reaches of the midlands and lowlands. A study conducted in Manimala River revealed that more than 60% of the wells in its floodplain were affected by water shortages due to river bed lowering consequent to sand mining.

Riparian flora and fauna suffer seriously from riverbank slumping, direct removal of vegetation along the river banks, bank undercutting and channel incision. In several circumstances, resting and nesting grounds of many migratory bird species are affected. The in-stream fish wealth of the rivers is also decreasing due to unabated sand mining (Arun 1999; Kurup *et. al.,* 2004).

Mined sand being transported

2.5. COASTAL PROCESSES

Littoral drift[11] plays an important role in shaping and orienting coastal landforms and finally in evolution of the coast. Information on coastal processes related to Vembanad-Kol wetlands is very limited. Gross annual sediment transport rates have been reported to be high in south Kerala (of the order 1.5 to 2 MCM) (Kunte and Wagle, 2000). The probable volume of sediment transport at 2 m depth has been estimated to be 9x $10^6/m^3$ towards south between Munambam and Vypeen and 7x $10^6/m^3$ between Fort Cochin and Anthakaranazhi (ibid). This is one of the factors leading to development of a sandbar at the mouth of Thottapally spillway, which is currently being maintained by periodic dredging at a significant annual cost.

2.6. BIODIVERSITY

High habitat diversity within Vembanad-Kol enables the wetland ecosystem to support a diverse range of species, several with high conservation significance. Connectivity with riverine and coastal environments leads to development of a salinity gradient within the estuary providing conducive condition for species migration. The wetland catchments form a part of the Western Ghats bio-geographic region which is identified as one of the 25 biodiversity hotspots[12] of the world (Myers et al, 2000). The low lying swamps and tidal creeks with patches of mangroves support juveniles of several economically important fish and prawn species of marine and freshwater origin and act as wintering grounds for migrating waterbirds, supporting one of the largest populations within the Central Asian Flyway.

Biodiversity within Vembanad-Kol exists within a highly modified and fragmented landscape. Reclamation of marshes for agriculture, rapid development of tourism infrastructure and increasing area under settlements has adversely affected habitats. The few species rich pockets as Pathiramanal Islands and Kumarokom need urgent protection so as to ensure that the biodiversity values of Vembanad-Kol backwaters are not lost in the course of increasing economic development.

Systematic inventorization and assessment of biodiversity of Vembanad-Kol wetlands is yet to be carried out. While studies on specific groups (mainly waterbirds, fish and mangrove) do provide information on species richness, major component of research is targeted on economically important species, with relatively little information available on the lower order floral and faunal species. Similarly, landscape scale interactions, particularly the impact of landscape fragmentation is yet to be comprehensively assessed. An overview of number of species recorded from the Vembanad-Kol wetlands is summarized in Table 2.4, and the overall status and trends discussed in the following sections.

[11] Littoral transport is the movement of sediments in near shore zones by waves and currents. Transport parallel to the shore is termed as alongshore, whereas perpendicular to the shore is termed as onshore-offshore transport. The material transported is called littoral drift.

[12] Over 4000 species of flowering plants (38% endemic), 289 fish (41% endemic), 135 amphibians (75% endemic), 156 reptiles (62% endemic), 508 birds (4 % endemic) and 120 mammals (12% endemic) have been recorded from Western Ghats (Daniels, 2003; Babu and Nayar, 2004; Dhanukar et al, 2004; Gururaja and Sahyadri, 2004)

Table 2.4 | Species recorded from Vembanad-Kol and their conservation status

Species group	No. of Species	Record Date	Data Source	IUCN Conservation Status						
				CR	EN	VN	NT	DD	LC	NE
Flora										
Phytoplankton	123	1998-99	ICMAM, 2002							123
Macrophyte	25	2006, 2012	Jhon et al., 2009 Jayan and Sathyanathan, 2012					25		
Mangrove	16	2009	KFRI, 2009					1	14	1
Mangrove associate	24	2009	KFRI, 2009						9	15
Fauna										
Zooplankton	24	1998-99	ICMAM, 2002							24
Fish	158	1978-80	Kurup et al., 1990			1	3	7	51	94
Crab	20	1988-99	Roy and Nandi, 2008							20
Clam	6	N.A	CMFRI,2005						2	4
Bivalve	2	2008	Suja and Mohamad, 2010						2	
Mussel	2	N.A	Rajan, 2011							2
Oyster	1	N.A	Rajan, 2011							1
Ave	225	1995-2007	AWC			1	10		215	

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

Floral diversity

With conversion of marshes of Kuttanad and Kol lands into agriculture, aquatic environment is mainly limited to Vembanad estuary and the interconnecting channels. Information on floral diversity pertaining to wetland complex is mostly focused on macrophytes and mangroves, and to a limited extent on terrestrial plant species in the surrounding areas. Overall 338 plants including 26 trees, 14 shrubs, 21 climbers, 237 herbs, and 40 mangrove and associate species (Sahu and Ambat, 2007; Jhon et al, 2009) have been reported from the wetlands. Information base on Kol and Pokkali areas is further limited. The annual mean Gross Primary Productivity and Net Primary productivity of Cochin backwater is reported to be 0.753 g C/m^3/ day and 0.603 g C/m^3/day respectively (Selvaraj *et al.,* 2003).

Assessments of 2002 by ICMAM indicate presence of 123 phytoplankton species (89 bacillariophyceae, 31 dinophyceae, 2 chlorophyceae and 1 cynophyceae). During monsoon, freshwater species dominates the backwaters replaced in post-monsoon by marine forms. Density of phytoplankton (all groups) ranges between 12,000 - 322,000 cells/l in the tidal-zone and 7,000-235,000 cells/l in backwaters (ICMAM, 2002; Selvaraj et al*.,* 2003).

CMFRI has carried diversity assessments of benthic marine algae for western Kerala coastline, recording presence of 34 species (Krishnamurthy, 1988). However, the coastline of Vembanad estuary is yet to be investigated. 8 species of seaweeds have also been

reported in the coastal zone between Tirumallavaram and Paraparangadi with luxuriant growth of *Enteromorpha compressa* and *Grateloupia filicina.*

Distribution of macrophytes within Kuttanad is mostly limited to channels and abandoned rice fields which remain waterlogged for prolonged periods. Overall 25 species of macrophytes belonging to 12 families and 3 species of pteridophyte *(Lycopodiu cernuum, Cyclosorus interruptus, Ceratopteris thalictroides)* have been reported (Jhon et al., 2009). High biomass density has been observed in certain pockets (91.2 g/m^2 dry weight) (Sasidharan et al., 1990). Dense coconut plantations have been developed all around polders. Several stretches of canals in Kol lands are infested with *Salvinia molesta* and *Eichhornia crassipes* (Annex 1).

Prolonged inundation in rice fields along with macrophytic infestation lead to creation of floating vegetation mats comprising 8 to 9 species at several locations in Kuttanad. The vegetation in these patches mainly comprises fodder grass *Ischaemum travancorense* (*Kadakal*), endemic to Kerala and Maharashtra (Jhon, et al., 2009). *Phragmites karka, Alternanthera philoxeroides* (Erect marginal), *Eichhornia crassipes, Salvinia molesta* (free floating), *Cabombo caroliniana* (rooted submerged), and *Ludwigia adscendens* (floating stem), several patches also have *Acrostichum aureum*, a mangrove associate fern. *Calophyllum sp.* (source of oil), *Oryza sp.* (wild rice), *Aponogeton sp.* (an edible tuber), *Kandelia sp.* (rare in the state), *Bacopa* (Brahmi a widely used medicinal plant), *Garcinia* and *Morinda* (commercial species known for its fruits), *Pandanus* (leaves harvested for mat weaving) have been also reported from the vicinity of the Kuttanad region.

Mangroves are one the important constituents of estuarine floral diversity. While lush stretches of mangroves have been reported in the past, these are currently confined to degraded patches in Kumarakom and Mangalavanam. In particular is the mangrove patch in Kumarakom, which is an important roosting and breeding site of Night heron, Darter, Cormorants, Indian Shags, Egrets, Herons and White Ibis. Assessments by Kottayam Nature Society have indicated the presence of 6 species of true mangrove and 17 species of mangrove associates in Kumarakom. Plantation of coconut and rubber are also seen abundant in the region (Ravi, N. 2002). Environmental groups have been pressing for the site to be declared as a bird sanctuary, but have been in conflict with

Mangrove and associates near Alangad (Ernakulam)

tour operators. The 8.4 ha mangrove protected area of Managalavanam is dominated by *Avicennia marina, Rhizophora mucronata* and *Acanthus ilicifoliusi* (of medicinal importance Jayson and Easa, 2000). Plantations of *Eucalyptus sp*. and *Tectona grandis* are can also be observed (ibid).

Proliferation of *Salvinia molesta* and *Eichhornia crassipes* within the channels of Kuttanad and Kol lands is a major concern as it impedes flow and aggravates waterlogging (Joy, et al., 1990; State of Environment Report, 2007). Closure of Thaneermukom Barrage for extended periods has led to significant reduction in tidal flushing in Kuttanad, which was a natural check to proliferation of these species. The problem is being further compounded due to increased nutrient enrichment from the agricultural fields.

Box 4 : Pathiramanal Island – A treasure trove of biodiversity

Pathiramanal (Sands of Night in Malayalam) is a 68 ha island located in the vicinity of Muhamma Panchayat. The uninhabited island covers an area of 68 ha and till 70s was under coconut and acacia plantation by a private land owner. In 1979, the island was transferred to Kerala Government following the Land Reforms Act, which handed it over to State Department of Tourism for development of tourism facilities.

The island stands out in terms of species diversity. 169 plant species from 64 families have been reported here, including 53 tree, 22 shrubs, 73 herbs and 12 climber species. *Mucuna gigantea* and *Flagellaria indica,* two large climber species with very restricted occurrence in Kerala, are abundant on this island (The Hindu, Aug 05, 2010). Rare plant species as *Aponogeton appendiculatus* [13] have also been found here. Pools and puddles have dense macrophytic vegetation. *Calophyllum inophyllum*, *Tylophora indica* and *Senna alata* found here are known to have medicinal properties.

The island is fringed by mangroves and associates. Overall 16 mangrove species have been recorded. *Ceriops tagal*, *Excoecaria agallocha* and *Cerbera odollam* (mangrove associate) are dominant while *Bruguiera gymnorrhiza*, *Sonneratia apetala* and *Excoecaria agallocha* are less abundant (Balasubramanium and Azeez, 2012).

The diversity of fauna is equally striking. 24 species of dragonflies and damselflies, 23 spiders, 34 butterflies, 88 birds, 58 fishes and 7 reptiles have been recorded. Oriental darter, a near-threatened bird species, is known to breed here. Indian rock python and smooth-coated otter, two globally threatened species, have also been found. Colonies of the *Villorita sp.,* a brackishwater clam, are found in adjoining waters.

Pathiramanal Island

[13] Listed as a threatened species in the Red Data Book of Indian Plants published by the Botanical Survey of India.

Faunal Diversity

Recorded faunal diversity in Vembanad-Kol complex includes 24 zooplankton, 8 macro-benthos, 20 crab, 158 fish, 2 freshwater turtles and 225 bird species (Kurup et al., 1993; ICMAM, 2002; CMFRI, 2005; Krishnakumar et al., 2007; Narayanan et. al., 2011; Ranjan et al., 2011). Instances of sighting of spinner dolphins (*Stenella longirostris*) have also been reported from Cochin mouth. *Crocodilus porosus* which were once present in the estuary are no longer sighted (Kokkal et al., 2007). Studies are mostly concentrated on specific groups and seasonal patterns. Information on impact of altered hydrological regime on habitat quality and faunal diversity is limited, except reference to changes in migration pattern of giant freshwater prawn (*Macrobrachium rosenbergii).*

Recent assessments conducted by CMFRI indicate presence of 17 groups of zooplankton in the estuary. The density ranged between 29,195 no/l to 18,87,866 no/l. Puthuvypu, near bar mouth above Vypeen which is also a nursery area for finfish and shell fish, was observed to have maximum abundance. Rotifers dominate during pre-monsoon which is correlated with high nutrient load in estuarine waters (Vargese and Krishnan, 2009).

Comprehensive studies conducted by individual groups are more focussed on fish and water birds, which are discussed in the following sections.

Fish and Fisheries

Connectivity with riverine and marine environments underpins presence of high number of fish species in Vembanad-Kol. Recorded fish diversity within wetland complex includes 149 species of 100 genera and 56 families (Kurup and Samuel, 1987). Among these 23 species are oligohaline, 79 euryhaline and 48 stenohalaine. Nine species of prawns, 3 species of crabs and 8 species of clams are commercial important (Kurup et al., 1990; Kurup et al., 1993). 7 species of fish endemic to the rivers of Western Ghats are also found in the estuary (*Dayella malabarica, Horabagrus brachysoma, Mastacembelus guentheri, Mystus malabaricus, Mystus oculatus, Puntius filamentosus, Labeo dussumieri*).

Fisheries production from Vembanad-Kol is unorganized and data on fishery resources is very scanty. Fish yield from Vembanad area was estimated by Kerala University during Indo-Dutch mission in 1988-1989 and ten fishing zones were identified. A total of 7200 MT of fish yield was reported during the period, of which 93% was from north of Thaneermukom Barrage. In 2000 – 01 the catch was reported to be only 687 MT (Padmakumar et al., 2002). Brackish water species are commercially most important. Mullets (*Mugil sp.),* Perches *(Lates calcarifer),* Milkfish (*Chanos chanos),* Catfishes *(Tachysurus maculatus),* Halfbeak *(Hyporhamphus sp.),* Elopiformes *(Megalops sp.)* and pearlspot *(Etroplus suratensis)* are commercially important estuarine finfish species. In earlier periods, the bulk of catch was constituted by Hilsa, oil sardines, mackerel, herrings, croakers, flatfishes and marine catfishes. Catch of freshwater fish like *Horobagrus brachysoma, Clarius batrachus* and *Ompak bimaculatus* are also reported to have dwindled (Kurup et al., 2003).

High preference for pearlspot, particularly by tourism industry has gradually led to target fishing. In 2000 – 2001, pearlspot comprised 29% of catch (Padmakumar et al., 2002). The breeding habitat of this species is unique, it utilizes submerged substratum for egg attachment. A fish sanctuary for pearlspot has been established at Kumarakom, which is the first of its kind in the country. An area of 10 ha within the open water of Vembanad has been encircled by planting coconut and bamboo piles. Artificial nest and reef substrates have been placed on the sanctuary bed to facilitate natural breeding and egg attachment (Padmakumar, 2003).

Vembanad estuary also serves as nursery ground for penaeid prawns *(Penaeus monodon, P. dobsoni* and *P. monoceros)*. A total of 3500 MT penaeid and 117.69 MT of palaeomonid prawns were recorded from landing centers during 1988-89. Fresh water

prawn *Macrobrachium idella* also contributed 6% of the total production followed by *M. rosenbergii* (0.32%). With the commissioning of Thaneermukom Barrage, the upstream and downstream migration of the giant prawns, *M. rosenbergii*, was disrupted leading to near decimation of its fishery in the estuary (Balamurugan et al., 2004). The annual catch of this species during the pre barrage period was 429 tons (Raman, 1967), which was now declined to the less than 27 tons per annum on the southern part of the barrage (Padmakumar et al 2002). This decline is mainly attributed to the physical obstruction inflicted by the barrage on the breeding migration of the spawners downstream and the reverse migration of post larvae to their home grounds in Kuttanad (Fig. 2.6).

Vembanad estuary is also a rich source of live as well as sub fossil deposit of clam. Six species of clam have been recorded here. A zonation in availability is indicated, which is correlated with salinity regimes. *Sunetta scripta* is found near the bar mouth, *Meretrix casta* and *Paphia malabarica* dominate 2-3 km away from the bar mouth (salinity 15 ppt), whereas *Villorita cyprinoides* are reported from freshwater regions (KFRI, 2005). Main clam fishing methods employed are hand picking and storing in a basket, combing and heaping in low tides with toothed-iron rakes and rakes fitted with bag nets.

The total area of live clam production in Vembanad estuary is about 1565 ha with an annual production of 50,275 tons (Suja and Mohamed, 2010). Sub-fossil deposits were estimated to be 4.5 million tons and rate of mining is 41,000- 69,000 tons /annum (Laxmilatha and Appukuttan, 2002). Travancore Cements Limited (TCL), Travancore Electrochemicals, Chingavanam and Kerala Construction Components Limited are the major industries dependent on sub-fossil deposits with an annual demand of 1, 31,000tons. Travancore Cements Limited, one of the largest consumers of white shells, uses dredgers for collection of sub-fossil deposits. Operation of dredger removes all the benthic organisms from the excavated site (Ravindran et al., 2006). Trends indicate declining availability of white clams which comprise over 80% of total harvest (Fig 2.7)

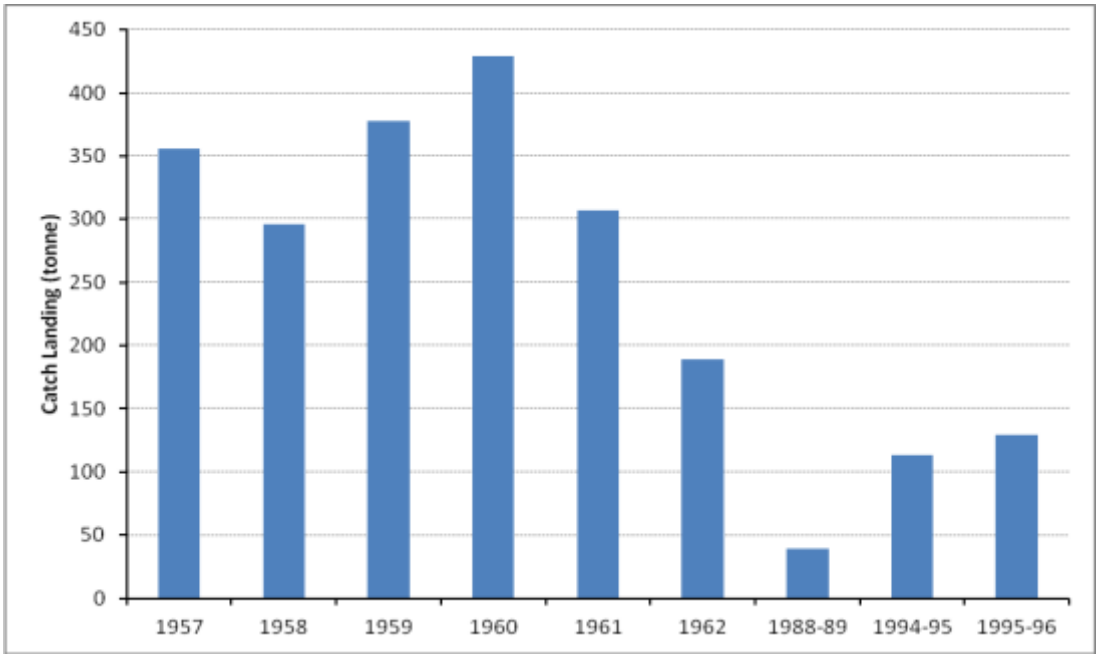


Fig 2.6 | Landing (t) of M. rosenbergii in Vembanad Lake (Source: Kurup and Harikrishnan, 2000

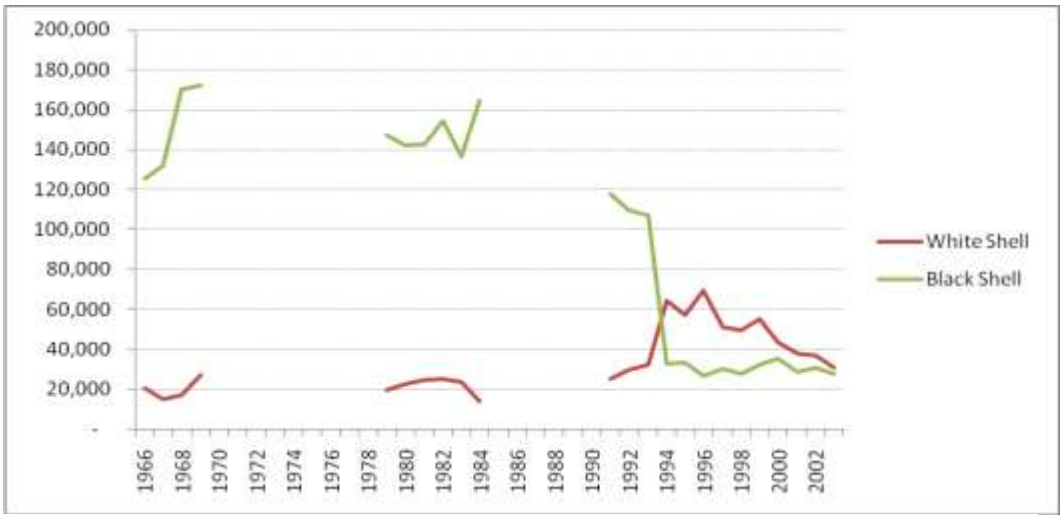


Fig 2.7 | White and black clam harvest in tons (Source: Maya, et al., 2009)

Declining fish catch has led to increasing pressure on harvest of clams as a livelihood resource. Scouring by trawlers also limits opportunities for regeneration of clam juveniles. Though the government has limited operation of TCL dredger to 50 acres of per year, the implications for lake water quality and benthic biodiversity has not been adequately investigated.

The polders of Kuttanad are also used for farming of freshwater prawns. Presently, around 5000 ha area in this region is used for this purpose. In 2002, it was reported that 248 ha of fallow polders were under mono-culture of scampi during January to August, while 4,750 ha was used for polyculture along with major carps during November to July (Kurup and Ranjeet, 2002). *Pokkali*, a traditional system of integrated rich-shrimp cultivation is also an important source of prawn production (Box 5: *Pokkali* farming system). Some of the polders are reportedly used for trapping fishes and prawns during monsoon. The catches from the polders comprise freshwater fishes (93.5%) and palaeomonid prawns (6.5%) (ibid).

A range of fishing gears is used in the wetland complex. Usually stake nets and Chinese dip nets are used. Marine prawns are captured during night and fishes, mainly mullets, during day. Baited long lines are used to capture fresh water prawns and crabs. The Chinese dip net (*Cheena vala* or *Kamba vala*) is used in the lower stretch of the estuary, particularly in the bar mouth region between of Cochin and Azhikode. A total of 1,428 dip nets are reported operating in the estuary, mostly to the north of Thaneermukom (Florence, 2012). Gill nets used are of two types i.e. set gill nets and drifting gill nets.

Conical shaped stake net or *Kutti vala* or *Valu vala* is used to catch prawns during ebb tides. Presently, 3862 stake nets are operated in Vembanad estuary of which nearly 30% have very fine mesh sizes (less than 8 mm) (Florence, 2012).

Seine nets of varying length, width and mesh size are used to catch of fish species. Eight types are commonly used i.e. *Valli valu, Pattu Kanni Vala, Paithu Vala, Neria Vala, Chemmeen Vala, Mandu Vala, Karimeen vala and Peru Val*a. More than 90% of pearlspot is caught using Karimeen vala south of the barrage. Fishers use cast nets or *Veechu vala* in the flat bottom and shallow areas. In northern sector cast nets are used to catch penaeid prawns whereas in southern part it is used for pearlspot.

Box 5: *Pokkali* Farming system

Rice fields converted to prawn fields. Gates at centre allow the post larvae and juveniles to enter the farm

Pokkali is an integrated rice and prawn farming system practiced around Vembanad estuary since over 3,000 years. The rice variety used in the farming system can withstand salinity upto 8 ppt and is known as *Pokkali* rice. In 2010, 6,274 ha area around the Vembanad estuary within the districts of Ernakulam, Alapuzza and Thrissur were under *Pokkali* farming.

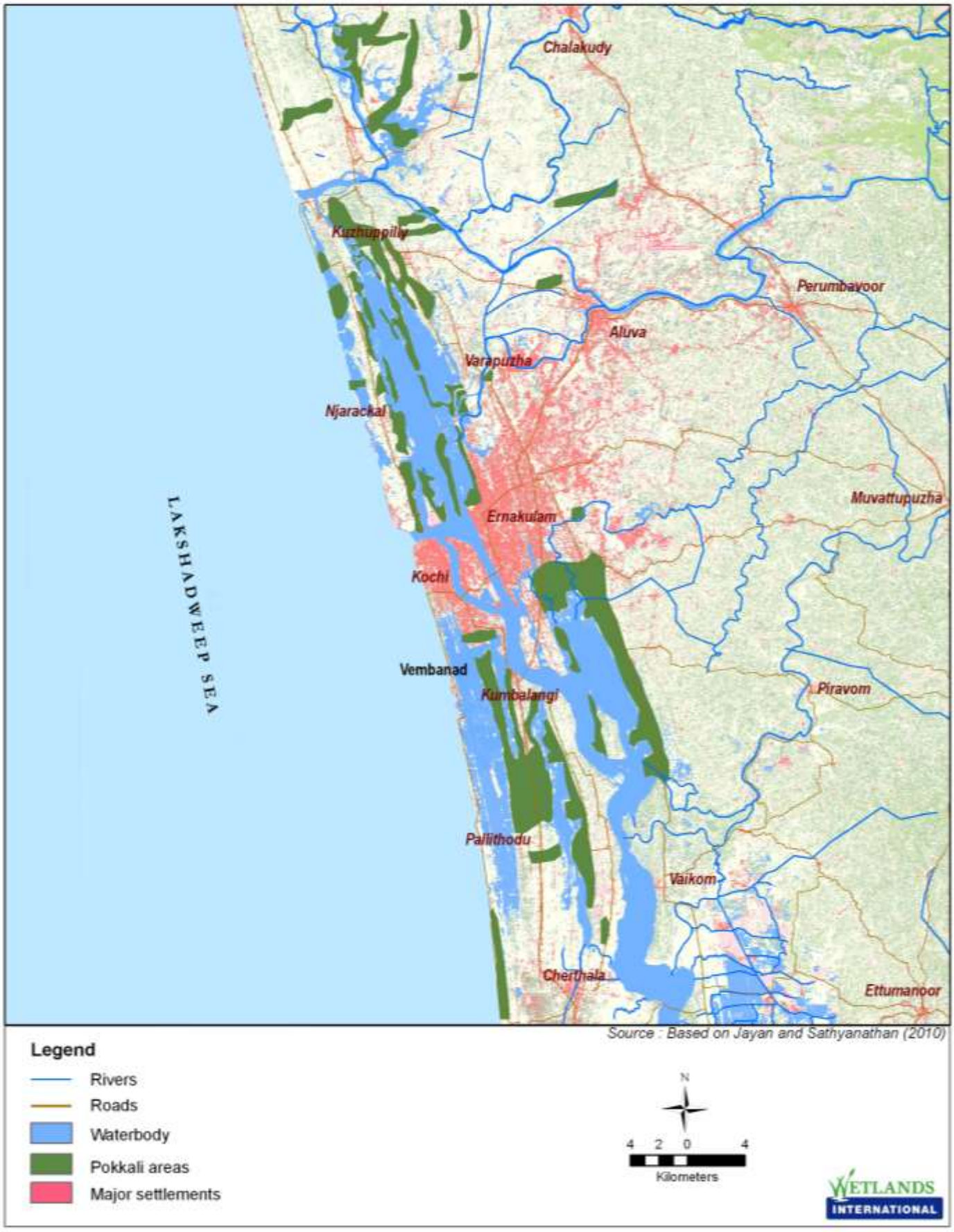
Pokkali rice is sown immediately after the onset of southwest monsoon in June. About 75 kg of seed is required for one ha of paddy field. The crop takes 90-100 days for maturing and is harvested by end of October or early November. The pinnacles of mature stalk are harvested and the rest is left to decay in the field. Mid-November onwards as salinity tends to increase, prawn / fish farming takes over. Relatively lower salinity in *Pokkali* fields in comparison to sea, trigger movement of prawn post larvae and fish juveniles to these areas. They are guided in the fields by sluice gates. The decaying stalks of *Pokkali* rice form the feed of prawn and fish juveniles. Harvesting of prawn starts from mid December and is done every 3-4 days before and after full moon and new moon. A conical net is fixed at the outer mouth of the sluice gate during low tide to trap the prawn and fish with outflow. A kerosene lamp is also hung at the sluice gate to attract the prawn juveniles from the field. Prawns form about 80% of the catch (*Peneaus monodon, P. indicus, Metapenaeus dobsoni, M. monoceros)* and the rest is contributed by fish (*Etroplus sp., Mugil sp. and Oreochromis mossambicus*).

Pokkali farming is completely organic. It continues to be profitable even after the increasing cost of inputs and labour. In a typical 1 acre of *Pokkali* rice farm, 1,300 kg of rice and 420-900 kg of prawns can be harvested. The net profit form *Pokkali* system is computed to be Rs 47,110 per cycle in comparison to Rs 10,100 from rice monoculture (Francis et al, 1999). In 2008, *Pokkali* rice was accorded Geographical Indication[14] status.

However, of late, the practice has been stressed due to various reasons. The land is increasingly being converted into prawn farms or for coconut cultivation. Reduced availability of labour is cited as one of the major reasons. Unscientific and ill planned constructions at the sea mouth and discharge of effluents from chemical factories have also impacted the arrival of prawn post larvae. However, with a gradual decline in natural recruitment, farmers have resorted to stocking the farms (0.15 – 0.2 million seeds per acre) resulting in a production of 2 – 3 MT per acre.

Efforts are underway to protect and promote this unique farming system of Kerala. The Kerala Agricultural University has developed five saline tolerant, high yielding varieties suited to Pokkali farming system of Kerala. The Kuttanad Package also includes investments aimed at promoting pokkali farming system.

[14] A geographical indication (GI) is a name or sign used on certain products which corresponds to a specific geographical location or origin (e.g. a town, region, or country). The use of a GI may act as a certification that the product possesses certain qualities, is made according to traditional methods, or enjoys a certain reputation, due to its geographical origin.



Map 2.10 : Pokkali areas around Vembanad-Kol

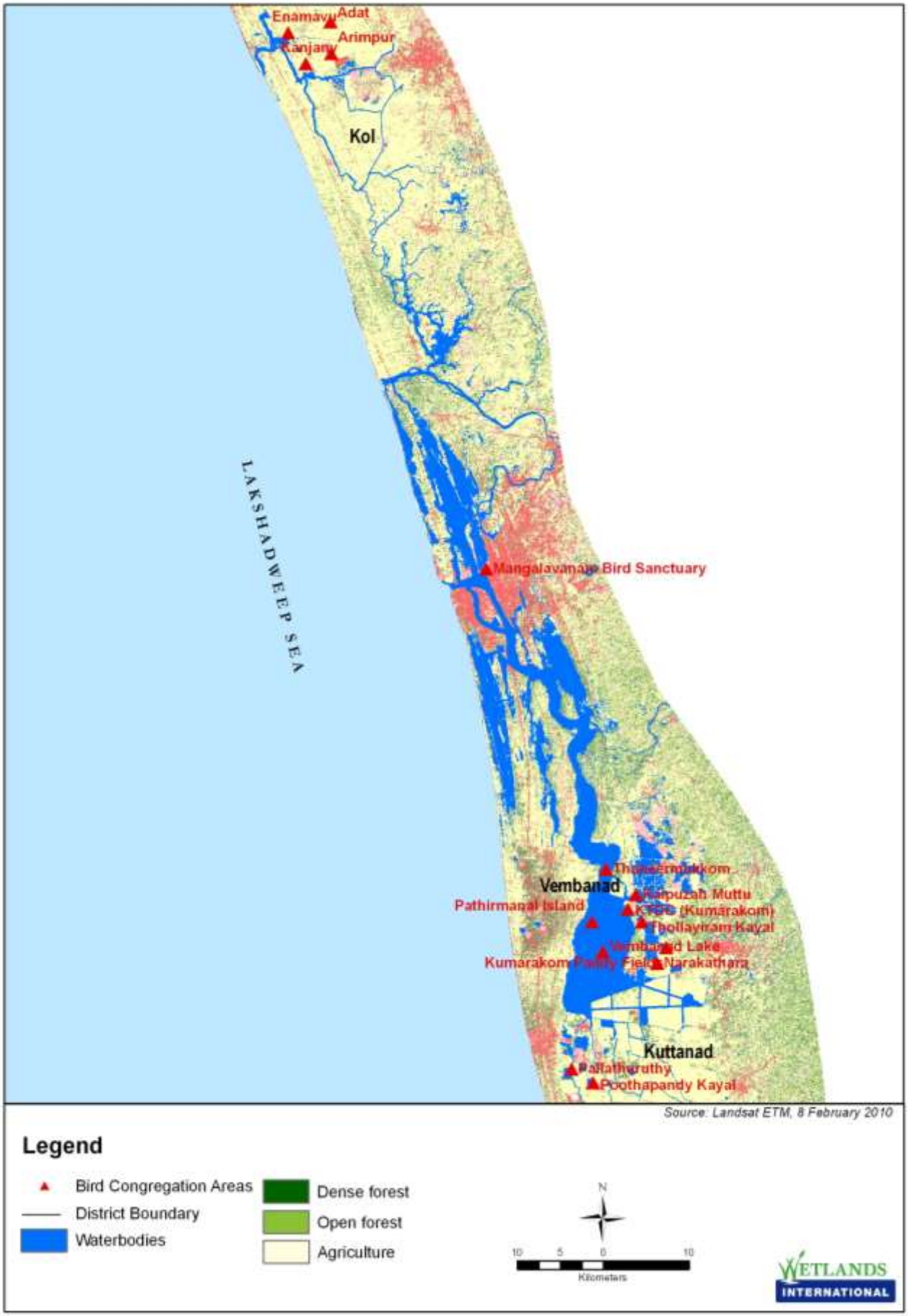
Usually small plank built canoes, 5.8 –9.0 m in length and 0.4-0.9 m in width are used for crab fisheries. *S. serrata* is fished by means of baited line with or without hooks, crab traps or hooked iron rods. Crab traps (*Njandu vala*) are mainly used during January to April. During new moon nights, crab fishing is done using powerful lights and scoop nets (locally called Ball fishing). Crabs are also caught in by-catch with other stationary nets along with other fishes (Kurup and Samuel, 1985).

Waterbirds

Birds are at the apex of the food chain within wetlands and good indicators of ecosystem health. Vembanad-Kol wetlands serve as habitats for a rich diversity of birds including number of migratory species. The wetland is an important stopover in the Central Asian Flyway and has been declared as an Important Bird Area. Annual census coordinated by Kottyam Nature Society under Asian Waterbird Census Programme provides important insights into the waterbird species and numbers in Vembanad-Kol. During 1995-2010, 225 bird species have been sighted of which over 50 are migratory (Kottayam Nature Society, 2011; Narayanan et al., 2011). One vulnerable (*Aquila clanga)* and 10 near threatened species (*Ichthyophaga ichthyaetus, Aythya nyroca, Anhinga melanogaster* , *Mycteria leucocephala, Coracias garrulous, Sterna aurantia, Pelecanus philippensis, Limosa limosa , Numenius arquata* and *Threskiornis melanocephalus*) have been reported from the Vembanad estuary (Narayanan et al., 2011). Overall, 15 congregation sites have been identified (Map 2.11). Species frequenting the sites mostly include Northern Pintail ducks, Lesser Whistling teals, Little Cormorants, Whiskered Terns, Pond Herons, Cattle Egrets, Common Teals, Medium Egrets and Purple Herons. Total population of bird during 2010 was 27,493 of which 75% were migrants (Kottayam Nature Society, 2011). Analysis of count data for 1993-2010 indicates high interannual fluctuation (Fig. 2.8).

In Kol, 167 species of birds, belonging to 16 orders and 39 families among which 81 species are wetland dependent birds have been recorded (Sivaperuman and Jayson, 2000). 53 species are winter visitors and include 9 ducks, 31 waders, 3 gulls and 2 terns. The major roosting sites in the region are Enamavu, Kanjany, Arimpur, and Adat. Little egret, cattle egret, little cormorant, pond heron, medium Egret and whiskered Tern were the most abundant species found in the Kol wetland. Spot-billed Pelican (a near threatened species) and Rufous Babbler (an endemic species of western ghats) is also known to frequent the region (Jayson and Easa, 2000). Indiscriminate fishing along the

Waterbirds in paddy fields near RARS, Kumarakom



Map 2.11 | Major bird congregation sites in Vembanad-Kol

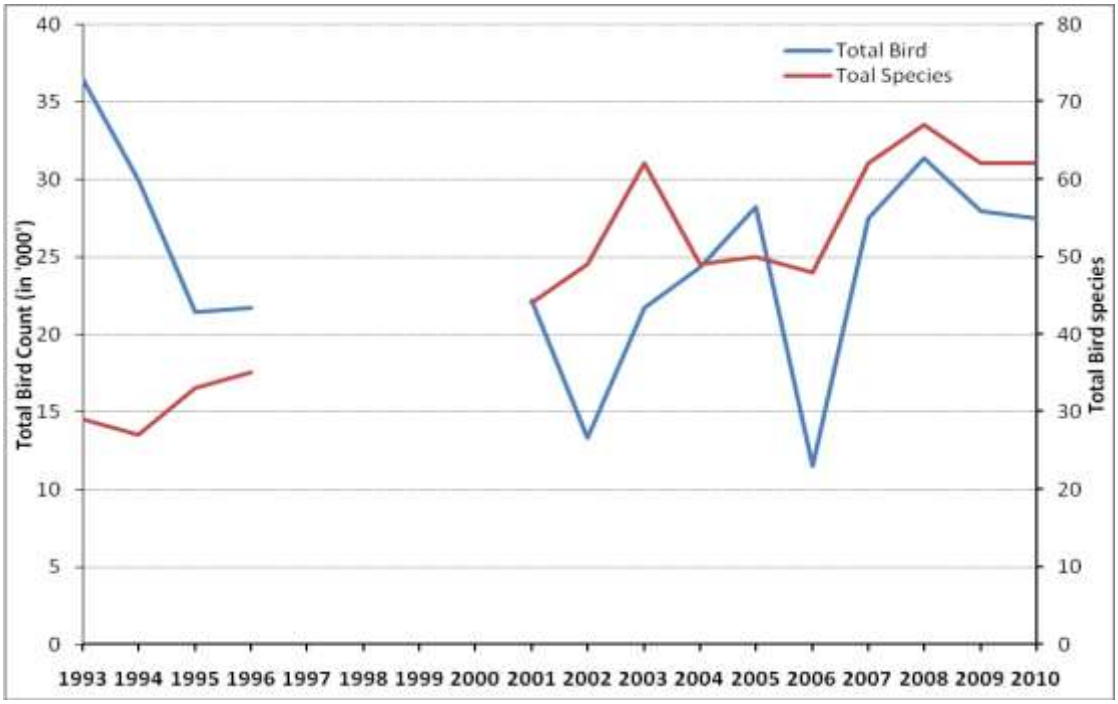


Fig 2.8 | Bird population in Vembanad Lake (1993 – 2010)

major breeding and roosting sites are affecting the food resource of the wetland dependent birds. Mortality of birds due to poaching as well as water high in concentration of pesticides and herbicides is also reported from these areas. Over the years, anthropogenic activities within Vembanad estuary have been on an increase creating stress for habitat.

The area of Kumarakom near Kerala Tourism Development Complex which once supported the largest heronry and served as an important breeding area for visiting waterbirds has suffered a sharp decline in numbers. Of the ten species found breeding here (Oriental darter, Little Cormorant, Indian Cormorant, Black-crowned night Heron, Little egret, Intermediate Egret, Great Egret, Purple Heron, Indian Pond heron and Black-headed Ibis), the breeding population of Black- crowned Night heron (*Nycticorax nycticorax*) has reduced by over 96% (Nayayanan and Vijayan, 2007). Reduction in extent of reed beds and mangroves for promoting tourism, discharge of sewage effluents and changes in food availability are presumably the major reasons. The increase in population of Oriental Darter (*Anhinga melanogaster)* may be attributed to altered salinity levels which has favoured freshwater fish population (ibid). In recent years Pathiramanal Island and Kaippuzha Muttu have emerged as important roosting sites for waterbirds due to availability of food and negligible human habitation in surrounding areas.

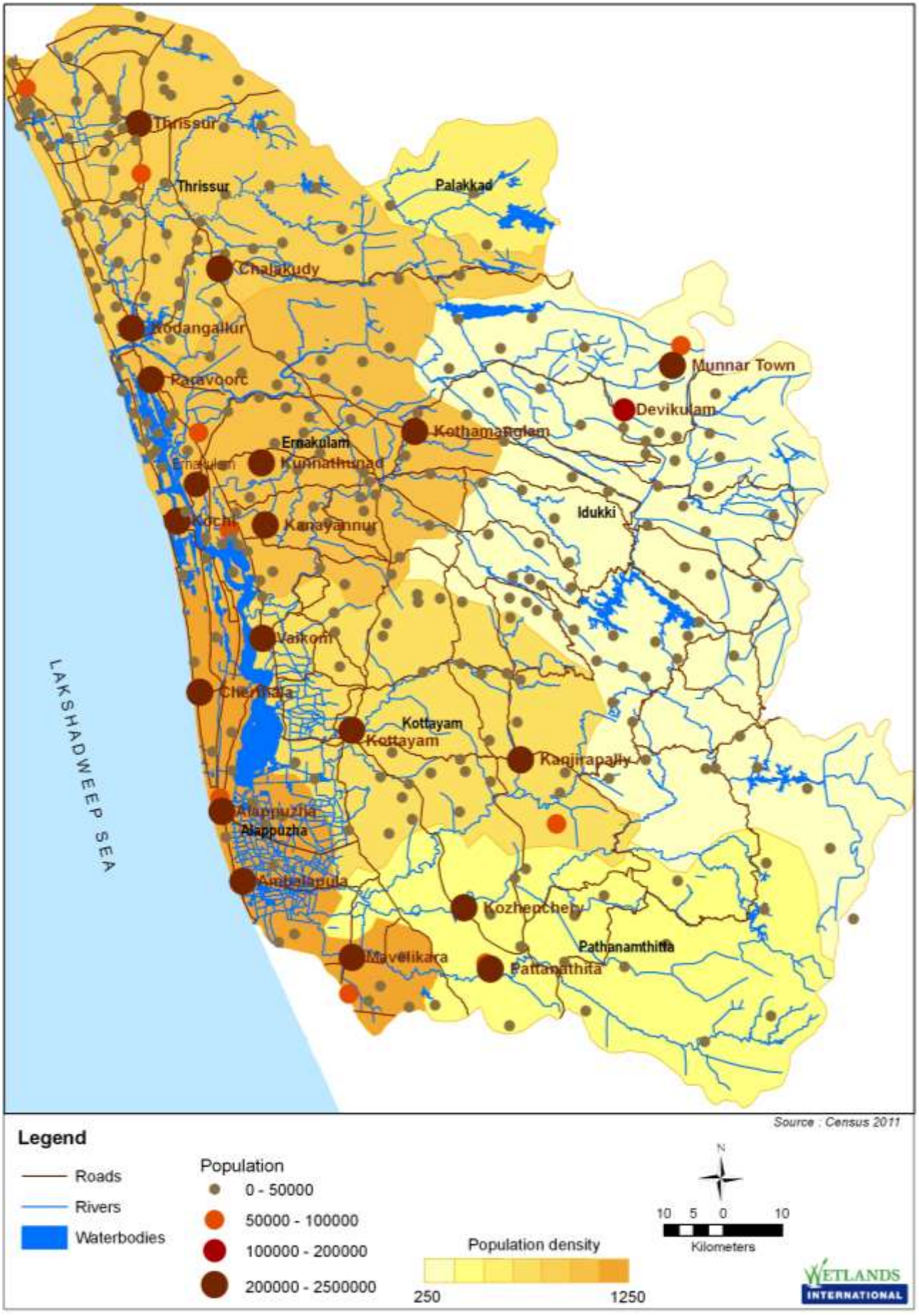
2.7. LIVELIHOODS

Socio-economic profile of wetland catchments

As per 2011 census, the catchments of Vembanad-Kol wetlands are inhabited by 8.98 million people, forming 27% of population of the entire state. Two-thirds of the population is concentrated in the 84 urban centres within the lowlands. Population density increases significantly from 500 persons / km^2 in the highlands to around 1100 persons / km^2 in the midlands and 1250 persons / km^2 in the lowlands (Map 2.12).

Of the total catchment population, 38% form the workforce[15]. Of this, one fourth is dependent on agriculture, with a high proportion (70%) being agricultural labour.

[15] Proportion of population which forms a part of the primary, secondary and tertiary sector workforce.



Map 2.12 | Population density in Vembanad-Kol catchment

Fisheries and household industries account for 9% and 3% of the workforce respectively. Within fishers, 60% is employed in marine fisheries sector. Rest are employed in secondary and service sector industries.

Access to social amenities has been higher in Kerala as compared to other parts of the country due to the sizeable investments into the sector under the various plans. Safe drinking water and sanitation facilities are available to 65% and 86% of the population respectively. Electrification has also been carried out for 71% of the population living within the region. However, slight variations in access were observed within the highlands and the rest of the region. Access to safe drinking water and electricity is lower in the highlands as compared to midlands and lowlands. Despite high access to sanitation facilities, deteriorating water quality of the Vembanad is a severe health hazard for the communities living in and around. High incidence of water borne diseases such as Weil's disease, diarrhoea, typhoid, cholera etc. has been reported from the Kuttanad region. While the state outperforms the entire country in terms of infrastructure indices (for example, the road density of the state is 374.9 km /100 km^2 as compared to national average of 74.9 km/100 km^2), the concentration of roads in floodplains of Kuttanad is way beyond the carrying capacity of the ecologically fragile region.

Economic prosperity of the communities living in the wetland catchments is indicated by high per capita income which has increased over a period of time. Between 1990–91 and 2010–11 the per capita income (GSDP based, at 2004–05 prices) in Kerala has increased from Rs 19,502 to Rs 56,107, an increment of 187 per cent (the national level increase for the period being from Rs 15,865 to Rs 40,752)[16]. The per capita income within the various catchment districts ranged from Rs. 23,014 to Rs. 34,079 (for 2004- 05 at prevailing prices). Districts having larger areas under plantations as well as industries have higher per capita incomes. The lowland districts, Alappuzha and Thrissur have comparatively lower per capita incomes. However, in terms of growth rates, the highland districts have recorded almost no increase. The lowland districts have recorded the fastest growth rates, driven mainly by nature based tourism.

Agriculture farmers in Kol

[16] Based on data from http://mospi.nic.in

The contribution of agriculture and allied services to the overall GSDP has fallen from about 30 per cent in 1990–91 to 10.6 per cent in 2010–11. During the same period, the tertiary sector contribution has increased from 29% to 60%. The per capita agricultural income in Kerala increased only marginally from Rs 4,187 to Rs 4,674, i.e an increase of only 11.6 per cent between 1990 and 2010. The number of cultivators as a proportion of workforce has reduced from 13.07% in 1981 to 7.20 % in 2011. Similar is the trend for agricultural labourers which decreased from 28.23 % to 16.1 % between 1990 -2010 (Devi, 2012). The economy is highly dependent on remittances of immigrants, which amounts to more than Rs. 15,000 crores per annum.

Community institutions play an important role in governing resource use patterns within the catchment. Village panchayats are the primary units of governance in the region as per the provisions laid under the Kerala Panchayat Raj Act, 1994 and Kerala Municipality Act, 1994. Besides, planning for village development, Panchayati Raj Institutions are also recognized as agencies for regulating tourism under the Kerala Tourism (Conservation and Preservation of Areas) Act, 2005. There are several user groups which function as collectivized production and processing guilds in the region. The region in and around Vembanad Lake has several coir retting societies, fisheries societies, agriculture farmers societies and boat owners' societies. These societies provide benefits to their members including subsidies in occupation input, protected prices and compensatory allowances for non-employment periods. They also serve as channels of the government for reaching aids / grants under various development schemes.

Wetland ecosystem services – livelihoods interlinkages

The rich biological diversity and associated ecological processes support a range of ecosystem services which form the base of livelihoods of wetland dependant communities. In several circumstances, these services have emerged as a consequence of wetland modification and conversion of habitats. The associated rights and power structures have consequences for wise use of wetland resources. Map 2.13 provides a generic distribution of stakeholder groups around Vembanad – Kol.

Agriculture Farmers | Wetland agriculture is the predominant resource use around Vembanad-Kol, particularly within the Kuttanad and Kol regions. Agriculture in Kuttanad alone provides sustenance to 90,000 farmers.

Farming in the reclaimed backwaters and marshes is highly organized and energy intensive activity. Each cluster of farms, known as *padashekharam*, has a committee to manage collective dewatering of the fields after monsoon. The committee owns a pump, operation and maintenance of which is financed by the members, and through subsidized electricity from the state government. Rice is the main crop grown in the region. Three cycles of cultivation currently exist, namely Punja (sown during northeast monsoon during October to December and which after construction of Thaneermukom Barrage has been extended to March), Virruppu (sown in mid-May and harvested in September). Since this crop has to bear the impact of southwest monsoon, the area planted is restricted to places less vulnerable to flood damage. A third crop Mundakan is a short duration crop cultivated during September to December. However, the practice has gradually declined to a large extent as the productivity is affected by monsoon. In areas downstream Kochi till Thaneermukom, an integrated system of rice paddy and prawn farming is practiced locally called Pokkali (Refer Box 5 : *Pokkali* farming system).

Of late, the intensity of rice cultivation in Kuttanad has been declining. Rising wage rates has been a key factor affecting profitability of agriculture. There is an acute shortage of agricultural labour leading to high wage rates (Rs. 400 – 900 per day as compared to Rs. 100 – 150 in the neighboring states). This has promoted some of the farmers, especially in the regions around Alappuzha to switch to less labour intensive coconut farming.

Map 2.13 | Major stakeholder groups within Vembanad-Kol

Clam Collector | Vembanad backwaters are a rich source of clam, which forms the basis of livelihoods for around 12,000 households. Black and white clam are used in the cement and calcium carbide industries. The meat of clams is a rich source of protein and also used as feed for poultry and fishes.

The clam collectors are organized in societies, which have been in existence since 40s. Presently, there are 13 clam collector's societies in Alappuzha and Kottayam districts, of which 8 are specific to black clams. Clams are collected from the lake bed using toothed iron rakes by individuals and mechanically using dredgers by Travancore Cements Limited. Clam collectors boil the black clams and remove flesh before selling it to societies while white clam is sold directly to societies after cleaning. The processing of clam is a family endeavor as this needs various stages of processing. While the male members are involved in clam collection, there is large input by the female members into processing.

Trading is done for a set of 20 tins (of 5 kg each) purchased from individual collectors at an average rate of Rs 222 and subsequently sold for Rs.286. The balance is used by the society to pay of tax and royalties, provident fund contributions, and for holiday wages during the period May-August. Nominal loans are also provided to the members @ 12% interest per annum. Average household income from clam collection ranges between Rs. 5,000 – 6,000 per month. Meat from clams is sold @ Rs. 35/ kg in the local markets. Declining availability of clams within the lake has created immense hardships for the clam collectors.

Fishers | Fisheries from Vembanad-Kol wetlands provided livelihood support to fishers living in 64 villages. Owing to significant changes in fisheries after construction of Thaneermukom Barrage, the overall importance of this livelihood system has declined, with a sizeable proportion moving out to alternate sources of employment, for example, clam collection. While the total number of fisher households in and around Vembanad was estimated to be 17,369 in 1992, this reduced to less than 5,000 in 2012. Fishing is done all the year round, barring June and July which are monsoon months. A group of six fishers return with a catch of 7 - 8 kg. Karimeen (*Etroplus suratensis*) is the most favoured and prized species for harvest. The high demand of the species by tourism industry has led to culture of Etroplus in water bodies adjacent to the wetland area particularly in Kuttanad region.

Head load of clams collected from Vembanad

Fisher selling Pearlspot near KTDC, Kumarakom

Most of the fishers belong to Dheevara and Ezhava communities which are, relative to others, less endowed socially and economically. Traditionally only Dheevara community was engaged in fishing. Ezhava community entered into fishing on the prospects of clam shell collection and processing. Along with the Fisheries Department, agencies like the Kerala Fishermen's Welfare Corporation, Kerala State Co-operative Federation for Fisheries Development commonly known as Matsyafed and the Kerala fishermen's Welfare Fund Board known as Matsya board and the Kerala Fishermen's Welfare Fund provide a range of social security benefits to members. The members of Dheevara community have strong affiliation towards Akhila Kerala Dheevara Sabha which has local units that actively takes up issues that affect their livelihoods and resource use.

Houseboat and Tour Operators | Backwaters are the main focus of tourism in Kerala. As per a survey carried by the Kerala Tourism Development Corporation, the wetland accounted for 55% of the total foreigners visiting the state. Based on the assessments under the Master Plan for Tourism Development, Vembanad accounts for 1.1 million tourists arrival annually, of which 95% are domestic tourists. This forms an economic base for nearly 85,000 households and an overall contribution of Rs. 469 crores to the local economy through direct and indirect linkages.

Houseboats are the key features of backwater tourism. Alappuzha and Kumarakom are the two major entry points of the lake, and have 750 and 120 houseboats registered with All Kerala Houseboat Owner's Association. Around 10 boats are known to operate individually. Each boat employs usually 3 – 5 persons. Number of houseboat has increased from less than 100 in 2002 to over 750 in 2012 in Alappuzha area. In Kumarakom, the increase has been from 50 to 120 house boats during the same period.

Coir Retters | Coconut husk retting is an important income generating activity carried out in the Vembanad region, particularly in Alappuzha district. Mainly carried by womenfolk, this activity provides income to 18,000 households living around Vembanad. As per 2012 estimates of Directorate of Coir Development, 3.58 tonnes of coconut fibre are annually retted in the region. There are presently 104 societies engaged in this operation around the wetland, generating around 4,00,000 days of employment to the local communities.

Till late 80s, Vemaband was a site of active retting. Coir retting involves defabrication of coconut husk by dipping in lake water for six months. The dried fiber is then spun into yarn using threading machines. The society provides a fixed quantity of yarn to its members, usually 3 bundles of 35 kg each, which in a week's time is converted into 100 yarns of 4 threads, each yarn being 7m long. The society members are paid Rs. 160 for each consignment of 100 yarns, with the overall quantity being marketed @ Rs. 3,750 / quintal. The process is labor intensive with significant health hazards. Incidence of skin diseases and asthama has been reported to be higher in the coir retters.

Coir retting in the Vembanad backwaters has been on decline since the construction of Thaneermukom Barrage which led to reduced saline water conditions in southern parts of the wetland. Moreover, with declining productivity of coconuts in Kerala, much of the coir presently used in the industry is imported from Sri Lanka or from the neighboring state of Tamil Nadu. The wages of coir retters are low compared to the hard work involved. The living conditions are also comparatively poorer.

Navigation Boat Owners | Vembanad backwaters form a part of the West Coast Canal System extending to an overall length of 546 km, 209 km of which has been declared as a National Waterway 3 by the Government of Kerala. The waterways formed by backwaters, estuaries, lagoons and canals, spreading over 196 km in north south and 29 km in east west directions are an important mode of transport for the communities living in and around the wetland. The Kottapuram – Chettuva waterway supports the inland navigation through the heart of Kol lands. Inland navigation through Vembanad presently supports livelihoods of more than 50 boat and 200 houseboat owners.

Vulnerability Contexts

Declining availability of resources | Growth in Kerala's economy has been fuelled by secondary and tertiary sectors. The overall contribution of the primary sector in the state GSDP has reduced considerably. The primary sector, which employees 37% of the workforce and includes mostly wetland dependent livelihoods has received lesser attention in developmental planning.

Despite a near continuous policy thrust in last five decades for ensuring self-sufficiency in rice production, area and production has been on a decline since late seventies. In the

Women weaving coir in a unit in Kokadmangalam village, Alappuzha

lowlands, diminishing returns and shortage of labour has made paddy cultivation increasingly unviable. Increased cost of inputs, small and uneconomic size of land holdings and excessive fragmentation, high incidence of crop failures, lack of availability of agricultural seeds, lack of proper marketing system, insufficient research and extension services and the trade union activism have also impacted profitability. The labour rates are high because of easy work opportunities in mining and construction sectors. There is high dependence on HYVs, use of pesticides and intensive cropping practices which further increase the cost of production, while at the same time adversely impacting ecological character of the wetlands.

The paddy cultivators are relinquishing rice cultivation in favour of less labour intensive as coconut farming and aquaculture. A sizeable area of the paddy fields is also left fallow during most part of the year. An assessment of 2001 indicated that 4000 ha of paddy fields were utilized for prawn/fish culture with or without integration of rice (Ranjeet and Kurup 2001). There were 122 aquaculture ponds farming freshwater prawn of which 67 were within polders.

Coconut invariably is an important crop contributing to the household incomes of small and marginal farmers. However its productivity has been declining for various reasons including widespread damage from root-wilt disease, coconut mite, red-palm and rhinoceros weevils. The declining price of coconut together with fall in productivity is severely hurting the income of all households.

Fishers are also facing decline in fish and clam catches. The average fish catch per fisher group (of 6 fishers) has also reduced to 7 – 8 kgs per day (for 200 days per annum) as against 20 kg reported in 2000. The number of fishers has been on a decline (in Plas Block, for example, the number of fishers has declined from 500 to 250 during the last decade, the rest having shifted to agriculture/construction labour or clam collection).

Industrial dredging has severely impacted community collection of clams. The number of black clam shell collectors has increased due to in-migration from fisheries. Engagement in fishing as well as clam collection provides means for stabilizing household incomes as

Industries adjoining Periyar River

well as provides opportunities for benefitting from organized marketing structure as is prevalent for clams. Fishers were also observed to diversify into non-fishing options as coir related occupations. Coconut husk retting operations eliminate prawn and marine fish nurseries. The traditional rice – prawn cultivation system (Pokkali) has also witnessed gradual decline. Incidence of white spot disease has impacted shrimp production since 2009.

Health hazards | Increasing pollution of wetland environment has created several hazards for communities living in and around wetlands. Major towns surrounding Vembanad-Kol do not have a systematic and planned drainage, as a result of which untreated sewage and sewerage is finally discharged into the wetland. The closure of Thaneermukom Barrage turns Kuttanad into a waste bowl. The sewage treatment plant at Kumarakom has insufficient capacity to treat the entire waste generated by the houseboats.

Pollution due to coir retting industries has led to significant local resistance due to impact on surface and ground water quality. Retting is still continued in isolated pockets around Vaikom, the effluents of which are a threat to water quality of Vembanad. Workers in coir retting industry have high incidence of respiratory diseases and skin disorders due to high concentration of lignin, tannin and polyphenols released in the retting process. Filariasis, eye diseases, skin diseases, and oedema of lungs are also common. Shell collectors work upto eight hours underwater and frequently report disruption of ear drums.

Conflicts and marginalisation of stakeholders | While there is a significant degree of collectivization of wetland resource uses, the power structures in favour agriculture farmers and tourist boat operators. Operation of Thaneermukom Barrage is a clear demonstration of how the needs of agriculture farmers have prevailed over those of fishers and clam collectors.

More recently, conversion of rice paddies to dryland farming within Kuttanad has drawn flak from labour unions. The unions vehemently argue that attrition of paddy lands will reduce their job opportunities. On the other hand, landowners are building pressure for amending provisions of The Kerala Conservation of Paddy Land and Wetland Act 2008,

Sewage treatment plant at Kumarakom

which prohibits any conversion of paddyland and wetland to alternate uses. The industries department of the state has already suggested amendments that precludes areas zoned for other purposes in the industrial zone and town planning schemes and notified industrial land including tourism, as service sector projects. The environmentalists, on the other hand, stress that conversion of wetland and paddy fields are detrimental to ecological balance of the region and should be arrested immediately.

The navigation of house boats through the active fishing zones results in the destruction of nets. Fishers claim that the turbines disturb the lake bed as well as the breeding ground of the fishes. Decline in fish diversity and catch is also attributed to destruction of mangroves. However, the overall development focus on tourism makes these groups hapless spectators. The tour operators claim that increasing pollution from Udyogmandal, Kuttanad and religious tourism in upstream reaches adversely affects the overall ecology of the backwaters and is a threat to the tourism prospects.

The clam society members mention apathy of the government towards clam resource base. Despite being a part of fisheries, it receives less attention as compared to the latter. The availability of clam shell has declined as a result of indiscriminate dredging by Travancore Cements Limited. Conflict between TCL industries and fisheries started in 1965 when the government of Kerala leased clam bed mining to minimize input costs. Post this, issues such as pit formation in lake bed as a result of indiscriminate mining and clay depositions in these pits that changed water current and affected overall productivity were raised by fishermen. In 2001, a move to grant mining permit to TCL in southern side of the barrage in Perumbalam region was vehemently opposed by traditional clam collectors. Nevertheless, permission was given and TCL presently dredges large quantity of clam both upstream and downstream of barrage. As an adaptive mechanism the clam collectors have resorted to culturing clam in their own waterlogged area, engage in marketing of clams through SHGs and fishing during lean season to meet livelihood needs.

Houseboats in Kumarakom

3 | Ecological character description

Vembanad-Kol wetland complex is a designated Wetland of International Importance under Ramsar Convention by Government of India since August 19, 2002[1]. This commits the Contracting Party of the Convention (Government of India) to ensure its wise use. Wise use of wetlands is described in Convention text as 'maintenance of ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development'. Ecological character is 'the combination of ecosystem components, processes and services that characterize the wetland at any given point in time.' Changes to ecological character of wetlands outside natural variation may signal that uses of the site are unsustainable, and may lead to the breakdown of its ecological, biological and hydrological functioning (Ramsar Convention 1996, Resolution VI.1). Assessing and responding to risks of human induced adverse change in ecological character is therefore fundamental to achieving wise use of wetland site.

An important purpose of management planning is to outline an approach for maintenance of ecological character, and in doing so, retain those essential ecological functions which underpin delivery of ecosystem services and maintenance of biodiversity. Implicit within this recommendation is the need to prioritize ecological character elements (ecosystem components[2], processes[3] and services[4]) so as to form the building blocks of management planning.

[1] Key qualifying site features included estuarine environment with large live clam and sub-fossil deposits (Criteria I – unique example of near-natural wetland type in a given biogeographic region) , habitat for spot-billed pelican (listed as vulnerable and therefore qualifying under Criteria 2 - supports vulnerable, endangered, or critically endangered species or threatened ecological communities), support to large population of waterbirds (Criteria 5 - regularly supports 20,000 or more waterbirds as per Asian Waterbird Census records) and habitat for a range of fish species (Criteria 8).

[2] The living (biotic) and non-living (abiotic) constituents of wetland ecosystem. These include: Geomorphic setting (landscape, catchment, river basin); Climate (precipitation , wind, temperature, evaporation, humidity); Physical setting (area, boundaries, topography, shape, bathymetry, habitat type and connectivity); Water regime (inflow, outflow, balance, surface – groundwater interactions, inundation regime, tidal regime, quality); Wetland Soil (texture, chemical and biological properties); and Biota (Plant and animal communities)

[3] Processes that occur between organisms and within and between populations and communities, including interactions with non-living environment, that result in existing ecosystem state and bring about changes in ecosystems over time. These include: Physical processes (water stratification, mixing, sedimentation, erosion); Energy – nutrient dynamics (primary production, nutrient cycling, carbon cycling, decomposition, oxidation – reduction); Processes that maintain animal and plant population (recruitment, migration); and Species interaction (Competition, predation, succession, herbivory)

[4] Benefits obtained by humans from ecosystems, categorized as: Provisioning (fisheries, use of aquatic vegetation for economic purpose, wetland agriculture, biochemical products); Regulating (maintenance

Clam from Vembanad being processed. Meat falls off after boiling and is sold separately

The Ramsar Convention's Guidelines for ecological character description are contained in Ramsar Resolution X.15. The national framework and guidance for ecological character description developed by Government of Australia is also a useful reference for this purpose (Department of Environment, Water, Heritage and the Arts, Government of Australia, 2008). However, both of these frameworks underemphasize social and livelihood interlinkages in wetlands. Vembanad-Kol can be best characterized as a nested socio-ecological system, wherein its ecological character stands influenced and modified by the way livelihood systems are linked to wetland resources, choices and trade-offs made by stakeholders and governance systems that influence their behaviour. The social construct of the ecological character provides insights into the ways ecological character connects with livelihood capitals, institutions and ultimately human wellbeing. Therefore, for the purpose of management planning of Vembanad-Kol, the ecological character description framework has been modified to include livelihood capitals of wetland dependent communities (Fig 3.1).

The current section of the management plan includes analysis of status and trends in ecological character, risks of human induced adverse changes and current knowledge gaps.

of hydrological regimes) and Cultural (recreation and tourism, spiritual, scientific and educational value). Supporting services have been included in definition of ecosystem processes.

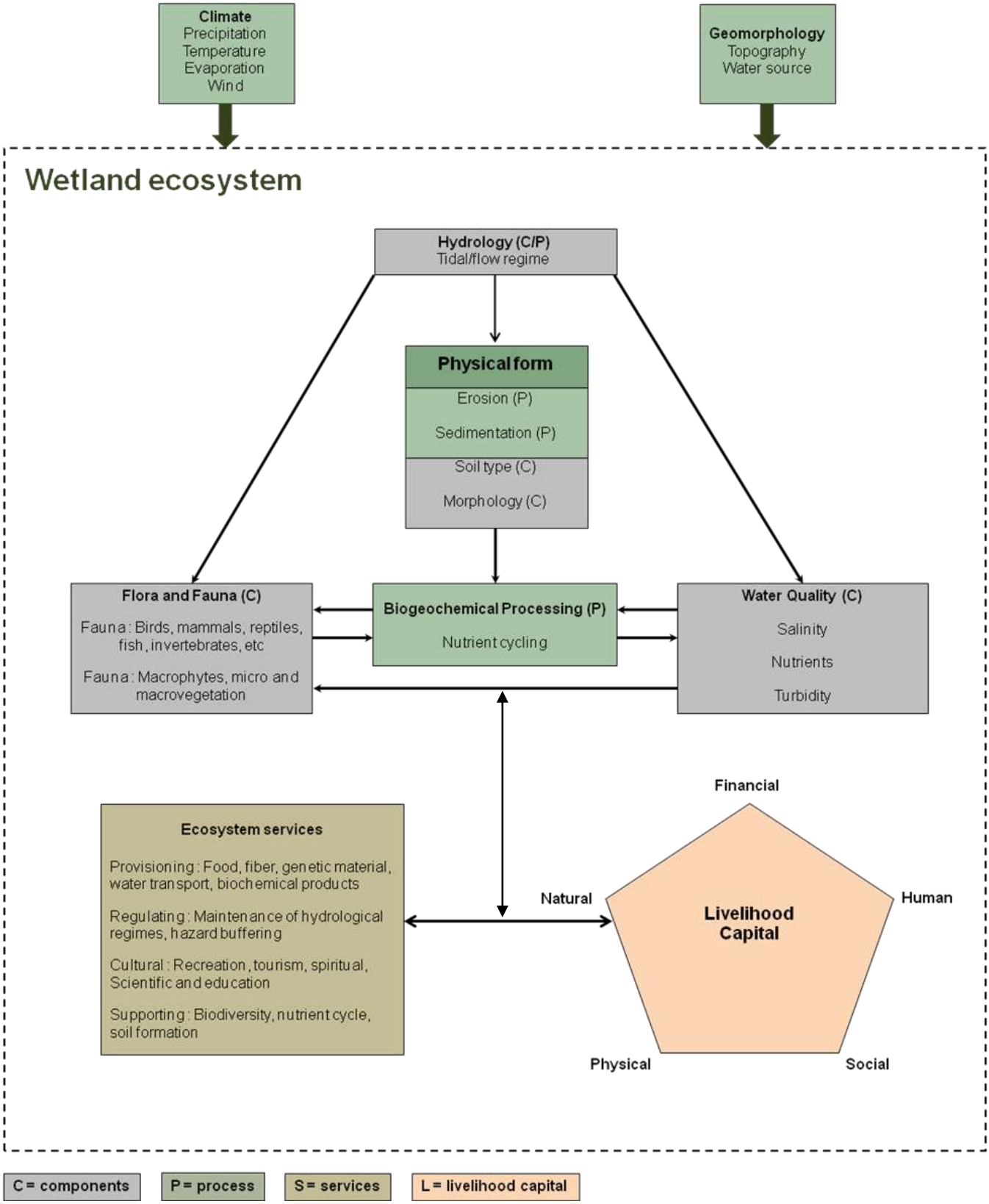


Fig. 3.1 | Framework for Ecological Character Description

3.1. STATUS AND TRENDS IN ECOLOGICAL CHARACTER

The wise use approach calls for 'maintenance of ecological character'. However, a review of features of Vembanad-Kol contained in Chapter 2 indicates that the wetland complex has been subject to continuous human modification, particularly since early 19th century. The genesis of wetland complex is attributed to geological and geo-morphological processes that led to formation of bar-built estuary flanked by river floodplains interconnected with a network of natural and manmade channels. In geological times, the entire region formed a part of an extensive Bay of Arabian Sea, which was gradually filled up with sediments brought in by the rivers giving rise to floodplain marshes of Kuttanad and Kol lands. Till early 18th century, the estuarine areas fringed with extensive mangrove swamps, supported diverse biodiversity habitats, highly productive fisheries and served as an important mode of inland navigation. Marshes were used for cultivation of rice paddies, productivity of which was constrained by inundation and salinity. Development of Cochin port in 1838 triggered rapid urbanization and industrial development around the wetland. Subsequent phases of development were focused on reclaiming marshes and the estuary for permanent agriculture. More recently, the emphasis has been on promoting backwater tourism and enhancing productivity of the reclaimed marshes through hydrological regulation. The current extent of Vembanad-Kol is only a fragment of an extensive wetland regime that once existed in the low lying coastal plains between Thrissur and Arattupuzha. Therefore the decision on ecological character elements that need to be maintained requires to be referenced to the changes in wetland regime, as well as related ecological, hydrological and social implications for wetland state.

Even in a highly modified regime, the Vembanad-Kol wetland complex has following prominent ecological character elements which underpin the need for scientific management:

1. **Ecosystem representativeness.** Vembanad-Kol is characteristic of estuarine – floodplain wetland complex characteristic of Malabar coastal plains.
2. **Rich source of live and sub fossil clam deposits.** Over 50,000 MT of clams are presently harvested from Vembanad estuary for industrial purposes providing base of livelihoods for 12,000 households.
3. **Wetland agriculture.** Production from 1,216 km^2 ha of rice paddies and plantations in Kuttanad and Kol lands is an important base for food security of the state.
4. **Important habitat for waterbirds in the Central Asian Flyway region**. Over 20,000 waterbirds of over 50 species visit the wetland complex every year.
5. **Biological diversity habitat.** Recorded diversity within the wetland complex includes 338 species of flora and 436 species of fauna. These include 2 vulnerable[5] and 13 near threatened species[6], as well as 16 true mangrove and 24 mangrove associate species.
6. **Site for traditional agricultural practices**. Integrated rice-shrimp farming system (pokkali) practices in brackish marshes around Vembanad estuary are unique examples of agricultural practices aligned with environmental conditions.
7. **Mode of inland navigation**. The Kollam-Kottapuram stretch of West Coast canal system which traverses through Vembanad-Kol wetlands has been declared as National Waterway presently used by over 50 passenger boats and 200 houseboats for navigation.
8. **Supports productive fisheries.** Diverse assemblage of fish and crustacean species support a productive fishery which is the base of livelihoods for nearly 5,000 fisher households.

[5] *Horabagrus brachysoma* amongst fish and *Aquila clanga* amongst birds

[6] 3 near threatened species in fish *(Ompak bimaculatus, Wallago attu, Mystus malabaricus)* and 10 near threatened species in birds *(Ichthyophaga ichthyaetus, Aythya nyroca, Anhinga melanogaster , Mycteria leucocephala, Coracias garrulous, Sterna aurantia, Pelecanus philippensis, Limosa limosa , Numenius arquata* and *Threskiornis melanocephalus*)

9. **Cultural and recreational values**. The backwaters of Vembanad and polders of Kuttanad form an important touristic feature of Kerala. Nearly 0.2 million tourists visit the backwaters annually, supporting livelihoods of owners and employees of 870 houseboats. Several spectacular boat races are held in the estuary each year which attract a large number of spectators.

Some of the underemphasised functions of Vembanad-Kol include its ability to regulate hydrological regimes, particularly providing flood protection, and as a freshwater source for agriculture.

The aforementioned elements provide a useful basis for prioritization of ecosystem components, processes and services. However, several of these have emerged as a result of shifting developmental planning priorities (key being wetland agriculture and tourism) and have induced adverse changes in ecosystem services and biodiversity (for example impact on hydrological regimes due to intensification of wetland agriculture, or increasing pollution due to wetland tourism). Hence, in addition to the above, three criterions, namely ecological significance, social significance and administrative and regulatory requirements have been used. Ecological significance of the elements has been evaluated in terms of criticality in supporting an important ecosystem component, process and service; ability to be an integrative indicator of ecosystem state; and species conservation status (for biotic components or keystone species). Social significance refers to importance for local livelihoods. Administration or regulatory requirements refer to the provisions under relevant international (Ramsar Convention), national (eg. Wetland (Conservation and Management) Rules, 2010, Wildlife Protection Act, 1972), and state level regulatory frameworks (eg. Kerala Conservation of Paddy Land and Wetland Act, 2008). Priority ranking of ecological character elements is presented in Table 3.1.

A key consideration while assessing status and trends in ecological character is that of a 'reference regime' against which 'adverse change in ecological character' can be defined. This is akin to conceptualizing the state of the wetland complex which management intends to achieve. There are two major considerations involved in defining a reference state. The first is availability of sufficient data and information to be able to describe and characterize the regime. The second is the need to consider the extent of change that can be reasonably managed to achieve wise use. Conversion of marshes for agriculture in Kuttanad is one such example, wherein a near permanent change has been induced, and rehabilitating to a previous state is not feasible considering biophysical and social implications. In absence of a well-defined monitoring system for Vembanad-Kol, data on various wetland features is patchy. However, there is reasonably sufficient data to characterize the wetland complex during the period of 60s, wherein much of the wetland reclamation had already taken place, but the hydrological connectivity between Vembanad-Kuttanad and Kol regions was relatively intact in absence of Thaneermukom Barrage. The status and trends in ecological character elements have thereby been interpreted in context of the wetland regime as it existed during the period and are summarized in Table 3.2. Complete analysis of status and trends in ecological character is contained in Table 3.4 at the end of this chapter.

An overview of Table 3.2 indicates that several of the ecological character elements bear an adverse trend. In particular, connectivity of surface waters, tidal and inundation regimes, and circulation and mixing patterns has been adversely affected by hydrological regime regulation and fragmentation. The physico-chemical characteristics of surface waters are indicative of degraded condition. Efforts made to intensity wetland agriculture and tourism has negatively impacted several of the ecological components and processes. Indicators of ecosystem service provision, namely production of fin and shell fish or wetland agriculture indicate a declining trend, coupled with stakeholder conflicts.

Table 3.1 | Prioritizing ecological character elements for Vembanad-Kol[7]

Ecological Character Descriptors	Order of Priority for managing Vembanad-Kol		
	High	Medium	Low
Ecosystem Components			
1.1 Geomorphic settings	Connectivity with surface waters	Water sources	Topography, Catchment soils
1.2 Climate		Precipitation	Air temperature, Evaporation, Wind Speed, Humidity
1.3 Physical settings	Area	Bathymetry	Shape
1.4 Water regime	Inflow, outflow and balance Nutrients, Salinity, Total and Faecal Coliform	Tidal regime Inundation regime Cations and Anions, Dissolved Oxygen, Biological and Chemical Oxygen Demand	Conductivity, Temperature, pH, Transparency
1.5 Wetland soils			Wetland soils
1.6 Wetland biota			
1.61. Plant communities	Mangroves	Planktons	Periphytons , Other aquatic plants
1.62. Animal communities	Fish, Clam, Waterbirds		Amphibians, Reptiles
Ecosystem processes			
2.1 Physical processes	Sedimentation, Mixing	Erosion	
2.2 Energy – nutrient dynamics		Primary Production, Nutrient Cycling	Carbon cycling, decomposition, oxidation – reduction
2.3 Processes that maintain animal and plant population	Recruitment, Migration		
2.4 Species interaction	Competition (Invasion)		Predation, Succession and Herbivory
Ecosystem services			
3.1 Provisioning services	Fisheries, Wetland agriculture	Inland navigation	
3.2 Regulating services		Regulation of hydrological regimes	
3.3 Cultural services	Tourism and Recreation		

[7] Ecological character elements have been prioritized on basis of relevance for wetland management and degree of influence on ecological character

Table 3.2 | Status and trends in ecological character

Ecological character descriptor	Significance	Status	Trends
Ecosystem Components			
1. Geomorphic settings			
1.1 Connectivity with surface waters	Connectivity with surface waters, especially between the sea, Vembanad estuary, Kuttanad and Kol regions maintains salinity regime and governs several critical components and processes for example macrophytic invasion, water quality and species migration	Operation of Thaneermukom Barrier impedes hydrological connectivity between Vembanad estuary and Kuttanad.	
2. Climate			
2.1 Precipitation	Precipitation influences inflows as all the inflowing rivers within the drainage basin are rain-fed	Average annual rainfall varies between 2,970 mm in Meenachil Basin to 4,360 mm in Manimala Basin.	While specific trends for Vembanad-Kol basin are not available, studies indicate increasing variability in rainfall, declining south-west rainfall and increase in post-monsoon rainfall. During the last 43 years, the mean maximum temperature for the state has increased by 0.8^{o}C.
3. Physical settings			
3.1 Area	Area needs to be maintained as per commitment under Ramsar Convention Maintenance of land use required under Wetland (Conservation and Management) Rules, 2010 and Kerala Conservation of Paddy Land and Wetland Act, 2008	The wetland extends to 1,780 km^2.	Analysis of remote sensing imageries for Kuttanad indicate that during 1963-2003, the area under paddy has declined, coupled with increase in area left fallow and converted to non-agricultural uses. Several encroachments exist all along Vembanad estuary. Kol lands are also undergoing transformation for non-wetland usages.
3.2 Bathymetry	Governs the ability to regulate hydrological regimes	Assessments available only for Vembanad estuary. Data for 1987 indicates that at 1 m amsl, the estuary has an area of 216.53 km^2 and 611.47 MCM in volume.	Gradual decline in waterholding capacity has been observed attributed to siltation of lake bed and reclamation of marshes. Aggradation of channels in Kuttanad has also been observed.
4. Water regimes			
4.1 Inflows, outflows and balance	Hydrological flux underpins ecological functioning	Annual projections indicate that the wetland complex receives 27,048 MCM as inflows from rivers and direct precipitation, of which 24, 574 MCM is drained to the sea.	Operation of upstream structures has altered the natural flow regimes (for example diversion of tail-race of Idukki reservoir in Muvattupuzha has altered salinity regimes north of Thaneermukom Barrage).
4.2 Tidal regime	Tidal regime influences salinity which in turn regulates several key processes, for example species migration and spread of invasives	Tidal actions are mostly in the north of Thaneermukom	Information available is limited. Tidal regimes are currently being managed to meet the needs of Cochin port and agriculture in Kuttanad, and natural regime is modified by operation of Thaneermukom Barrage.
4.3 Inundation regime	Inundation regime in Kuttanad and Kol lands are important for maintenance	Limited information	Construction of polders has adversely affected inundation regimes in Kuttanad and Kol

Ecological character descriptor	Significance	Status	Trends
	of wetland characteristics		regions.
4.4 Physico-chemical water	Governs life processes within the wetland		
4.4.1 Nutrients		Wetland is nutrient rich (high nitrate-nitrogen and phosphate-phosphorus concentrations)	Increased trends in nitrate, phosphate and silicate, linked to increased discharge of sewage from adjoining settlements and houseboats.
4.4.2 Salinity		Overall brackish. Higher salinity towards Cochin mouth. Kuttanad and Kol remain in near freshwater conditions for nearly 8 months through operation of Thaneermukom Barrage.	Drastic alternation in salinity regime. During 1970s, salinity levels upto 21 ppt were observed in Kuttanad. An overall decline in salinity has been observed in Kuttanad region with near freshwater conditions with closure of Thaneermukom Barrage.
4.4.3 Biological Oxygen Demand		BOD beyond permissible limit for inland surface water	Increasing trend in BOD over a decade. This is indicative of insufficient waste management infrastructure in and around the wetland complex.
4.4.4 Total and fecal coliform		High faecal coliform counts	Historic records unavailable to discern trends. However, open water areas under marine influence report lower faecal coliform
4.4.5 Cations and Anions		High calcium, sodium, chloride and phosphate observed north of Thaneermukom during closure of barrage. With onset of monsoon and opening of Thaneermukom barrage the minimum concentration is recorded in cations and anions in both the sides	Increasing trend in sulphate concentration is indicated by the available data.
5 Biota			
5.1 Mangroves	Serve as important breeding and feeding grounds for juveniles of fin fish and shell fish and roosting sites for waterbirds. Mangroves stabilise coastal areas and buffer storms. They are also effective in trapping sediments and removing heavy metal contamination from water	Mangrove concentrated in isolated patches. A 2.74 ha area in Mangalavanam has been declared as protected area.	Major mangroves areas around Vembanad estuary have been depleted and degraded.
5.2 Planktons	Occupy the lowest niche in food chain and important as primary producers and consumers in aquatic system.	High diversity in phytoplankton and zooplankton. Desmids and rotifers dominate the system prior to monsoon indicating high organic load in estuarine water.	Limited data.
5.3 Fish	Second order consumer responsible for transforming energy and matter through pelagic, benthic and detrital food chain. Important livelihood	High diversity of oligohaline, euryhaline and stenohaline species. Seven species endemic to Western Ghats are	The Thaneermukom barrage has impeded the availability of freshwater prawns which move downstream to estuarine areas for breeding.

Ecological character descriptor	Significance	Status	Trends
	resource.	also found in the estuary. Mullets, milk fish, catfish, half-beak and pearl spot along with 3 brackish and 2 freshwater prawns are commercially important	
5.4 Waterbirds	Water birds occupy the highest niche in aquatic system and are good indicators of ecosystem health	Vembanad estuary is an Important Bird Area supporting criteria A4i and A4iii. Over 20,000 birds are regularly sited in the 10 congregation areas in Vembanad- Kol wetland.	Human disturbance of habitats is increasing. Construction of KTDC complex has led to destruction of several herenories.
5.5 Clam	Play an important role in benthic food chain. These are filter feeders and they filter suspended particles from water.	Black clam (*Villorita cyprinoides*) and white clam (sub-fossil deposit) are commercially exploited for lime and cement industries	Over the last decade a reduction in availability of white clam has been observed.
Ecosystem processes			
6 Physical processes			
6.1 Sedimentation	Impacts water holding capacity and related physical processes	Limited data	Data on bathymetry and depth of estuary indicate increase sediment accumulation. Mouth of Cochin estuary is artificially maintained to support port operations.
6.2 Mixing	Influences water quality and related hydrological processes	Limited data	Thaneermukom has adversely affected mixing. Freshwater invasives that were naturally controlled by salinity are currently proliferating.
7 Energy – Nutrient Dynamics	Important for transfer of energy and matter to maintain the aquatic food chain and life processes	No assessment.	No assessment.
7.1 Primary production		High primary productivity	Limited data.
7.2 Nutrient cycling		No assessment.	No assessment.
8 Processes that maintain animal and plant population	Important for breeding and feeding of species which in turn affects recruitment and stocking	Specific studies on recruitment and migration are yet to be carried out, except giant fresh water prawn	Thaneermukom barrage has affected upstream and downstream migration
8.1 Fish recruitment			
8.2 Fish migration		No information.	No information.
9 Species interaction	Important for understanding the prey predator relationship, feeding habit and habitat relationship	No information.	No information.
9.1 Competition	Governs natural selection and community structure in stressed environment	Limited information. Spread of aquatic invasives in Kuttanad is choking waterways.	Limited information.
Ecosystem Services			
10.1 Fisheries		Capture fishery supports livelihood of 5000 households around Vembanad. However, catch from capture fisheries is considerably low. *Etroplus suratensis* is	Fishery has declined post Thaneermukom. Households depending on capture fishery are now moving towards collecting clam. However, availability of clam is declining. Unsustainable harvest practices, particularly scouring of

Ecological character descriptor	Significance	Status	Trends
		the most favoured species. Tilapia and African catfish have also been recorded in catch. Vembanad is a rich source of clam fishery (white and black clam) which is a source of livelihoods for 12,000 households	estuary beds is one of the causative factors.
10.2 Wetland agriculture		The backwater areas of Vembanad estuary has been reclaimed for agriculture in Kuttanad, Kaipad, Kol and Pokkali areas. Three major crops namely Punja, Virupu and Mundakan are cultivated in the region. Pokkali farming system in brackishwater marshes is unique to the region.	Since the last three decades, agriculture production has declined. In particular, there is decline in second crop (Viruppu) owing to increased risk of flooding during monsoon.
10.3 Inland navigation		50 boat and 200 house boat operate for inland navigation covering a total distance of 546 km.	Number of boats for navigation has increased in the last three decades.
10.4 Recreation and tourism		Backwaters of Vembanad are one of the major tourist destinations. Alappuzha and Ernakulum have high concentration of houseboats.	Increasing trends have been observed in tourist inflow.

3.2. THREATS TO ECOLOGICAL CHARACTER

Shrinkage of wetland regime

Vembanad-Kol wetland complex has been under consistent threat of modification and reclamation for agriculture. Nearly 550 km^2 of Vembanad estuary and floodplain marshes have been converted in Kuttanad region alone. Channelization of Kuttanad and Kol has altered the natural inundation regimes. In the last five decades, mangrove marshes on the shoreline of the estuary have been reclaimed for development of infrastructure for tourism. Remote sensing analysis of the Kuttanad region indicates increased instances of conversion of wetland paddies for non-wetland usages in the last three decades. The riparian habitats of inflowing rivers, particularly of Pamba and Muvattupuzha are being affected by unregulated sand mining.

Changes in hydrological regimes

The natural salinity gradient prevalent in the wetland complex has been altered to increase freshwater conditions in order to support agriculture. Circulation and mixing patterns have also been impeded by operation of Thaneermukom Barrage. Increased siltation from land use changes in the catchments has led to increased sedimentation of the estuary and a concomitant loss of water holding capacity.

Ecological requirements for wetland functioning not addressed in water management planning and decision making

Water management within the Vembanad-Kol wetland basin is mainly governed by the objectives of increasing agricultural productivity and operational requirements for Cochin

port. Ecological requirements for maintaining wetland processes, for example species migration, control of invasives, and water circulation and mixing are very inadequately addressed, and are at best, incidental to human demands. Operation of Thotapally spillway and Thaneermukom Barrage are based on the needs of freshwater for sustaining agriculture in Kuttanad, and have led to several adverse impacts on the estuary, including proliferation of freshwater invasives, decline in fisheries and deterioration of water quality.

Increasing anthropogenic pressure on waterbird habitats
The floodplain marshes and the mangroves on the fringes of Vembanad estuary served as important habitats for waterbirds but have been gradually degraded and converted for alternate use. Clearing of mangroves has affected several herenories. Indiscriminate use of pesticides and conversion of floodplain marshes for brick kilns and construction purposes are major pressures on waterbird habitats in Kol lands.

Pollution
Vembanad-Kol wetlands are the ultimate recipients of untreated sewage and sewerage from the industrial and manufacturing units and settlements which dot its periphery. With an increase in number of houseboats catering to backwater tourism, commensurate waste management facility is yet to be developed. Intensification of agriculture and use of high yielding varieties of rice has also led to increased use of fertilizers and pesticides. Coupled with changes in circulation and mixing pattern, excessive loading of nutrients is promoting growth of freshwater invasives in Kuttanad, clogging the channels and increasing waterlogging. The incidence of water borne diseases within the farming, fisher and clam collecting communities is high.

Mangroves cut for household timber in Kumbulam village (Vyttila block)

Stake nets near Thaneermukom. These nets usually have very fine mesh sizes

Declining wetland resources and increasing stakeholder conflicts

Production of fisheries, clams as well as wetland agriculture has declined in recent periods stressing livelihoods of dependent communities and creating stakeholder conflicts. The operation of Thaneermukom Barrage is a perennial conflict between fishers (preferring natural salinity regime) and farmers (preferring freshwater conditions all the year round). Local clam collectors' societies are highly impacted by commercial clam trawling operations (major being Travancore Cements) which lead to considerable shifting of beds and harvesting of juveniles. Environmental groups which have for long rallied against increasing tourism operations in biodiversity hotspots as Kumarakom and Pathiramanal islands. Declining aesthetics due to spread of invasive and degrading water quality put tour operators in conflict with industrial operations in Udyogmandal region.

3.3. MONITORING MECHANISMS AND KNOWLEDGE GAPS

An overview of current monitoring mechanism based on which status and trends of ecological character have been derived is presented in Table 3.3. Much of the information that is available today is on account of research studies which have been conducted with specific purpose. Interpretation of long term trends from these studies is challenged due to differences in sampling sites and research methodologies. On an overall there is a need to put in place a hierarchical wetland inventory, assessment and monitoring system so that changes in ecological character are known at periodic intervals, and adequate management response strategies identified.

Table 3.3 | Knowledgebase status and gaps

Ecological character element	Current monitoring system	Existing information base	Knowledge Gaps	
			High / Immediate priority	Lower priority
Ecosystem components				
Geomorphic setting	Periodic research based on remote sensing imageries	Land use and Land cover	Land use and land cover change trends for Vembanad-Kol catchment	
Climate	Weather data for select stations within wetland catchment	Rainfall, humidity, wind-speed, evaporation, air temperature sunshine	Scenarios of climate change and likelihood of change in ecological character	
Physical settings	Individual research studies on aspects as wetland area, bathymetry, and surface water connectivity	Land use and land cover for wetland region, bathymetry (1987),soil characteristics (1996), qualitative information	Wetland area demarcation, Trends in bathymetry	

Ecological character element	Current monitoring system	Existing information base	Knowledge Gaps	
			High / Immediate priority	Lower priority
		on surface connectivity		
Water regimes	Gauge data on river flows from CWC sites for all rivers, tide monitoring by Cochin port, Periodic studies on water quality by CWRDM and other research organizations / universities	Water inflows Water quality (select parameters for varying stations) River siltation Sediment flows for select gauge stations	Water balance for Vembanad-Kol wetland system Hydrological characterization of Kol wetlands Historical rates of wetland sedimentation (coring assessments)	Impact of sectoral development (tourism, urbanization, industrialization) on wetland water quality
Wetland soil	Individual research studies for agricultural purposes	Soil texture and chemical properties for a very limited time-frame		Updated mapping of soil types within and around wetland
Biota	Individual research for select groups	Species richness for select groups (mangroves, macrophytes, fin and shell fish) Waterbird species and numbers (Mid-winter counts)	Habitat evaluation for waterbirds	Biodiversity associated with mangroves in Vembanad estuary Systematic baseline assessment of floral and faunal diversity Impact of water regime change on species composition and diversity
Ecosystem processes				
Physical processes	Limited information on catchment erosion Research studies on littoral drift on west coast	Quantification of river erosion Land capability mapping for wetland basin (1996)		Prioritization of catchments based on assessment of erosion and wetland sedimentation data Changes in land use and impacts on catchment erosion and sedimentation
Energy-nutrient dynamics	No published research / assessment		Trends in primary production	Nutrient and carbon cycling in wetland
Processes that maintain animal and plant populations	Limited information on prawn migration	Production of prawns pre and post construction of Thaneermukom Barrage		Species specific studies on migration and recruitment
Species interaction	Limited information on macrophytic invasion in Kuttanad; Presence of invasive fish species	Select references to impact of invasive species on water regimes in Kuttanad	Mapping of invasive species and implication for wetland complex	
Ecosystem services				
Provisioning services	Production statistics for a limited timeframe for fin fish and shell fish groups	Fin fish and shell fish yield for select time frame with reference to operation of Thaneermukom Barrage	Species-wise catch of fin and shell fish from culture and capture sources within Vembanad-Kol	Economics of ecosystem services of Vembanad-Kol

Ecological character element	Current monitoring system	Existing information base	Knowledge Gaps	
			High / Immediate priority	Lower priority
	Area under wetland agriculture Routes and number of boats for inland navigation	Trends in land use in Kuttanad	Livelihood systems linkages with wetland ecosystem services, with specific emphasis on benefit sharing within various stakeholder groups	
Regulating services	No published assessments		Role of Vembanad-Kol in regulating hydrological regimes	
Cultural services	Tourism department records of tourist arrivals; number of houseboats by All Kerala Houseboat Association	Trends in tourism arrivals, number of houseboats	Carrying capacity of Vembanad-Kol wetland with respect to tourism	

Table 3.4 | Analysis of ecological character elements of Vembanad – Kol wetlands

Ecological Components	Status	Data assessment year and source	Trend
1. Physical Form			
a) Area	Vembanad-Kol wetland (VKW) regime comprises a mosaic of habitats including backwaters (Vembanad Lake), polders (in Kuttanad and Kol lands), mangroves, aquaculture farms, Cochin estuary and an intricate network of canals located in a shallow depression extending along the coastlines of Alappuzha, Ernakulam and Thrissur Districts of Kerala. The wetland regime extends between 9°16' and 10°36' N latitude and 76°01' and 76° 35' E longitude in an area of 1780 km^2.	Gopalan et al., 1983; Gopakumar and Takara 2009; Topographic maps, 2010 Satellite data	VKW has been subject to extensive modification, particularly reclamation for agriculture. During 1834 -1983, approximately 237km^2 of the backwaters have been reclaimed for agriculture, aquaculture, fishing harbours and industries (Gopalan et al. 1983). The open water area of Vembanad estuary has been reported to decline from 290.9 km^2 during 1917 to 243 km^2 2010. Kerala Tourism Development Complex in Kumarakom previously known as Baker Estate had the longest mangrove stretch in the entire Kerala coastline till 1990s. However, mangroves were subject to rapid felling during 1990-96 to pave way for construction of tourism complex.
b) Bathymetry	VKW is located between elevation 20m above msl and 9.9 m below msl. Elevations for the lake vary between 2 m above msl to 9.9 m below msl. While depth variations are marginal for the wider southern portion, deeper sections with elevation up to 9.9m below msl exist between Thaneermukom (TM) barrage and Cochin. At an elevation of 2m MSL, the Vembanad lake has a water spread of 227.5 km^2 and a volume of 834.2 MCM.	Bathymetric survey data of 1987; DEM; Gopakumar and Takara, 2009	The depth of Vembanad Lake has been reported to reduce by 40-50 % in all zones except between Aroor and Willingdon island and the Kochi port zone, which is artificially maintained by dredging for harbour operations (Gopalan et al. 1983).
c) Shape	Saucer shaped basin flanked by laterite hills in eastern and western margin		

Ecological Components	Status	Data assessment year and source	Trend
2. Wetland Soils			
a) Texture	Soils are primarily of fluvio-estuarine origin, with a high component of black carbonaceous clay with peaty substratum in major areas. Within the lake, the sediment texture is sandy loam. Content of sand, silt and clay is 81.25%, 5 % and 13.75% respectively.	Nasir, 2010	No previous assessments available.
b) Chemical properties	Soils within Kuttanad and Kol regions are acidic with high organic content. pH of lake sediment ranges between 4 and 8; percentage of organic carbon ranges from 1.84% to 11.84%; total nitrogen content of the lake varies from 1512 mg/ka to 4480 mg/Kg and the total phosphorous content in the sediments varies from 255mg/Kg to 1680mg/Kg.	Nasir, 2010	No previous assessments available
c) Biological properties	Assessments yet to be carried out		
3. **Physico-chemical Water**			
a) Nutrients	Vembanad is a nutrient rich wetland system • Nitrate: 0.01-1.06 mg/l • Phosphate: trace-0.45 mg/l • Silicate: 0.16-19.9 mg/l	Sujatha et al., (2009); ICMAM (2002)	Comparison with assessment of 1995-96 (James et al., 1996) indicate increasing trend. Reported level in 1996 • Nitrate (0.04-0.5 mg/l) • Phosphate (trace to 0.03 mg/l) • Silicate (0.7-11 mg/l)
b) Conductivity	High (167-313 micromhos/cm)	Vincy et al., 2012	No previous assessments available
c) Cations and Anions	• Calcium: 17.6-160mg/l • Magnesium: 4.9- 413 mg/l • Sulphate: 5-357 mg/l • Chloride: 150-6350 mg/l	Nasir, 2010	No previous assessments available

Ecological Components	Status	Data assessment year and source	Trend
d) Temperature	Surface water temperature in Vembanad Lake range between 29 -33.0^{0}C	Sujatha et al., (2009)	Assessment in 1998 by ICMAM indicate similar range (23.3- 31.0^{0}C) (ICMAM, 2002)
e) Dissolved Oxygen	DO in lake waters observed to vary between 2.81-5.64 ppm	Vincy et al., (2012)	Compared with values of 1995-96 (5.9 – 8.1 ppm), DO has declined.
f) pH	Water of Vembanad is alkaline 7.1-8.5. However, the backwater areas with tourist boats are slightly acidic (6.6-6.8)	Sujatha et al., (2009); Vincy et al., (2012)	Similar levels recorded in 1995 – 96 (6.1- 7.2) (James et al., 1996)
g) Salinity	Varies from 4.5 in Kuttanad to 33.1 ppt in the Cochin mouth.	Sujatha et al., (2009)	Construction of TM has drastically altered salinity regime. Prior to construction, high salinity levels upto 21 ppt was recorded in Kuttanad, which in the post barrage operation period has reduced to 0.5- 4 ppt (CWDRM, 2006)
h) Nutrient cycling	Assessments yet to be carried out		No previous assessments available.
i) Transparency	Ranges between 1.1- 1.86 m	CWRDM, 2006	No previous assessments available.
j) Biological Oxygen demand	High values observed during 2008-12 (3.45-5.9 mg/l). This is even beyond the permissible limit of 3 mg/l for inland surface water subjected to effluent discharge.	Vincy et al., 2012; IS:2490-1974	Overall increase if compared to BOD values of 1982 (0.5-3 mg/l) (Balchand and Nambisan, 1986). The increase is correlated with discharge of untreated effluents from sewage and industries into VKW.
k) Total and faecal coliform	Range from nil to >2400 MPN/100ml. Areas with marine inflows report lower values. However, there is abrupt increase in faecal coliform counts in wetland areas under direct influence of municipal sewage	CWRDM, 2006	No previous assessments to discern trends
4. **Biota**			
a) Wetland plants	Comprehensive assessments for VKW yet to be carried out. Assessments in Kuttanad, Pathiramanal Island, and Vembanad indicate presence of 338 plant species of	Sabu and Ambat, 2007; John et al., 2009; (1982-1983) Sashidharan et al., 1983	No previous assessments to discern trends

Ecological Components	Status	Data assessment year and source	Trend
	which 26 are tree species, 14 are shrubs, 21 are climbers, 237 are herbs, 16 mangrove species and 24 associates. 24 species of macro-vegetation belonging to 12 families have been reported of which one species of fodder grass *Ischaemum travancorense* (Kadakal) endemic to Kerala and Maharashtra Dry weight of macrophytes was reported higher in Kuttanad region- Karappadom (91.2 g/m^2), Kari (23.2 g/m^2) land and Kayal land (22.9 g/m^2).		
b) Mangroves and associates	6 species of true mangrove and 17 species of mangrove associates have been reported from Kumarakom dominated by *Avicennia officinalis, Bruguiera gymnorrhiza* and *Rhizophora mucronata.* In particular, these mangrove patch, serve as major roosting and breeding site of Night heron, Darter, Cormorants, Indian Shags, Egrets, Herons and White Ibis. Overall 16 mangrove and 24 associate species have been recorded from Pathiramanal Island. *Ceriops tagal, Excoecaria agallocha* and *Cerbera odollam* (mangrove associate) are dominant while *Bruguiera gymnorrhiza, Sonneratia apetala* and *Excoecaria agallocha* are less abundant species in the Island.	Department of Forests and Wildlife, & Kottayam Nature Society, 2002 and 2003; Balasubramanium and Azeez, 2012	No previous assessments to discern trends
c) Vertebrate fauna			
- Fish	149 species of fish belonging to 100 genera and 56 families. 23 species of fish are	Kurup et al., 1990; Kurup et al., 1993	Construction of TM has impacted fish migration.

Ecological Components	Status	Data assessment year and source	Trend
	oligohaline, 78 euryhaline and 48 stenohaline 9 prawn species, 20 crabs and 6 clams are reported from the lake 7 species of fish endemic to the rivers of Western Ghats are found in the estuary (*Dayella malabarica, Horabagrus brachysoma, Mastacembelus guentheri, Mystus malabaricus, Mystus oculatus, Puntius filamentosus*, *Labeo dussumieri*).		
- Amphibians	No previous assessments		
- Reptiles	Two species of fresh water turtle, Indian black turtle (*Melanochelys trijuga coronate*) and the Indian flap-shelled turtle (*Lissemys punctata punctata*) have been reported from Vembanad and associated Punnamada wetland	Kokkal *et al.,* 2007; Krishnakumar et al., 2007	*Crocodilus porosus* in no longer sighted in estuarine areas (Kokkal *et al.,* 2007). Regular trade in *Melanocheyls trijuga coronate* is a threat considering their conservation status(Near Threatened).
- Waterbirds	Managalvanam Bird Sanctuary, Pathiramanal Island and Kumarakom, are the major congregation sites in Vembanad-Kol. However recently, the paddy fields of Kaippuzha Muttu in Kuttanad hold maximum bird population. Kottayam Nature Society regularly conducts bird counts in 10 sites south of TM barrage. Counts for 2001-2010 indicate numbers over 20,000 regularly. Over 50 migratory species visit the lake during winter. 225 species of birds have been recorded from the lake during 1995-2010 of which 38% were migrants and 55 were found to	1995-2007 Narayan et.al., (2011); Kottayam Nature Society, 2011 Sivaperuman and Jayson, 2000 (1998-99); (Jayson and Easa, 2000	Destruction of mangroves in Kumarakom has impacted an important congregation site. Breeding colonies of Night Herons, Cormorants and Darters have been severally affected.

Ecological Components	Status	Data assessment year and source	Trend
	breed in the area. One vulnerable (*Aquila clanga)* and 10 near threatened species (*Aythya nyroca, Mycteria leucocephala, Threskiornis melanocephalus, Pelecanus philippensis, Anhinga melanogaster, Ichthyophaga ichthyaetus, Limosa limosa, Numenius arquata, Sterna aurantia* and *Coracias garrulous*) have been reported from the Vembanad estuary Kol wetland records includes 167 species of birds, belonging to 16 orders and 39 families among which 81 species are wetland dependent birds. Spot-billed Pelican (a near threatened species) and Rufous Babbler (an endemic species of Western Ghats) are known to frequent the region.		
d) Phytoplanktons	Assessments of 1998-99 indicate presence of 123 phytoplankton species including 89 Bacillariophyceae, 31 Dinophyceae, 2 species of Chlorophyceae and 1 species of Cyanophyceae. Density ranged between 12,000 to 322,000 cells/l in the tidal-zone and 7,000-235,000 cells/l in backwaters.	ICMAM, 2002 (2001-2002) Selvaraj *et al.,* (2003)	Gopinathan et al., (1974) indicated a higher abundance (90, 000- 606400 cells/l during 1972-73. However, this is one time study and does not support discerning trend.
e) Zooplankton	Assessments of 1998-99 indicated presence of 24 species. The density ranged between 29,195 no/l to 18,87,866 no/l.	ICMAM, 2002	No previous assessment to discern the trends

Ecological Components	Status	Data assessment year and source	Trend
f) Aquatic macro-invertebrates	6 clam species and two pearl producing bivalves have been reported from the lake. The backwaters of Kerala show zonation in clam availability based on the salinity profile of the wetland system. *Sunetta scripta* near the bar mouth, *Meretrix casta* and *Paphia malabarica* dominate 2-3 km away from the bar mouth (salinity 15 ppt), *Villorita cyprinoides* are reported from regions with freshwater 18 Brachyuran species reported from VKW. *Scylla serata* is harvested for sale.	CMFRI, 2005; Ranjan et al., 2011; Suja and Mohamed, 2010; Kurup et al., 1990; Nasser and Noble, 1995	No comprehensive assessments to discern trends
5. Climate			
a) Precipitation	The annual rainfall for Alappuzha, Kottayam and Ernakulam districts for 2012 was 1846 mm, 2299 mm and 2610 mm. About 60 % of the rainfall is received during South-West monsoon.	Indian Meteorological Department, 2012[8]	
b) Air Temperature	Ranges between 21^0 to 36^0C	Indian Meteorological Department,2012	Not available
c) Evaporation	Potential evapotranspiration estimated to be 91.1 m^3/sec	Gopakumar and Takara 2009	
d) Wind	Wind speed in coastal stretch ranges between 6.7-10.9 km/hr	Jagtap et al., 2004	
e) Humidity	80 To 95%	CWRDM (2006)	No historical records / assessments available
6. **Geomorphology**			
a) Topography	Major part of Vembanad wetland is located	DEM; Gopakumar and	

[8] Indian Meteorological Department 2012. Web-Link: http://www.imd.gov.in/section/hydro/distrainfall/kerala.html

Ecological Components	Status	Data assessment year and source	Trend
	at altitude between -6 m MSL to 20m MSL with mean elevation of 4.6 m MSL. There are narrow stretches in lake bed with elevations 10m below MSL. 398.1 km^2 of the total wetland area is located below MSL. The drainage basins may be divided physiographically into three near-parallel north-south zones, viz. the highland (above 75 m above sea level), the middle reaches (7.5 m – 75 m above sea level) and the lowland (below 7.5 m above sea level).Geologically the catchment area has Crystalline rocks in higher reaches; Tertiary sedimentary rocks, laterite capping over crystalline and sedimentary rocks, mainly in the middle reaches and Recent & sub recent sediments in low-lying areas and river valleys. The Alappuzha-Ponnani stretch is composed of purely alluvium of recent deposits with prominent palaeo strandlines. Palaeo beach ridges or regression-transgression features are prominent in the landmass lying from Cochin mouth to the south. One of these sets of features run parallel to Alappuzha-Cochin coast line and separates the Vembanad- Kuttanad area from the Lakshadweep sea.	Takara 2010; Chattopadhya, 2010	
b) Connectivity to surface waters	VKW is fed by 10 rivers, all originating in Western Ghats and draining into Arabian Sea. Wetland connects within the sea at three locations: Azikode, Cochin and at Thottapally.		Natural connectivity of surface waters has been impeded by construction of saltwater barriers, bunding and extension of agriculture, ports and spillways. Operation of the Thaneermukom salinity barrage divided the lake in to two different water regimes viz. The freshwater dominant southern zone and the salt-water dominant northern zone.

Ecological Components	Status	Data assessment year and source	Trend
c) Water sources	Major water sources are rainfall from south-west monsoon, freshwater river flows and marine flows from sea.		
d) Soils	Studies conducted in the Kole area reveal wide variation in morphological and physico-chemical characteristics of soils. Soils in this area are mainly the product of weathering of river alluvial deposits and colluvium. Based on the physiographic position soils can be grouped into two viz (1) soils of the flood plain, comprising of Perumpuzha, Anthikkad and Konchira series and (2) soils of slightly higher elevation occupying the outer fringes consisting of Manalur, Edathuruthy, Ayyanthole and Kizhipallikkara series. Forest loam soils occur in the highlands. The wetland areas mostly have coastal alluvium soils.	Johnkutty and Venugopal, 1993.	
e) Erosion	Comprehensive assessments yet to be carried out	CWRDM, 2006	Catchment degradation due to clearing of forests and urbanization has led to extensive siltation and concomitant loss of water holding capacity of the wetland. Although baseline bathymetric surveys of the wetland have not been carried out, progressive decline in wetland depth of upto 5 m has been reported for the period 1940 - 1992 by Kerala Sastra Sahitya Parishad.
7. **Hydrology**			
a) Water balance	Total inflow from ten rivers draining the VKW has been calculated to be 22,568 MCM. The outflow to the sea was 24,574 MCM.	Based on Gopakumar and Takara 2009; CWRDM, 2006; IIT and CWRDM, 2011	Data on water balance is from a one-time assessment, so trends cannot be discerned.
b) Groundwater infiltration and seepage	Assessments yet to be carried out		No assessments available

Ecological Components	Status	Data assessment year and source	Trend
c) Surface -groundwater interactions	Assessments yet to be carried out		No assessments available
d) Inundation regime	Assessments yet to be carried out		No assessments available
8. **Energy - nutrient dynamics**			
a) Primary production	The annual mean Gross Primary Productivity and Net Primary productivity of Cochin backwater is reported to be 0.753 g C/m^3/ day and 0.603 g C/m^3/day respectively.	Meera, 2010	Comparison with assessments conducted during 2001-02.Selvaraj et al., 2003 indicate comparable results (ranging between 0.446 g C/m^3/day to 1.316 g C/m^3/day in Cochin backwaters during 2001-02).
b) Nutrient cycling	Assessments yet to be carried out		No historical records / assessments available.
c) Carbon cycling	Assessments yet to be carried out		No historical records / assessments available.
d) Decomposition	Assessments yet to be carried out		No historical records / assessments available.
e) Oxidation -reduction	Assessments yet to be carried out		No historical records / assessments available.
9. Process that maintain animal and plant population			
a) Fish recruitment	Specific studies on fish recruitment are yet to be undertaken for Vembanad. However, commissioning of Thaneermukom barrage has impacted recruitment of post-larvae of Giant freshwater prawn (*Macrobrachium rosenbergii)* and brackishwater species. The Kol lands act as breeding ground for commercially important shrimps like *Penaeus indicus, P. monodon, Metapenaeus dobsoni, M. Monoceros, M. affinis and M. rosenbergii.*	Kurup and Harikrishnan, 2000; Rajan *et al.,* 2011	Reduction in number of closure days of barrage from 160 to106 days has improved the stock of *M. rosenbergii* by three fold (Kurup and Harikrishnan, 2000)
b) Fish migration	Upstream migration of prawn post- larvae occurs during pre-monsoon and	Kurup and Harikrishnan, 2000	No historical records / assessments available

Ecological Components	Status	Data assessment year and source	Trend
	downstream migration of berried females during monsoon and post monsoon. However, species specific migratory assessments are yet to be reported from Vembanad.		
10. Species interaction			
a) Competition	Assessments yet to be carried out		No historical records / assessments available.
b) Predation			
c) Succession			
d) Herbivory			
11. Physical processes			
a) Stratification	Limited information		No historical records / assessments available.
b) Mixing	Assessments yet to be carried out		No historical records / assessments available
c) Sedimentation	Based on the reservoir sedimentation surveys carried in seven reservoirs of the river basin draining the wetland, the average sediment yield was observed to be 26t/ha/yr. The total sediment yield from all the river basins draining into Vembanad lagoon and Kol lands has been estimated to be 32 million tonnes and 4 million tonnes respectively. CWRDM has estimated an annual sediment yield of 0.48 million tonnes based on the sediment data of 1995 – 1999.	CWRDM, 2006	No historical records / assessments available
d) Erosion	Assessments yet to be carried out		No historical records / assessments available

Ecosystem Services	Status	Data assessment year and source	Trend
12. Provisioning Services			
a) Fisheries	Systematic assessment of catch is not carried out. Most recent assessment of 2002 indicate fish and prawn catch (from capture sources) to be 687 MT and 3617.67 MT respectively. The capture fish catch is considerably low. Invasive alien species *Clarius garipenus and Oreochromis mosambicus* are being increasingly reported in recent catches. Contribution of Tilapia to total catch is second highest after prawn. Fisheries from Vembanad-Kol wetlands provided livelihood support to fishers living in 64 villages. Fisher households in around Vembanad was estimated to be 17,369 in 1992, this has been reduced to less than 5,000 at present. Fishing is done all the year round, barring June – July, which are the peak monsoon months. A group of six fishers return with a catch of 7-8 kgs. *Karimeen, Etroplus suratensis* is the most favoured species for harvest.	Padmakumar et al., 2002	Declining trend has been observed in fish catch (7200 MT during 1988-89). Construction of Thaneermukom barrage has led to rapid decline in capture fisheries which has seriously affected the livelihood of fishers living in and around the lake. Within Kottayam district, the fish catch declined from 17,000 tons to 584 tons. Similarly, within Alappuzha, the fish catch declined from 800 tons to 500 tons. The overall marine and freshwater prawn yield has also declined by 35 – 40%. Decline in annual catch of giant fresh water prawn from 429 t during 1967 (Raman, 1967) to 27 t during 200-01 (Padmakumar et al., 2002) is attributed to TM barrage and impeded upstream and downstream migration
	Vembanad lake is an important source of clam. Data of 2010 indicate annual production to be 50,275 tons. Rate of mining of sub-fossil deposit is 41,000-69,000 tons /annum Vembanad backwaters are a rich source of clam, which form the base of livelihoods for around 12,000 households. The clam	Suja and Mohamed, 2010; Laxmilatha and Appukuttan, 2002	White clam, which constitute 80% of the clam harvest, are declining (Maya et al, 2009)

Ecological Components	Status	Data assessment year and source	Trend
	collectors are organized in societies, which have been in existence since 40s. Presently, the 13 clam collector's societies in Alappuzha and Kottayam districts, of which 8 pertain to black clams. Average household income ranges from Rs. 5,000 – 6,000 per month. Trading is done for a set of 20 tins (of 5 kg each) being purchased from the individual collectors at an average rate of Rs 222 and subsequently sold for Rs.286. The balance is used by the society to pay of tax and royalties, provident fund contributions, and for holiday wages during the period May-August. Nominal loans are also provided to the members @ 12% interest per annum. Meat from clams is an important source of protein and is sold @ Rs. 35/ kg in the local markets.		
b) Wetland agriculture	Agriculture in Kuttanad alone provides sustenance to 90,000 farmers. The average landholding is very small and ranges from 0.48 ha in Idukki district to 0.19 ha in Alappuzha district. Farming in the backwaters is highly organized and energy intensive activity. Each cluster of farms, known as *padashekharam,* has a committee to manage collective dewatering of the fields after monsoon. The committee own a pump, operation and maintenance of which is financed by the members, and through subsidized electricity from the state government. Rice is the main crop grown in the region. Three cycles of cultivation currently exist, namely *Punja*		While the number of operational holdings has increased by 31% during 1991- 1995, the overall area has increased by only 5% during this period, leading to substantial decrease in holding sizes. The practice of *Mundakan* has gradually declined to a large extent as the productivity is affected by monsoon.

Ecological Components	Status	Data assessment year and source	Trend
	(sown during northeast monsoon during October to December and which after construction of TM Barrage has been extended to March), *Virruppu* (sown in mid-May and harvested in September). Since this crop has to bear the impact of southwest monsoon, the area planted is restricted to places less vulnerable to flood damage. A third crop *Mundakan* is a short duration crop cultivated during September to December.		
c) Use of aquatic vegetation for economic purposes	Altogether 36 species of macrophytes are uses as herbal medicine. *Calophyllum* sp. (Traditional source of oil), *Oryza fatua* (wild rice), *Aponogeton appendiculatus* (an edible tuber), *Kandelia candel* (dry stem and leaves are used as fuelwood), *Bacopa monneiri* (Brahmi a widely used medicinal plant), *Pandanus* sp. (leaves harvested for mat weaving) have been reported from VKW.	Sanilkumar and Thomas, 2007;	No historical records / assessments available
13. **Regulating Services**			
a) Maintenance of hydrological regimes	Assessments yet to be made		
14. Cultural services			
a) Recreation and tourism	Vembanad backwaters are one of the major tourist destinations. International tourist arrival in Kerala has been estimated as 0.5 million in 2006. Domestic tourist visiting the backwaters was recorded as 60 lakhs in 2006. This forms an economic base for	Government of Kerala, 2002 a and b	Kerala's share of international tourist coming to India has increased from 5.54% in 1994 to 8.85% in 2005. Tourist arrival increased from 116 crore in 1994 to 1988.40 crore in 2006. The number of boats plying in Vembanad is

Ecological Components	Status	Data assessment year and source	Trend
	nearly 85,000 households and an overall contribution of Rs. 469 crores to the local economy through the direct and indirect linkages. Allepy and Kumarakom are the two major entry points of the lake, and have 750 and 120 houseboats respectively registered with All Kerala Houseboat Owner's Association. The development of tourism in Vembanad Lake could be attributed to the Nehru Trophy Boat Race held during Onam festival in August on the Punnamda Lake, near Alappuzha. The Boat race started during 1952 which became a part of tourism realm during early 80's.		much above the carrying capacity of lake (1 boat in 25 acres for recreational activities Wagner, 1991). Microbial contamination of lake from toilets and septic tanks has increased faecal coliforms. This prevents tourists from engaging in water sports. Motor boats also aid in spreading of invasives, specifically *Eichhornia crassipes*. Clearing of mangrove swamps for tourist activities affects the breeding habitats of migratory waterbirds.
b) Scientific and educational	The Vembanad-Kol wetland complex has been of interest for scientific investigations by a number of institutions, research organisations and universities.		No discernible trends

A view of Cochin Port

4 Institutional arrangements

Institutions play an important role in governing and coordinating relationships between various wetland stakeholders, and thereby their fit with ecosystem components and processes which underpin biodiversity and ecosystem services has an important influence on wise use outcomes. Institutional requirements for conservation and sustainable management of the wetland complex are defined by the ability to ensure integration of site management within broad scale environmental management and development planning (including river basin and coastal zone management), and enabling participatory management, particularly ensuring involvement of local communities whose livelihoods are linked to ecosystem services and biodiversity of wetlands. The current institutional arrangements for management of Vembanad-Kol wetlands are evaluated in terms of three major aspects, i.e policy framework (in terms of inclusion of wetland conservation and wise use objectives in sectoral policies), regulatory regimes (in terms of sufficiency in addressing drivers and pressures of wetland degradation) and agencies (in terms of inter-agency coordination for securing wetland conservation and wise use outcomes).

4.1 Review of existing institutional arrangements

Policy framework

Conservation and sustainable management of wetlands have been referred to in several state policy documents. Loss of mangroves and degradation of rivers have been highlighted as one of the core environmental issues for the state. The State Water Policy (2008) stresses on ecosystem integrity, river basin planning and cross sectoral coordination. Conservation and sustainable use of wetlands for ensuring water and food security and economic benefit of the people is included as specific action plan within the policy. Protection, conservation and management of wetlands have been identified as areas for special attention of the Government through legal and programme initiatives. The management of wetlands is intended to include its utilization, maintenance and development within conservation framework. The need for rational use of ecological resources for nature based tourism is highlighted in the State Tourism Policy (2012). The policy also envisages dispersing houseboats across the backwaters, so as to reduce clustering in Alappuzha.

At national level, India's accession to Ramsar Convention in September 1982 signifies its commitment to ensure wise use of all wetlands within her territory. Designation of Vembanad estuary alongwith associated Kol lands as a Wetland of International Importance commits the national and state government to undertake measures for maintaining ecological character of the wetland ecosystem. Conservation of wetlands and their integration in river basin and sectoral development planning have been stressed in the New Environment Policy of 2006.

Despite specific mention of wetlands in several sectoral policies, integrated programmes for conservation of wetlands in general and for Vembanad-Kol wetlands in particular have failed to emerge in the state. There is an overall emphasis on sustaining wetland agriculture and promoting tourism, with no attention paid to the issues related to ecological integrity. Throughout the 18th and 19th century, reclamation of Vembanad estuary and floodplain marshes have been promoted through state supported incentives (details in Box 1 – Wetland agriculture in Kuttanad). Agricultural development programmes like the Intensive Agricultural District Programme (IADP) of 1960-61, the Intensive Paddy Development Programme (Package Programme) of 1971-72, the Operational Research Project in Integrated Rice Pest Control implemented from 1975 to 1995, the Group Farming Programme of 1989-90 and the Integrated Programme for Rice Development (IPRD) of 1994-95 were designed exclusively for the development of the state's paddy farm sector. In 1972 Government of Kerala launched the 1st Kuttanad Development Project to improve infrastructure for paddy cultivation in this region. Construction of Thotappally Spillway and Thaneermukom Barrage were driven by the need to regulate hydrological regimes to intensify agriculture.

In 2010, the state government initiated implementation of the Kuttanad Package - a set of interventions recommended by the M.S. Swaminathan Research Foundation to mitigate agrarian distress in Alappuzha and Kuttanad Wetland System with a total outlay of Rs. 1,840 crore. The package envisages developing six agronomic zones of Kuttanad, namely Kayal Lands, Lower Kuttanad, Upper Kuttanad, North Kuttanad, Purakkadu Kari and Vaikom Kari and spatially reorganize *padashekharams* into smaller units to support decentralized small scale production. While the design of the package includes references to the issues of pollution and invasive species which are adversely affecting the ecological character of the wetland complex, the overall focus remains on agricultural practices within Kuttanad. Despite inclusion of Vembanad as a national priority site under National Wetland Conservation Programme[1] of the Ministry of Environment and Forests, an integrated management plan for the site is yet to be developed and implemented.

Regulatory regimes

At state level, the regulatory regime for wetlands is set by **The Kerala Conservation of Paddy Land and Wetland Act, 2008** which restricts conversion of paddy lands and wetlands to alternate uses. The mangrove areas, fish breeding grounds and backwaters of Kerala and backwater islands have been classified respectively under categories CRZ I and CRZ V – Areas requiring special considerations as per the **Coastal Regulation Zone Notification, 2011** under the Environment Protection Act 1986. CRZ I includes areas under mangroves and CRZ V includes areas requiring special consideration for the purpose of protecting the critical coastal environment. The Act specifies activities that are prohibited or regulated in these categories, with the most stringent regulations applying to CRZ I. Activities such as setting up of new industries, manufacture or handling oil storage or disposal of hazardous substance; setting up and expansion of fish processing units; land reclamation, bunding or disturbing the natural course of seawater; discharge

[1] The National Wetland Conservation Programme (NWCP) was the flagship programme of the Ministry of Environment and Forests introduced in the 7th plan period (1985-1990) to provide 100% financial assistance to the state governments for design and implementation of management action plans. In 2001, a National Lake Conservation Plan (NLCP) was introduced to address pollution issues in urban and semi-urban environments through interception, diversion and / or treatment of pollution load entering the lake. As on December 2012, 115 wetlands and 40 lakes were provided financial assistance under the NWCP and NLCP respectively. In February 2013, the Government approved merger of the NWCP and NLCP into a unified scheme titled National Plan for Conservation of Aquatic Ecosystems to be operational in the 12th plan period with an overall allocation of 900 crores. The financing pattern has been changed to the central governments and the respective state governments sharing the cost in the ratio of 70:30 (90:10 in the case of northeastern states). Modalities for implementation of the NPCA were still being worked out at the time of writing of this report.

of untreated waste and effluents from industries, cities or towns and other human settlements; reclamation for commercial purposes are prohibited barring a few exceptions. Vembanad is recommended to be declared as Critical Vulnerable Coastal Area (CVCA) in consultation with local fisher and dependent communities with the objective of promoting conservation and sustainable use of coastal resources and habitats. The Kerala State Coastal Zone Management Authority has been constituted. There is provision for preparation of Coastal Zone Management Plans by engaging reputed and experienced scientific institutions. Despite these measures a number of violations of CRZ have been reported from the area mostly by industries and tourism sector.

The Kerala Tourism (Conservation and Preservation of Areas) Act 2005 passed by Government of Kerala envisages conservation, preservation and integrated development of special tourist zones. Special tourist zones are notified in government gazette, and the act prohibits developmental activities within the notified areas. Till date, Kovalam, Munnar, Kumarakom and Fort Kochi have been brought under the purview of this Act.

The Environment (Protection) Act (1986), The Indian Wildlife Protection Act (1972 and amended upto 1992), Biological Diversity Act (2002) are some of the key national legislations that pertain to protection of biodiversity and environment of wetlands in the country. A network of protected areas has emerged as the main institutional framework within the context of wetland management, with the Forest and Environment Department as the nodal agency**.** Mangalavanam was declared a Bird Wildlife Sanctuary in 2004 to protect the important bird congregation area of 2.7 ha around the lake.

The Wetland (Conservation and Management) Rules, 2010 under the Environment (Protection) Act 1986 sets out the regulatory framework for wetlands at the national level. The Rules apply to Ramsar sites, high altitude wetland having an area equal to or more than 5 ha, sites or wetland complexes below 2,500 m with an area exceeding 500 ha, and sites designated as World Heritage. The rules prohibit a range of activities in the notified wetlands, key being hydrological fragmentation, conversion to non-wetland uses and discharge of untreated sewage and sewerage. A Central Wetland Regulatory Authority

Kumarakom notified special tourist zone

(CWRA) has been constituted for the purpose of enforcement of these Rules.

The rules as mentioned above provide a sufficient legal basis for conserving Vembanad-Kol wetlands. However implementation of the regulatory framework remains a challenge. The entire shoreline and islands have been subject to construction of tourist facilities. In August 2013, the Supreme Court took suo-moto cognizance of the fact that Vembanad Backwaters was "undergoing severe environmental degradation and there has been large scale encroachment and constructions going on in violation of the CRZ Notifications", and directed the state government to identify all the CRZ violations around Vembanad backwaters and its islands. In July 25, The Kerala High Court ordered demolition of 59 villas and constructions on the island of Nediyathuruthu, near Cochin. Similarly, land use change analysis within Kuttanad indicates slow but increasing incidence of conversion of paddy lands for alternate uses. Discharge of untreated or partially treated industrial waste into rivers and water bodies continues unabated. Conserving mangroves has been equally challenging as they are located on lands with private titles.

Agencies and cross sectoral engagement

A formal structure for managing wetlands of Kerala is yet to emerge. The Department of Environment and Climate Change is the nodal agency responsible for conservation of wetlands. The Kerala State Council for Science, Technology and Environment (KSCSTE) (an autonomous body constituted in November 2002 to encourage and promote science and technology related activities in the Kerala State) has been entrusted the task of management planning for wetlands, including Vembanad-Kol. Knowledgebase to support management planning is derived based on the research and assessments made by several organizations, notable of which are Centre for Water Resources Development and Management (CWRDM) (for hydrological regimes), National Institute of Oceanography (on coastal processes), Fisheries College and Central Marine Fisheries Research Institute (on Fisheries), and Kerala Agricultural University (on agriculture).

A range of agencies operate on various wetland features to achieve sectoral outcomes. The Kerala Prosperity Council oversees implementation of Kuttanad Agricultural Package which aims to sustain agriculture within Kuttanad and Alappuzzha districts and alleviate farmer distress. Operation of Thaneermukom Barrage and Thotapally Spillway is done by the Irrigation Department. The tourism department is entrusted with the objective of developing backwater tourism within Vembanad estuary. Cochin Port Trust maintains the Cochin Port and Willingdon Island area to ensure that the physical condition of Cochin mouth are conducive for operation of port and harbour. Kerala Coastal Zone Management Authority has been constituted in December 2011 to implement the provisions of Coastal Regulation Zone Notification, 2011.

The role of community institutions in influencing wetland governance is significant. Kerala is one of the front runners among the Indian states in terms of ensuring community led planning and development through local self governments. Presently more than 70% of the development budget is allocated to the Panchayati Raj Institutions for planning and implementation. Decentralized planning was initiated through local governments in 1996 – 97 through the Kerala Panchayat Raj Act, 1994[2] and Kerala Municipality Act, 1994. The Act formulated in line with the 73rd and 74th Constitutional Amendment, envisaged local panchayats as the primary unit responsible for planning and administration of development projects. The PRIs presently manage the developmental

[2] Amendments have been made in the Act in 1996, 1999, and 2000 leading to devolution of more powers to local self-governments and enabling decision making at the local levels. A number of steps were undertaken in 2001 to institutionalize and strengthen Panchayati Raj in the state keeping with the objectives of constitutional amendments and the existing state government laws. In 2002 – 2003, the decentralized plan was termed as the "Kerala Development Plan".

programmes for agriculture and allied sectors, minor irrigation, traditional industries, school education, primary and secondary health care, social security systems, women and child development, poverty reduction programmes and responsibilities, drinking water (except large urban schemes), extension of electricity, connectivity other than major district roads and highways and creation of infrastructure for all transferred functions. Besides, planning for village development, Panchayati Raj Institutions are also being recognized as agencies for regulating tourism under the Kerala Tourism (Conservation and Preservation of Areas) Act, 2005.

Besides the Panchayati Raj Institutions, there are several user groups which function as collectivized production and processing guilds in the region. The region in and around Vembanad Lake has several coir retting societies, fishery societies, agriculture farmer's societies and houseboat owner's societies. These societies also provide benefits to their members including protected prices and compensatory allowances for non-employment periods. The institutions also serve as channels of the government for reaching aid and grants under various developmental schemes. The groups wield significant informal power to regulate sectoral activities and protect interests of their members. An example of the influence of user groups on wetland governance is exhibited in the manner in which Thannermukkom Barrage is operated. While the irrigation department physically operates the barrage, a decision on the closure dates is through a committee under the District Collector, Alappuzha with members drawn from *padashekharam* committees.

Within the current institutional set up there is an apparent absence of a coordination mechanism, and an identified agency to ensure that sectoral development programmes do not create adverse impacts of wetland ecosystem components, processes and services. Local federations of farmers and tour operators have been able to negotiate their interests, but the voice and needs of other user groups as fishers and clam collectors have remained unrepresented.

4.2 NATIONAL EXPERIENCES

Wetland management requires coordination between multiple stakeholders and sectors across river basins and coastal zones within which the wetlands are located. In several

Office of Karappuram whitelime shell co-operative society

states, this is being done through creation of dedicated wetland authorities. The Loktak Development Authority (LDA) constituted in 1986 was one of the first such institutions in the country. This was in the context of rapid degradation of Loktak Lake, one of the largest freshwater lakes in the northeast due to species invasion, shrinkage in area and reduction in water holding capacity, particularly after the commissioning of Loktak Hydro-electric Project in 1983. The Authority was initially placed under the aegis of Irrigation and Flood Control Department, but later on transferred under the administrative control of the Forest and Environment Department. In 1992, the Government of Orissa constituted the Chilika Development Authority to address the pressures on Chilika Lake, the largest brackishwater lagoon on the east coast threatened by increasing silt load, declining fisheries and expansion of shrimp aquaculture. In 1997, the Government of Jammu and Kashmir constituted the Lakes and Waterways Development Authority under the aegis of the Housing and Urban Development Department for restoration of Dal and Nigeen Lakes. Within the decade of 2000, separate wetland authorities were created for waterbodies of Madhya Pradesh, lakes within Bengaluru City, and East Kolkata Wetland. The Lake Conservation Authority of Madhya Pradesh initially focused on Bhoj Wetlands but was entrusted the mandate for conservation of all waterbodies of the state in 2004. The State of Odisha constituted a distinct wetland authority for the entire state in 2012.

Most of the wetland authorities have been formed as government societies under the provisions of the Societies Registration Act. The governance structure includes a governing body for strategic planning and decision making; an executive body for approving management plans and projects and an authority office to implement the approved actions plans. The authorities function as strategic bodies responsible for planning, ecosystem monitoring, networking, stakeholder participation and awareness generation. Field implementation of the restoration activities is organized through line departments and external agencies. East Kolkata Wetlands Management Authority and Loktak Lake draw their constitution and powers through specific acts, and therefore have "statutory authority" in the true sense. The Government of Odisha is also in advanced stages of considering a regulatory backing for Chilika Development Authority, particularly to control detrimental fishing practices. Absence of a regulatory backing to the authorities is seen as a major constraint for most of the wetland management authorities. The ability of the wetland authorities to spearhead design and implementation of integrated restoration plans is evident.

Of the 7 authorities, 5 have site management plan in place and all (except the recently established Odisha State Wetland Authority) are implementing restoration and management plans. The Chilika Development Authority has successfully enabled a participatory ecosystem restoration leading to restoration of ecological environs as well livelihoods of dependent communities. The restoration of Chilika has been recognized by Ramsar Convention with the prestigious Ramsar Wetland Conservation Award to the Authority in 2002, and removal of the site from the Montreaux Record. Loktak Development Authority has formulated an integrated management plan for the site at river basin level and has been able to secure financial support of Rs. 400 crores from the Planning Commission for implementation of the plan. The Lake Conservation Authority implemented a restoration plan for Bhoj wetlands with financial support of Japan Bank for International Cooperation leading to tangible improvement in lake environments. However, changing complexities within the river basin and securing financial support have been major challenges faced by most of the authorities.

The following are the key lessons and experiences with reference to establishing wetland management institution:

- **Distinct institution for wetland management:** The cross sectoral and multi-stakeholder needs for wetland management can be best served by designating a separate institution responsible for ensuring cross sectoral coordination and

balancing interests of stakeholders while ensuring ecological integrity of the wetland system.

- **Strategic planning and coordination function**: Wetland authorities need to function as strategic planning and coordinating bodies maintaining an overview of the overall ecological state and trends and the drivers and pressures on wetland ecosystem within the wider landscapes as river basins and coastal zones. The capacity to implement interventions for ecological restoration is available within the respective departments, however, the wetland authorities need to provide the integrated cross –sectoral plans, evaluate implementation effectiveness and suggest mid-course corrections.
- **Capacity and financing:** The success of wetland authorities is closely related to availability of adequate human and financial resources to design and implement ecological restoration plans. Infrastructure for wetland monitoring and evaluation form a critical part of this capacity.
- **Adaptable management:** Wetland management institutions need to be adaptable to be able to work in ever changing ecological and socio-political landscapes. The success of management is linked to the ability to modify management based on a continuous evaluation of features and governing factors.
- **Participation and awareness:** The governance structure of wetland authorities should reflect the diversity of stakeholders influencing the state of wetlands. A mix of political, technical, administrative and civil society representation on the governing body enables better coordination and ensured sanctity to the management processes. The institutional mechanisms responsible for wetland management also need to create an enabling environment by enhancing awareness on wetland ecosystem services and biodiversity.
- **Regulatory regimes:** Wetlands are open systems and as such are exposed to a range of pressures including those from unsustainable use. In several circumstances, application of state acts and regulations provide a means to regulate these activities to ensure ecological integrity of wetlands. However, in wetlands which are intensively used for livelihoods and placed within a context of rapid urbanization and industrialization, wetland authorities need to be empowered with suitable regulation to ensure conservation and wise use.

4.3 Proposed institutional arrangements for managing Vembanad-Kol

Rationale | It is proposed to set up Kerala Wetland Management Authority (KWMA) to address the need of a unified institutional mechanism for conservation and management of wetlands of the State of Kerala.

Legal Status | The Authority can be registered as a non-profit organization under Societies Registration Act, 1860. As per the provisions of the Act, a Memorandum of Association defining the jurisdiction, aims and objectives and governance structure will need to be submitted to the Registrar of Authorities. Rules and Regulations detailing the membership, powers and functions of governing and executive bodies, accounting and audit procedures, and management of property of the authority will also need to be formulated and submitted to the Registrar.

The administrative control of the authority is proposed to be under the aegis of Department of Forest and Environment which has an overarching mandate for conservation of the state's natural resources.

Mission | The KWMA will work towards the mission "to conserve, restore and sustainably manage wetlands of the state to maintain and enhance their biodiversity and ensure

sustained provision of their full range of ecosystem services to support well-being of dependent communities".
Initially, the authority may be mandated to be responsible for management of three wetland sites prioritized by the state government for integrated management, i.e. Vembanad-Kol, Sasthamcotta and Asthamudi. Over a period of time, however, management of all wetlands should be consolidated under this authority. Site management can then be divested to wetland committees, under the overall administration of KWMA.

Powers and Functions | Initially, the authority can draw it powers based on The Kerala Conservation of Paddy Land and Wetland Act, 2008; Wetland (Conservation and Management) Rules, 2010 and Coastal Regulation Zone Notification, 2011. For this, the required procedure for notification of these wetlands under the wetland rules will need to be completed. In the case of Vembanad-Kol, the management of entire wetland complex should be vested, and a principle of zoning applied for management (Further detailed in Chapter 5).

KWMA will serve as the autonomous regulatory, planning and policy making body for conservation, restoration and sustainable management of the wetlands of the state. Its functions will include establishing policy framework, regulation, providing technical advice, design and coordinating implementation of integrated management plans, networking and collaboration, capacity building, and communication and outreach on wetland management. Specific functions are as below:

1.	Policy	1.1	Formulate policy guidelines for conservation and sustainable management of the wetlands of the state
		1.2	Identify and make recommendations for designation of wetlands as Wetlands of International Importance (Ramsar Sites), National Importance (for example under the National programme on Conservation of Aquatic Ecosystems) or any other international and national programme
2.	Advise	2.1	Advise the state government, its agencies, local authorities and autonomous agencies on matter pertaining to conservation and management of wetlands
		2.2	Act as a clearing house for all technical matters related to wetlands
3.	Regulation	3.1	Act to regulate and control all activities detrimental to maintenance of biodiversity and other ecological components, processes and services of wetlands
		3.2	Ensure compliance with the existing national and state level regulatory frameworks related to wetlands
		3.3	Approach the state government for enactment of any regulation for achieving conservation and sustainable management of wetlands in the state
4.	Integrated management planning	4.1	Formulate integrated management plans for conservation and sustainable use of prioritized wetlands
		4.2	Work towards mainstreaming wetlands in sectoral programmes and policies , *inter alia,* water resources development, rural development, agriculture, urban development to ensure complementarity of the sectoral programmes with wetland ecosystem services and biodiversity and in particular prevent any detrimental impact
5.	Wetland management	5.1	Coordinate and facilitate implementation of the following activities (within the ambit of site management plans) by organizations, institutions, departments, and local communities:

		a) restoration of hydrological regimes, including improvement of water quality b) control of silt load from catchments c) management of plant and animal invasives d) ecological restoration and habitat improvement e) sustainable development of capture and culture fisheries f) livelihood improvement and disaster risk reduction with communities living in and around wetlands g) community-managed eco-tourism development 5.2 Work towards resolution of trans boundary, trans catchment and multi-stakeholder conflicts
6.	Monitoring and Evaluation	6.1 Develop and maintain a wetland inventory, assessment and monitoring system, based on scientific guidelines, to assess and respond to changes in wetland components, processes and services 6.2 Commission strategic environmental assessments for developmental projects likely to create detrimental impacts on wetland biodiversity and ecosystem services 6.3 Collate and disseminate periodic reports on status of wetlands of the state.
7.	Capacity Building	7.1 Upgrade management and professional skills of authority members, staff and local communities involved in wetland management
8.	Research	8.1 Promote multi-disciplinary research on wetlands to support integrated and adaptive management
9.	Networking and collaboration	9.1 Collaborate with other state, national and international institutions to promote the cause of conservation and sustainable management of wetlands
10.	Awareness generation	10.1 Develop a communication and outreach strategy for wetlands of Kerala 10.2 Maintain a dedicated website on wetlands of Kerala 10.3 Create awareness on wetland biodiversity and ecosystem services through organizing special events, communication and other channels as may be appropriate
11.	Financial management and fund raising	11.1 Secure funds for implementation of wetland management plans by developing collaborative projects for funding support by state, national and international donors 11.2 Acquire by gift, purchase, exchange, lease, hire or otherwise any property movable or immovable necessary for implementing the objectives of the society 11.3 Draw, accept, make and endorse for the purpose of the authority, discount and negotiate Government of India and other promissory notes, bills of exchange, cheques or other negotiable instruments.

Governance | A three tier governance structure is proposed for KWMA with the Governing Body at the apex, an Executive Committee responsible for approval of implementation plans and projects, and an office of the Chief Executive to implement the programmes (Table 4.1).

The Governing Body, being responsible for the overall strategic direction for wetland management should have a broad based membership with the secretaries of all concerned state government departments, elected representatives, local administration, community representatives, non-government organizations and external experts. It is proposed to have Chief Minister of the state as the Chair to ensure political leadership and cross sectoral coordination at the highest level.

The Executive Committee is envisioned to be responsible for operationalization of the strategic direction as set by the Governing Body through implementation plans and projects. The Committee will approve management plans and various projects of the authority. It is proposed to constitute a wetland management advisory group to provide strategic review and advise on action plans to the Executive Committee.

Implementation of the plans and projects will be done through the office of the Chief Executive in coordination with line departments. The office will be responsible for inventory, assessment and monitoring of the sites; conduct periodic review of management plan implementation to support decision making; create awareness amongst stakeholders; build capacity of wetland managers and stakeholders and conduct research and development on various aspects of wetlands.

Table 4.1 | Governance Structure of KWMA

Governance level	Role and Functions	Membership Structure
Governing Body	▪ Frame wetland regulation with approval of the state government ▪ Approve annual plan and budget of the authority ▪ Make, amend or repeal bye laws of the authority ▪ Decide and recommend to the state government wetland to be brought under the authority ▪ Enter into an agreement for an behalf of the authority for furtherance of its objectives ▪ By resolution, appoint advisory boards or other special committees to support implementation of objective of the authority	<u>Chairperson</u> ▪ Chief Minister, GoK <u>Members</u> ▪ Minister, Forest and Environment, GoK ▪ Chief Secretary, GoK ▪ Secretary, Environment and Forests, GoK ▪ Principal Chief Conservator of Forests, GoK ▪ Chief Wildlife Warden, GoK ▪ Principal Secretary, Animal Husbandry and Fisheries, GoK ▪ Principal Secretary, Water Resources, GoK ▪ Chief Engineer, Water Resources, GoK ▪ Principal Secretary, Tourism, GoK ▪ Principal Secretary, Rural Development, GoK ▪ Chairman, Kerala State Pollution Control Board ▪ Advisor (Wetlands), Ministry of Environment and Forests, GoI ▪ District Collector (for the districts in which the wetlands are located)

	▪	▪ Representative, Fisher Society ▪ Representative, Farmers Society ▪ Representative, Clam Collector Society ▪ Representative, Coir Society ▪ Representative, Non-Government Organization working on wetland issues of the state ▪ Experts (2 / 3) drawn from universities / research institutions <u>Member Secretary</u> ▪ Chief Executive, KWMA
Executive Committee	▪ Appoint and maintain service conditions of staff of the authority ▪ Grant approval for integrated management plans for implementation ▪ Seek funds for implementation of wetland management plans ▪ Constitute sub-committees for implementation of management plans ▪ Enforce regulations for maintenance of ecological character of wetlands within the ambit of KWMA	<u>Chairperson</u> ▪ Principal Secretary, Forest and Environment, GoK <u>Members</u> ▪ Principal Chief Conservator of Forests, GoK ▪ Chief Wildlife Warden, GoK ▪ State Director, Animal Husbandry and Fisheries, GoK ▪ Chief Engineer, Water Resources, GoK <u>Member Secretary</u> ▪ Chief Executive, KWMA
Office of Chief Executive, KWMA	▪ Formulate, coordinate and supervise the projects ▪ Institute and defend proceedings on behalf of the authority ▪ Wetland assessment, monitoring and evaluation ▪ Communication and outreach on wetlands ▪ Capacity building and training ▪ Research and development	

Chinese dipnet in Fort Kochi

5 | Management planning framework

5.1 Goal and Purpose

Vembanad—Kol wetlands are situated amongst an intensive development landscape. The wetland is located in one of the most populous coastal segments of the Malabar coastline, in the vicinity of one of the largest industrial belts of Kerala, includes the rice bowl of the state and is a center of backwater tourism. Developmental planning has focused on a narrow range of ecosystem values (wetland agriculture and tourism) creating adverse impacts for the biological diversity of the wetland complex and drastically curtailing the ability of the wetland ecosystem to regulate hydrological regimes. Management planning for Vembanad-Kol calls for maintaining the site's values and functions while at the same time delivering ecosystem services now and into the future.

The goal of management planning for Vembanad-Kol is to **conserve its rich biological diversity and maintain full range of ecosystem services derived from the wetland complex in order to sustain livelihoods of dependent communities**.

The purpose is to put in place **effective management practices which enable integration of biological diversity and ecosystem service values in river-basin and coastal zone level conservation and developmental planning.**

5.2 Management Strategy

Creation of a dedicated institution for wetland management and intersectoral coordination | Integrated management of Vembanad- Kol requires a dedicated institution for coordinating implementation of sectoral action plans, maintaining an overview of status and trends of wetland and associated catchments, stakeholder engagement and representing the concerns related to wetlands in sectoral planning. Based on review of existing institutional arrangements and national experiences, it is recommended to constitute Kerala Wetland Management Authority (KWMA) as the nodal institution to ensure integrated management in collaboration with concerned state government agencies, Ministry of Environment and Forests, research agencies, non-government organization, civil society organization and local communities. An important task of the authority will be to ensure a unified vision of wetland conservation and wise use in the sectoral plans, especially for agriculture, water resources, fisheries, rural development and climate change adaptation.

Management zoning for multiple ecosystem services| The three physiographic divisions of Vembanad-Kol, namely the Vembanad Estuary, Kuttanad and Kol lands,

though interlinked and forming an integral part of the wetland complex, have distinct ecosystem services and biological diversity characteristics. Vembanad Estuary is the predominant waterspread area wherein capture fisheries and clam are available, is a major focus of tourism and which can be managed for achieving hydrological regime regulation function of the wetlands. Kuttanad and Kol lands have been modified as production systems wherein rice paddies and aquaculture co-exist with high biological diversity, particularly waterbirds. Given the level of site-complexity, a zoning strategy can be used for Vembanad-Kol wherein production values of Kuttanad and Kol are managed to avoid any adverse impacts on Vembanad Estuary, and the estuary managed to support ecological processes, for example ensuring circulation and mixing, and species migration. Management of sites with high recorded species diversity as Pathiramanal Island, Mangalvanam Bird Sanctuary and Kumarakom can be aligned with biodiversity conservation objectives of wetland management.

A stakeholder led wetland management that balances biodiversity conservation and livelihoods and are compatible with wetland regimes should be encouraged. Further, in the entire wetland catchment, land and water use needs to be influenced to ensure that the wetland retains its hydrological connectivity with the rivers and the sea and the natural regimes of water spread and salinity are maintained.

Sustainability of backwater tourism | Backwater tourism has emerged as a hallmark of Kerala. High concentration of tourism infrastructure in Alapuzzha region (number of houseboats, tourist accommodation) and insufficient waste treatment facilities are major threats on ecological character of Vembanad-Kol. It is important that tourism in Vembanad-Kol is managed based on carrying capacity, and ecological as well social safeguards are put in place so that the sector is synergized with conservation and wise use of wetland complex.

Sustaining wetland agriculture | Rice paddies of Kutttanad and Kol have been developed to meet the food security needs of the state. However, at least in Kuttanad, there are several indications of ecological and social limits to the levels of production and productivity that can be achieved. It is important that these limits are recognized in planning, and production strategies diversified so as to ensure that management objective of maintenance of ecological character are met in ecologically and socially efficient manner. Farming systems that are compatible with wetland environments need to be promoted in the two regions.

Ensuring appropriate balance of estuarine and coastal processes and hydrological connectivity | In its current state, hydrological regimes of Vembanad-Kol are managed as per the needs of agriculture and flood control. Water needs for ecological purposes (maintenance of water quality, species migration etc.) would need to be included within the current water management planning and decision making based on a stakeholder driven process. Hydrological regime requirements of wetland will need to be integrated in operation of upstream hydraulic structures as well as Thaneermukom Barrage.

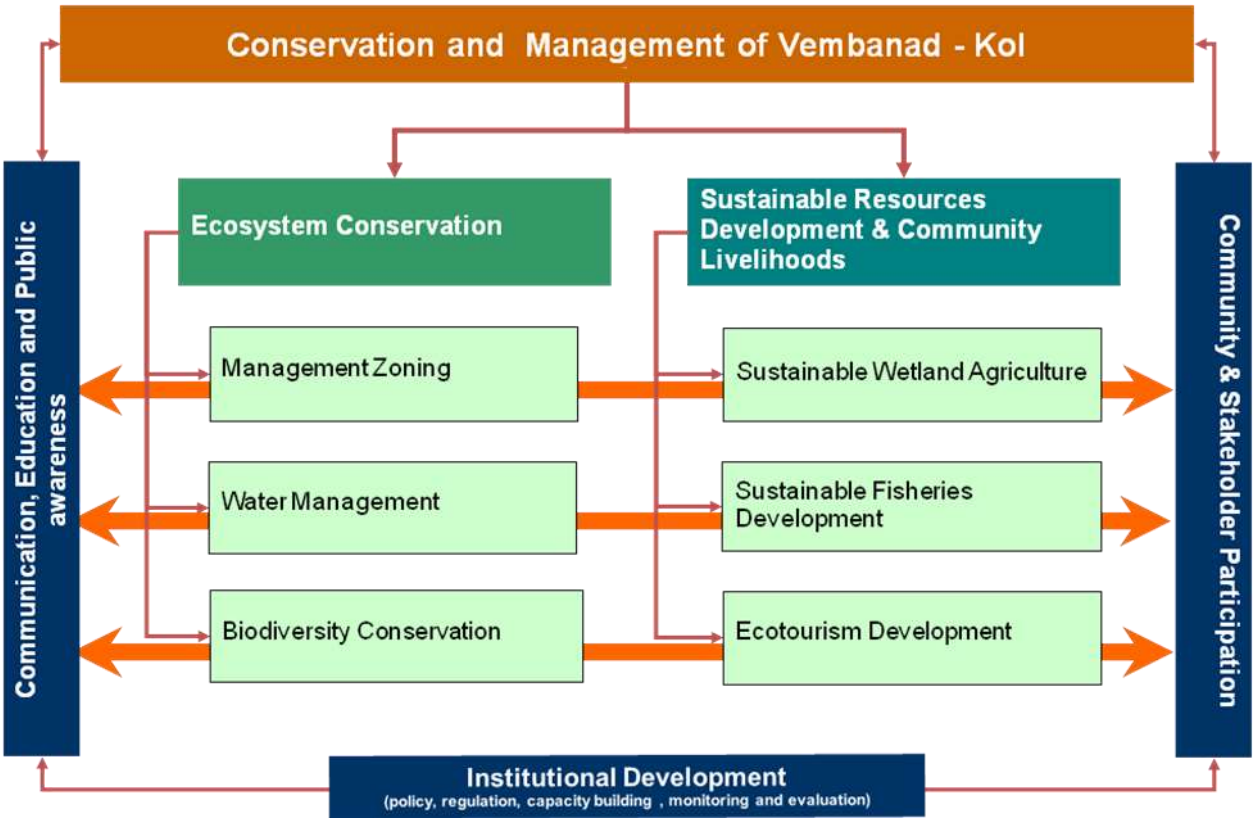
Monitoring and evaluation for ecological character change | Monitoring and evaluation is critical to assess changes in ecological character of Vembanad-Kol wetlands. Management planning would therefore strive to put in place an integrated wetland inventory, assessment and monitoring system to support establishment of ecological and socioeconomic information baseline, assessing efficiency of management interventions and determining impacts of developmental projects on Vembanad-Kol. An important part of the strategy would be to involve stakeholders, particularly local communities and civil society organizations in wetland monitoring. The KWMA would also work towards creating a network of specialist organizations to support assessments and independent review of quality and outcomes of inventory, assessment and monitoring efforts.

Capacity building | A major factor limiting integrated management of Vembanad-Kol is lack of effective capacity amongst concerned state government departments, stakeholders and local communities. The management plan therefore emphasizes on building capacity on wetland management, particularly recognizing biodiversity and ecosystem services features and governing factors and integrating these in planning, decision making and implementation at all levels.

Adaptive management | Given the range of drivers and pressures that act on Vembanad-Kol at multiple spatial, temporal and political scales, its management planning needs to be prepared for and accommodative of uncertainties and challenges. This is envisaged to be achieved by using adaptive management strategy allowing for suitable modification of management based on continuous site monitoring and assessment of new information. Since the ability of the plan to meet all site management objectives is influenced by availability of information as well as resources, management is considered as a process, with planning gradually getting complex from a minimal version to the one meeting all site management requirements as resources and information become available.

5.3 Action Plan

The action plan is envisaged under three components namely institutional arrangements, ecosystem conservation and sustainable resource development and community livelihoods.



Component I: Institutional arrangements

Expected Results

- An effective arrangement for cross sectoral coordination and multi-stakeholder engagement in wetland management established and operationalized
- Systematic wetland inventory, assessment and monitoring system established to support decision making management
- Capacity of concerned state government departments and agencies, civil society organizations and local communities for integrated wetland management developed and enhanced

Activities

1.1 Establishment of Kerala Wetland Management Authority
KWMA is proposed to be established as a nodal agency mandated for coordinating integrated management of Vembanad-Kol. The rationale, powers and functions, and governance structure have been discussed in Chapter 4 of the report. Specific activities to be undertaken include:

- Finalization of Memorandum of Association and governance structure
- Notification of KWMA
- Registration under appropriate act (eg. Societies Registration Act)

1.2. Establishment of integrated wetland inventory, assessment and monitoring system
An integrated wetland inventory, assessment and monitoring system is proposed to be set up to address the overall information needs of wetland management and to provide robust decision support system for the same. Specific activities include:

- Establishment of a wetland monitoring and research centre (Given the state of infrastructure and human resource capabilities, it is recommended that CWRDM is designated as wetland monitoring and research centre for the state)

- Development of a database management system. This includes development of data quality and management plan specifying data collection objectives, sampling programme design, data and metadata documentation procedure, data quality control methods and performance audit procedures. A GIS based database management system should also be developed as an implementation platform.

- Wetland monitoring and evaluation as per agreed protocols (outlined in section 5.5) to be implemented.

- Assessment studies. Following studies are recommended to be commissioned to inform wetland management;

    - Environmental flows assessment to define water regime requirements for maintaining water circulation and mixing, species migration and other ecological processes

    - Fish breeding and migration to assess interaction between riverine, estuarine and marine environments, presence and status of breeding grounds, strategies for improving habitat condition

- Ecological character risk and vulnerability to determine limits of acceptable change for critical ecosystem components, processes and services; sensitivity and adaptive capacity; and risk of adverse change

- Ecosystem service valuation to assess contribution made by wetland ecosystem services to local livelihoods and regional food and water security; thresholds and required conditions for delivery of ecosystem services; conservation – development tradeoffs and strategies for incentivizing ecosystem services stewardship

- Climate risks and vulnerability to assess degree of risks for priority ecological character elements; climate scenarios for wetland ; and risk management options

1.3 Capacity building

Capacity building of KWMA, concerned state government departments, agencies and resource user groups (padashekharam committeees, coir retting units, clam collectors units) needs to be undertaken through professional training in integrated wetland management, water management, biodiversity conservation, wetland inventory and assessment and sustainable livelihoods.

1.4 Communication and outreach

Stakeholder engagement in wetland management will be promoted through creating awareness of values and functions of Vembanad-Kol, management strategies and opportunities for participation. Specific activities:

- Workshops and public events on conservation and wise use of Vembanad-Kol involving media, research agencies, NGOs and CBOs
- Maintenance of an interactive web-site on Vembanad-Kol as a means of information dissemination
- Observation of World Wetlands Day and other environment related occasions
- Publication of newsletter and thematic brochures

Component II: Ecosystem Conservation

Expected Results

- Wetland regimes are maintained
- Hydrological regime requirements for maintenance of wetland processes and ecosystem services are integrated in water management planning and decision making
- Key biodiversity habitats and migratory pathways are restored and enhanced
- Water quality of wetland is improved to support biological diversity and reduce health impacts on communities living in and around

Activities

2.1 Management zoning

GIS based delineation of Vembanad estuary; Kuttanad and Kol areas will be carried out. For each of the three physiographic zones, a zonal plan setting thresholds of various development activities with consideration of existing regulatory regimes (provisions of Kerala Conservation of Paddy Land and Wetland Act (2008), Wetland (Conservation and Management) Rules, 2010 and Coastal Regulation Zone Notification (2011)), ecological sensitivities and socio-economic requirements will be developed. These plans would be used as a basis for intersectoral coordination by KWMA.

2.2 Water management

2.2.1 Improvement of hydrological regimes

Design and implementation of stakeholder endorsed policy for operation of Thaneermukom Barrage

Building on the assessments of IIT and CWRDM on upgradation of Thaneermukom Barrage to address salinity and flooding concerns, it is recommended that an improvised operation regime considering the ecological needs (as species migration, water circulation and flushing and maintenance of biodiversity habitats) is designed and implemented with participation of major stakeholders. Following steps are recommended:

- Set water management objectives to be achieved through reoperation of Thaneermukom Barrage
- Define water regime requirements for wetland agriculture in Kuttanad
- Define water regime requirements for wetland ecosystem processes and maintenance of biodiversity habitats
- Develop scenarios for barrage operation and assess outcomes for identified objectives
- Evaluate scenario outcomes based on agreed ecological and social indicators
- Identify required barrage operation schedule and monitoring mechanism
- Barrage reoperation and performance evaluation
- Review and adaptation of barrage operation rules

Improved hydrological connectivity

- Comprehensive assessment of canal networks in Kuttanad and Kol to identify flow impediments and extent of siltation
- Improvement of canal network in Kuttanad and Kol by removing flow impediments, encroachments and selective desiltation
- Assessment of road networks (particularly AC road) in terms of flow orientation
- Construction of culverts and bridges to ensure adequate water conveyance (C and D Blocks in Pulinkunnu panchayat and Rani and Chithira blocks in Kainakari and in the AC 11 canal flanking the AC road have been identified as priority intervention areas by MSSRF)
- Selective desilting of confluence of inflowing rivers with Vembanad Estuary
- Regulation of sand mining in river channels and floodplains based on Strategic Environmental Assessments (Periyar and Muvattupuzza to be taken on a priority)
- Maintenance of connectivity with the sea through management of freshwater inflows and selective dredging

Reduce siltation

- Assessment of silt loading from rivers and identification of degraded watersheds
- Preparation of micro-watershed conservation plans
- Delineation and identification of critical watersheds using capability assessment
- Controlling deforestation and destruction of natural forest cover
- Afforestation, regeneration and activities to stabilize stream banks through small scale soil conservation measures.
- Creation of silt traps at high sedimentation locations

2.2.2 Water quality improvement

- Preventing discharge of untreated industrial waste from Udyogmandal Region
- Comprehensive sanitation coverage in villages around Vembanad-Kol wetland complex and banning direct discharge of household sewage
- Pilot projects for treating effluents of coir retting units (major concentration in Parur and Vaikom), upscaling based on ecological, economic and social efficiency

- Comprehensive coverage of waste collection and treatment for houseboats
- Expansion and upgradation of waste treatment facility at Kumarakom
- Upgradation of waste management facilities in major population centres as Kochi and Ernakulam
- Upgradation of waste management facilities at Sabarimala

2.3 Biodiversity conservation[1]

2.3.1 Improving waterbird habitat

- Detailed waterbird habitat mapping for major congregation sites in Vembanad-Kol wetland complex
- Baseline assessment for creation of a community conservation reserve including KTDC Complex – Pathiramnal Island
- Community mobilization for controlling poaching and regulating use of pesticides in waterbird congregation areas in Kuttanad and Kol
- Improvement of habitats in Muhamma, River Kavanar, Kaipuzha muttu (Vaikom) (other sites to be identified based on detailed assessments) through construction of artificial nesting sites (floating platforms / earthen mounds, earthen mounds, marshes and trees near wetland area) with plantation by native species and watch towers
- Strengthening waterbird habitat assessment and monitoring network through specialized training, awareness and participation incentives

2.3.2 Mangrove restoration

- Survey and demarcation of mangrove areas in and around wetland complex
- Promotion of incentive based mangrove restoration programmes in pilot sites around Kumarakom for private land owners
- Creation of community awareness on values and functions of mangrove ecosystems

Component III: Sustainable resource development and community livelihoods

Expected results

- Wetland based production systems sustained
- Community ownership of wetland resources is promoted
- Livelihoods diversified to reduce dependence on wetlands and provide additional income sources for wetland dependent communities
- Wetland based ecotourism developed as an incentive for communities to benefit from biodiversity conservation and maintenance of wetland habitat

[1] Interventions for maintaining fish and clam diversity have been included in Component III on sustainable resource development

Activities

3.1. Sustainable wetland agriculture[2]

- Pilot testing and upscaling of integrated farming models to diversify cropping patterns aligned with ecological conditions
- Improvizing polders through use stiff clay and materials which reduce environmental impacts on wetland and have lower maintenance costs
- Development and enforcement of crop calendar harmonized with ecology of estuary
- Polder reorganization and crop cycle management to improve ecological and economic efficiency
- Create incentives for organic farming, and reducing use of chemical fertilizers and pesticides
- Increase awareness on pokkali farming system, and mechanisms for enhancing area and economic viability, including branding as sustainable produce

3.2. Sustainable fisheries development

- Assessment and demarcation of breeding and spawning ground of fin and shell fish
- Tagging experiment on commercially important fish species to assess migratory pathways, distribution and growth rates
- Community mobilization to prevent fishing operations in breeding and spawning grounds near lake mouth and river confluence
- Regulation of use of fishing gears with small mesh size (priority for stake nets)
- Mapping clam beds and imposing cyclical closed periods for revival
- Promote use of aquaculture best practices in culture fisheries around wetland complex
- Promote culture of ornamental fish species as an alternate livelihood option for fisher

3.3. Ecotourism development

- Carrying capacity assessment of Vembanad backwaters for tourism
- Developing an action plan for regulating tourism below carrying capacity
- Creation of a wetland interpretation center at Kumarakom focused on biological diversity and ecosystem services of Vembanad-Kol
- Development of signage on Vembanad-Kol wetlands at major tourist entry locations – Kumarakom, Alappuzza and Kochi
- Training of houseboats owners on ecological features and sensitivities
- Development of guidance on do's and don'ts for tourists

5.4 PHASING AND PRIORITIZATION

Implementation of integrated management plan for Vembanad-Kol needs to be taken up in phases. The first priority needs to be accorded to putting in place an institutional arrangement for managing Vembanad-Kol, and defining reoperation schedules for Thaneermukom Barrage considering ecological and human requirements for water regime. A process of community engagement for management of Vembanad-Kol should also be initiated, along with investment in communication and education on wetland values and functions.

In the second stage, the designated authority should take up development of management zoning plans and implement regulatory measures to secure the wetland boundary and coastal zone, and prevent direct dumping of untreated waste and sewage.

[2] Recommendations of MSSRF study have been incorporated

Interventions for augmenting waste management infrastructure should also be taken up. Reoperation of Thaneermukom Barrage will provide opportunities for undertaking actions for sustainable agriculture and fisheries development. In this phase, it is envisaged that the monitoring and evaluation mechanism for Vembanad-Kol would be ready for implementation.

5.5 MONITORING AND EVALUATION

Management of Vembanad-Kol is aimed at maintaining its ecological character, and in doing so, retaining those essential ecological and hydrological functions which ultimately enable the wetland to provide its provisioning, regulating and cultural services. Having a system to describe, monitor and detect changes in ecological character is therefore critical to support decision making for wise use of Vembanad-Kol.

The present system for monitoring the wetland complex is highly fragmented and disjointed. A few agencies (for example, Department of Water Resources, Central Water Commission, Central Ground Water Board, State Pollution Control Board, Zoological Survey of India, NGOs as Kottayam Nature Society) collect information on specific parameters of interest. There is no system at present systematic collection of data on various wetland features and collating the same to support management. This severely limits the possibility of objectively defining the status and trends of various wetland features, and identification of related drivers and pressures.

Developing a monitoring plan for Vembanad-Kol requires addressing the inter-related requirements of wetland inventory (the collection and collation of core information for wetland management), and wetland assessment (identification of status and threats to wetlands as a basis for collection of more specific information). The imperative therefore is to put in place an integrated Wetland Inventory, Assessment and Monitoring System (WIAMS) to address the overall information needs of wetland management, and to provide a robust decision support system for the same. The specific objectives for establishing WIAMS include:

- Developing an up-to-date and scientifically valid information on status and trends of wetland features and influencing factors
- Establishing a baseline for measuring change in ecological character
- Informing decision makers and stakeholders on the status and trends in biodiversity, ecological functioning, ecosystem services and biodiversity of the wetland
- Supporting compliance to national and state legal requirements and regulatory regimes
- Assessing efficiency of wetland management interventions
- Determining impacts of developmental projects on ecosystem components, processes and services
- Identifying risks to ecological character and support development of response strategies

Ecological character of Vembanad-Kol is influenced by a range of drivers and pressures acting at multiple scales and mediated by several factors. The monitoring strategy is therefore aimed at detecting any change causing or likely to have adverse effect on ecological character (and limiting the possibility of achieving wise use) to ensure appropriate management response.

Since these information pertain to various spatial scales, the overall information requirements can be classified at three hierarchical levels: a) Vembanad Estuary, b) Vembanad-Kol wetland complex, and c) VEmbanad-Kol wetland basin. A hierarchical classification of inventory, assessment and monitoring needs is presented in Table 5.1. The information needs for inventory are derived from the core datasets needed to

establish a baseline on ecological character for Vembanad-Kol, and contain all the essential ecosystem components, processes and services, as well as management related parameters that characterize the site. At the basin scale, the information requirement is related to geo-morphological and climatological setup, as well as basin wide management arrangements, particularly those related to land and water resources. Within the wetland complex, the focus is on assessing the habitat connectivity and water, sediment, energy and nutrient flux which influence ecological character of Vembanad-Kol. Finally, at the site scale, the information requirements pertain to important ecosystem component, processes and services, which are applicable to the site condition. At all levels, information on institutional arrangements and management practices is included so as to enable creation of a baseline on sectoral programmes, and the linked stakeholders, which are likely / have an impact on the wetland state.

Information needs related to assessment are aimed at deriving the status, trends and existing / likely threats to wetland system. At the site and wetland complex scale, the focus is on deriving ecological character change, and the vulnerability of ecological character change, based on deriving limits of acceptable change for the ecological character feature of interest. Specific assessments related to fish migration, waterbird habitats and invasive macrophytes have also been identified based on the review of wetland features contained in previous chapters. While not explicitly mentioned, strategic environmental assessments can be commissioned for any developmental project that has / likely to have negative impact on the wetlands.

The monitoring and assessment needs are envisaged to be addressed by a dedicated monitoring programme and specific research and assessment projects. Inventory, being based on collated information on identified wetland features and management practices, will be developed based on the monitoring and assessment information, as well as secondary sources.

Table 5.1: Inventory, assessment and monitoring needs for managing Vembanad-Kol

	Information Purpose		
Information Scale	**Inventory**	**Assessment**	**Monitoring**
Vembanad-Kol Basin	**Climate** (Precipitation, temperature, wind, humidity, evaporation) **Land use, land cover and management practices** **Water regimes** (riverine flows, bankflows and connectivity with wetlands, regulation, abstraction) **Sectoral programmes and institutional arrangements** for management of land and water resources and biodiversity conservation	**Climate risk and vulnerability** (perception of climate related risks based on sensitivity and adaptive capacity of critical ecological character elements, ecological character change scenarios and risk management options) **Environmental flows** (degree to which the water and sediment flows required to maintain ecological integrity and ecosystem services of Vembanad-Kol are provided for and maintained)	**Land use and land cover change** **Hydrological regimes** (riverine flows of water and sediment; inundation regime; riverine connectivity; surface-groundwater connectivity; water quality; water use pattern)

Vembanad-Kol wetland complex	**Climate** (precipitation, temperature, wind, humidity, evaporation) **Physical setting** (area, boundary, connectivity) **Water regime** (inflow, outflow, balance, surface-groundwater interactions, inundation regimes, quality) **Sediment regime** (inflow, outflow, balance, distribution and transport) **Biota** (plant and animal communities, conservation status) **Energy and nutrient dynamics** (primary production, nutrient cycling) **Species interaction** (invasion) **Processes that maintain animal and plant population** (migration) **Ecosystem services, stakeholders and tradeoffs** (Regulatory, provisioning, cultural, supporting) **Institutional arrangements** (governance, formal and informal rights and ownership, application of acts and regulations)	**Ecological character risk and vulnerability** (limits of acceptable change for critical ecosystem components, processes and services; sensitivity and adaptive capacity of critical components; risks of adverse change in ecological character) **Fish migration** **Bird habitat assessment**	**Hydrological regimes** (water and sediment inflow, outflow and balance; inundation regime; riverine connectivity; surface-groundwater connectivity; water quality; water use pattern) **Ecological components and processes** (abundance and diversity of plankton, benthos, macrophytes, fish and birds; fish catch, effort, recruitment and migration; waterbird congregation sites and habitat quality) **Socioeconomics and livelihoods** (community dependence on wetland resources, ecosystem services and livelihood interlinkages, conflicts)
Vembanad estuary	**Physical setting** (area, boundary, topography, shape, bathymetry, habitat type and connectivity) **Climate** (precipitation, wind, temperature, humidity) **Water regime** (inflow, outflow, balance, surface-groundwater interactions, inundation regimes, quality) **Sediment regime** (inflow, outflow, balance, distribution and transport) **Wetland soils** (texture, chemical and biological properties) **Biota** (plant and animal communities, conservation status) **Energy nutrient dynamics** (primary productivity, nutrient cycling, carbon cycling, decomposition, oxidation-reduction) **Processes that maintain animal and plant population** (recruitment, migration) **Species interaction** (competition, predation, succession, herbivory) **Ecosystem services, stakeholders and trade-offs** (regulating, provisioning, cultural, supporting) **Institutional arrangements** (governance, formal and informal rights and ownership, application of acts and regulations)	**Ecological character change** (change in ecosystem components, processes and services – can also be derived based on assessment of indicators related to ecosystems, habitat, species and / or management) **Ecosystem services valuation and tradeoffs**	**Hydrological regimes** (water and sediment inflow, outflow and balance; water and sediment chemical quality; water use pattern) **Ecological components, processes and services** (abundance and diversity of plankton, benthos, macrophytes, fish and birds; fish catch, effort, recruitment and migration; waterbird congregation sites and habitat quality) **Socioeconomics and livelihoods** (community dependence on wetland resources, ecosystem services and livelihood interlinkages, conflicts)

5.6 BUDGET AND FUNDING

Much of the management plan implementation can be achieved through creating a designated institution for wetland management and coordinated implementation of sectoral development plans major being Kuttanad Package and Pamba River Action Plan. A ball-park estimate of resource requirement for management plan is presented below, which can be further fine-tuned based on detailed activity based budgeting. Funding can be secured under the National Plan on Conservation of Aquatic Ecosystems as well as dovetailing with ongoing projects.

Components		Budget (Rs. Crore)		
Component I: Institutional arrangements			10	
1.1	Establishment of KWMA	0.3		
1.2	Establishment of Wetland Inventory, Assessment and Monitoring System	5		
1.3	Capacity building	2		
1.4	Communication and outreach	2.7		
Component II: Ecosystem Restoration			145.5	
2.1	Management zoning	0.5		
2.2	Water management	125		Funding for water quality to be leveraged from Pamba Action Plan
2.3	Biodiversity conservation	20		
Component III: Sustainable resource development			200	
3.1	Sustainable agriculture development	100		Funding to be leveraged from Kuttanad Package
3.2	Sustainable fisheries development	50		
3.3	Ecotourism development	50		
			355.5	

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Annex I

Macrophytes of Vembanad

Free floating

1. *Eichhornia crassipes* Mart.
2. *Salvinia molesta* Mitch.
3. *Azolla pinnata* R.Br.
4. *Lemna minor* Linn.

Emergent

1. *Ischaemum travancorense* Stapf ex C.E.C.Fisch.
2. *Colocasia esculenta* Linn.
3. *Pandanus odoratissimus* Jacq.
4. *Melastoma malabathricum* Linn.
5. *Syzygium* sp.
6. *Lygodium microphyllum* Cav.
7. *Mikania micrantha* Kunth.
8. *Hymenachne acutigluma* Steud.
9. *Sacciolepis interrupta* Willd.
10. *Hygrophila ringens* Linn.
11. *Acrostichum aureum* Linn.
12. *Phragmites karka* Retz.
13. *Typha angustata* Bory. & Chaub.
14. *Cyperus cephalotes* Vahl.
15. *Limnocharis flava* Linn.
16. *Leersia hexandra* Sw.
17. *Alternanthera philoxeroides*[≠] *Mart.*
18. *Ludwigia adscendens*[≠] Linn.
19. *Bacopa monnieri* Linn.

Submerged

1. *Aponogeton appendiculatus* H.Bruggen.
2. *Cabomba caroliniana* A. Grav.

([≠]Jayan and Sathyanathan, 2012)

Annex II

Mangrove and associates of Vembanad-Kol

Shrubs

1. *Acanthus ilicifolius* Linn.
2. *Acrostichum aureum* Linn.
3. Lumnitzera racemosa Willd.

Small Tree

1. *Aegiceras corniculatum* Linn.
2. *Avicennia marina* (Forsk.) Vierh.
3. *Bruguiera cylindrica* (Linn.) Bl.
4. *Bruguiera sexangula* (Lour.) Poir
5. *Ceriops tagal* (Perr.) C.B.Rob
6. *Kandelia candel* (Linn.) Druce
7. *Rhizophora apiculata* Blume.
8. *Rhizophora mucronata* Lamk.
9. *Excoecaria agallocha* Linn.

Medium sized Tree

1. *Avicennia officinalis* Linn.
2. *Excoecaria indica* (Willd) Mull.Arg.
3. *Sonneratia caseolaris* (Linn.) Engl.

Large Tree

1. *Bruguiera parviflora* W & A. exGriffith

Mangrove associates

Herbs

1. *Alternanthera sessilis* (Linn.) R. Br. Ex.DC
2. *Crinum defixum* Ker.
3. *Cyperus alopecuroides* Rottb.
4. *Cyperus* sp.
5. *Fimbristylis dichotoma* Vahl.
6. *Fimbristylis spathacea* Roth.
7. *Paspalum vaginarum* S.W.

Shurbs

1. *Ardisia littoralis* Andr.
2. *Clerodendrum inerme* Gaertn.
3. *Cyperus javanicus* Houtt.
4. *Phragmites karka* Trin.

Climbing Shurbs

1. *Caesalpinia crista* Linn.
2. *Dalbergia candenatensis* Prain.
3. *Derris trifoliata* Lour.

Small Tree

1. *Cerbera odollam* Gaertn.
2. *Hibiscus tiliaceus* Linn.
3. *Pandanus fascicularis* Lamk.
4. *Premna serratifolia* Linn.
5. *Quassia indica* (Gaertn.) Noteb.

Medium sized Tree

1. *Barringtonia racemosa* (L.) Spreng.
2. *Dolichandrone spathacea Seem.*

Large Tree

1. *Calophyllum inophyllum* Linn.
2. *Heritiera littoralis* Dryand.
3. *Thespesia populnea* (Linn.) Sol. Ex Correa.

(KFRI, 2009; Ram and Shaji, 2013; CWRDM, 2006; IUCN Red data list 3.1 accessed on 4 November 2013)

Fin and shell fish of Vembanad

Oligohaline fish

1. *Parambassis dayi* (Bleeker, 1874)
2. *Ambylpharyngodon mola* (Hamilton, 1822)
3. *Anabas testudineus* (Bloch, 1792)
4. *Anguilla bicolor bicolor* (McClelland, 1844)
5. *Channa striata* (Bloch, 1793)
6. *Dayella malabarica* (Day, 1873)
7. *Heteropneustes fossilis* (Bloch, 1794)
8. *Horabagrus brachysoma* (Günther, 1864)
9. *Mastacembelus armatus* (Lacepède, 1800)
10. *Mastacembelus guentheri* (Day, 1865)
11. *Mystus malabaricus* (Jerdon, 1849)
12. *Mystus oculatus* (Valenciennes, 1840)
13. *Ompok bimaculatus* (Bloch, 1794)
14. *Puntius amphibious* (Valenciennes, 1842)
15. *Puntius filamentosus* (Valenciennes, 1844)
16. *Puntius sarana* (Hamilton, 1822)
17. *Tetraodon leopardus* (Day, 1878)
18. *Wallago attu* (Bloch & Schneider, 1801)
19. *Xenentodon cancila* (Hamilton, 1822)
20. *Labeo dussumieri* (Valenciennes, 1842)
21. *Stenogobius gymnopomus*

Euryhaline fish

1. *Ambassis gymnocephalus* (Lacepède, 1802)
2. *Colletteichthys dussumieri* (Valenciennes, 1837)
3. *Brachirus orientalis* (Bloch & Schneider, 1801)
4. *Caranx sexfasciatus* (Quoy & Gaimard, 1825)
5. *Cynoglossus puncticeps* (Richardson, 1846)
6. *Daysciaena albida* (Cuvier, 1830)
7. *Ehirava fluviatilis* (Deranivaqala, 1929)
8. *Etroplus maculatus* (Bloch, 1795)
9. *Etroplus suratensis* (Bloch, 1790)
10. *Gerres filamentosus* (Cuvier, 1829)
11. *Gerres setifer* (Hamilton, 1822)
12. *Glossogobius giuris* (Hamilton, 1822)
13. *Hyporhamphus limbatus* (Valenciennes, 1847)
14. *Hyporhamphus xanthopterus* (Valenciennes, 1847)
15. *Leiognathus brevirostris* (Valenciennes, 1835)
16. *Leiognathus equulus* (Forsskål, 1775)
17. *Liza macrolepis* (Smith, 1846)
18. *Liza parsia* (Hamilton, 1822)
19. *Lutjanus argentimaculatus* (Forsskål, 1775)
20. *Megalops cyprinoides* (Broussonet, 1782)
21. *Mugil cephalus* (Linnaeus, 1758)
22. *Mystus gulio* (Hamilton, 1822)
23. *Oxyurichthys microlepis* (Bleeker, 1849)
24. *Oxyurichthys formosanus* (Nichols, 1958)
25. *Platycephalus crocodilus* (Cuvier, 1829)
26. *Tachysurus maculatus* (Thunberg, 1792)
27. *Terapon jarbua* (Forsskål, 1775)
28. *Sillago sihama* (Forsskål, 1775)
29. *Dendrophysa russelli* (Cuvier, 1830)
30. *Chelonodon patoca* (Hamilton, 1822)
31. *Tachysurus subrostratus* (Valenciennes, 1840)
32. *Sarotherodon mossambicus* (Peters, 1852)
33. *Oxyurichthys tentacularis* (Valenciennes, 1837)
34. *Psammogobius biocellatus* (Valenciennes, 1837)
35. *Sillago vincenti* (McKav, 1980)
36. *Valamugil cunnesius* (Valenciennes, 1836)
37. *Scaptophagus argus*
38. *Ambassis commersonii* (Lacepède, 1802)
39. *Anodontostoma chacunda* (Hamilton, 1822)
40. *Chanos chanos* (Forsskål, 1775)
41. *Dasyatis sephen* (Forsskål, 1775)
42. *Eleutheronema tetradactylum* (Shaw, 1804)
43. *Elops machnata* (Forsskål, 1775)
44. *Epinephelus tauvina* (Forsskål, 1775)
45. *Escualosa thoracata* (Valenciennes, 1847)
46. *Lates calcarifer* (Bloch, 1790)
47. *Muraenesox bagio* (Hamilton, 1822)
48. *Nematalosa nasus* (Bloch, 1795)
49. *Pomadasys argenteus* (Forsskål, 1775)
50. *Pseudorhombus arsius* (Hamilton, 1822)
51. *Siganus javus* (Linnaeus, 1766)
52. *Sphyraena jello* (Cuvier, 1829)
53. *Stolephorus commersonii* (Lecepede, 1803)
54. *Stolephorus waitei* (Jordan & Seale, 1926)

55. *Strongylura strongylura* (Van Hasselt, 1823)
56. Thryssa kamalensis
57. Thryssa purava
58. *Thryssa mystax* (Bloch & Schneider, 1801)
59. *Triacanthus brevirostris* (Temmnick & Schlegel, 1850)
60. *Liza subviridis* (Valenciennes, 1836)
61. *Lutjanus johnii* (Bloch, 1792)
62. *Platycephalus indicus* (Linnaeus, 1758)
63. *Ilisha sirishai* (Seshaqiri Rao, 1975)
64. *Ilisha melastoma* (Bloch & Schneider, 1801)
65. *Pisodonophis boro* (Hamilton, 1822)
66. *Stolephorus insularis* (Hardenberq, 1933)
67. *Tylosurus crocodilus crocodilus* (Peron & Lesueur, 1821)
68. *Gambusia affinis* (Baird & Girard, 1853)
69. *Atherina duodecimal* (Valenciennes, 1835)
70. *Carangoides praeustus* (Bennett, 1830)
71. *Drepane punctata* (Linnaeus, 1758)
72. *Awaous guamensis* (Valenciennes, 1837)
73. *Acentrogobius viridipunctatus* (Valenciennes, 1837)
74. *Acentrogobius caninus* (Valenciennes, 1837)
75. *Siganus canaliculatus* (Park, 1797)
76. *Leiognathus splendens* (Cuvier, 1829)
77. Secutor ruconius (Hamilton, 1822)
78. Zenarchopterus dispar (Valenciennes, 1847*)*

Stenohaline fish

1. *Alectis indicus* (Ruppel, 1830)
2. Dasyatis uarnak
3. *Dussumieria acuta* (Valenciennes, 1847)
4. *Johnius belangerii* (Cuvier, 1850)
5. *Mylio berda* (Forsskal, 1775)
6. *Plectorhinchus nigrus* (Cuvier, 1830)
7. *Protonibea diacanthus* (Lecepede, 1802)
8. *Scomberoides tol* (Cuvier, 1832)
9. *Stolephorus indicus* (Van Hasselt, 1823)
10. *Synaptura commersonnii* (Lecepede, 1802)
11. *Taenioides cirratus* (Blyth, 1860)
12. *Thyrsoidea macrurus* (Hamilton, 1822)
13. *Upeneus sulphureus* (Cuvier, 1829)
14. *Upeneus vittatus* (Forsskal, 1775)
15. *Valamugil speigleri* (Bleeker1858)
16. *Valamugil seheli* (Forsskal, 1775)
17. *Sardinella longiceps* (Valenciennes, 1847)
18. *Sardinella gibbosa* (Bleeker1849)
19. *Thryssa setirostris* (Broussonet, 1782)
20. *Saurida undosquamis* (Richardson, 1848)
21. Rhynchorhampus georgii
22. *Megalaspis cordyla* (Linnaeus, 1758)
23. *Alepes djedaba* (Forsskal, 1775)
24. *Scomberoides tala* (Cuvier, 1832)
25. *Trachinotus blochii* (Lecepede, 1801)
26. *Lutjanus fulviflamma* (Forskal, 1775)
27. *Lutjanus russelli* (Bleeker, 1849)
28. *Lutjanus rivulatus* (Cuvier, 1828)
29. *Gerres abbreviatus* (Bleeker, 1850)
30. *Lethrinus microdon* (Valenciennes, 1830)
31. *Parupeneus indicus* (Shaw, 1803)
32. *Eleotris fusca* (Foster, 1801)
33. *Butis butis* (Hamilton, 1822)
34. *Bunaka gyrinoides* (Bleeker, 1853)
35. *Gobiopsis macrostomus* (Steindachner, 1861)
36. *Taenioides buchanani* (Day, 1873)
37. *Trypauchen vagina* (Bloch & Schneider, 1801)
38. *Acanthurus matoides* (Forskal, 1775)
39. *Siganus lineatus* (Valenciennes, 1835)
40. *Synbranchus bengalensis* (McClelland, 1844)
41. *Solea ovate* (Richardson, 1846)
42. *Cynoglossus bilineatus* (Lecepede, 1802)
43. *Tetraodon fluviatilis* (Hamilton, 1822)
44. *Leiognathus bindus* (Valenciennes, 1835)
45. *Leiognathus daura* (Cuvier, 1829)
46. *Leiognathus berbis* (Valenciennes, 1835)
47. *Secutor ruconius* (Hamilton, 1822)
48. *Gazza minuta* (Bloch, 1795)

Estuarine prawn

1. *Metapenaeus dobsoni* (Miers, 1878)
2. *Metapenaeus monoceros* (Fabricius, 1798)
3. *Penaeus canaliculatus* (Olivier, 1811)
4. *Penaeus indicus* (H. Milne Edwards, 1837)
5. *Penaeus monodon* (Fabricius, 1798)
6. *Penaeus semisulcatus* (de Hann, 1844)

Freshwater prawn

1. *Macrobrachium idella* (Hilgendrof, 1898)
2. *Macrobrachium rosenbergii* (De Man, 1879)
3. *Macrobrachium scabriculum* (Heller, 1862)

Crab

1. *Portunus sanguinolentus* (Herbst, 1783)

2. *Portunus pelagicus* (Linnaeus, 1758)
3. *Scylla serrata* (Forskal, 1775)
4. *Ebalia malefactrix* (Kemp, 1915)
5. *Elamenopsis alcocki* (Kemp, 1915)
6. *Halicarcinus* sp.
7. *Scylla tranquebarica* (Fabricius, 1798)
8. *Portunus gladiator* (Fabricius, 1798)
9. *Charybdis lucifera* (Fabricius, 1798)
10. *Benthopanope indica* (de Man, 1887)
11. *Viaderiana* sp.
12. *Metopograpsus messor* (Forskal, 1775)
13. *Parasesarma plicatum* (Latreille, 1803)
14. *Pseudosesarma edwardsi* (de Man, 1888)
15. *Clistocoeloma balansae* (H. Milne Edwards, 1873)
16. *Xenophthalmus* sp.
17. *Dotilla* sp.
18. *Uca lacteal* (de Haan, 1835)
19. *Uca* sp.
20. *Spiralothelphusa hydrodroma* (Herbst, *1804)*

Clam

1. *Villorita cyprinoides* (Gray, 1825)
2. *Sunetta scripta* (Linnaeus, 1758)
3. *Meretrix casta* (Gemlin, 1791)
4. *Paphia malabarica*
5. *Villorita cornucopia* (Prashad, 1921)
6. *Meretrix meretrix* (Linnaeus, 1758)

Pearl producing fresh water bivalves

1. *Lamellidens marginalis* (Lamark, 1819)
2. *Parreysia corrugata* (Muller, 1775)

Mussels

1. *Perna viridis* (Linnaeus, 1758)
2. *Perna indica* (Kuriakose & Nair, 1976)

Brackishwater Oyster

1. *Crassostrea madrasensis*

(Kurup et al., 1990; Kurup et al., 1993, CMFRI, 2005; CWRDM, 2006; Suja and Mohamed, 2010; Ranjan et al., 2011; IUCN Red data list 3.1 accessed on 6 November 2013; fishbase accessed on 10 November 2013)

Birds of Vembanad-Kol

Accipitridae

1. *Pandion haliaetus* (Linnaeus, 1758)
2. *Elanus caeruleus* (Desfontaines, 1789)
3. *Haliastur Indus* (Boddaert, 1783)
4. *Circus aeruginosus* (Linnaeus, 1758)
5. *Accipiter badius* (Gmelin, 1788)
6. *Aquila clanga* (Pallas, 1811)
7. *Milvus migrans* (Boddaert, 1783)
8. *Circus pygargus* (Linnaeus, 1758)
9. *Ichthyophaga ichthyaetus* (Horsfield, 1821)
10. *Accipiter nisus* (Linnaeus, 1758)
11. *Aquila nipalensis (*Hodgson, 1833)
12. *Hieraaetus pennatus* (Gmelin, 1788)

Alaudidae

13. *Eremopterix griseus* (Scopoli, 1786)
14. *Galerida malabarica* (Scopoli, 1786)
15. *Alauda gulgula* (Franklin, 1831)

Alcedinidae

16. *Alcedo atthis* (Linnaeus, 1758)
17. *Pelargopsis capensis* (Linnaeus, 1766)
18. *Halcyon smyrnensis* (Linnaeus, 1758)
19. *Ceryle rudis* (Linnaeus, 1758)
20. *Ceyx erithaca* (Linnaeus, 1758)
21. *Halcyon pileata* (Boddaert, 1783)

Anatidae

22. *Dendrocygna javanica* (Horsield, 1821)
23. *Tadorna ferruginea* (Pallas, 1764)
24. *Nettapus coromandelianus* (Gmelin, 1789)
25. *Anas clypeata* (Linnaeus, 1758)
26. *Anas acuta* (Linnaeus, 1758)
27. *Anas querquedula* (Linnaeus, 1758)
28. *Aythya nyroca* (Güldenstädt, 1770)
29. *Anas crecca* (Linnaeus, 1758)
30. *Anas poecilorhyncha* (Forster, 1781)

Anhingidae

31. *Anhinga melanogaster* (Pennant, 1769)

Ardeidae

32. *Ardea cinerea* (Linnaeus, 1758)
33. *Ardea purpurea* (Linnaeus, 1766)
34. *Casmerodius albus* (Linnaeus, 1758)
35. *Bubulcus ibis* (Linnaeus, 1758)
36. *Ardeola grayii* (Sykes, 1832)
37. *Ixobrychus sinensis* (Gmelin, 1789)
38. *Ixobrychus cinnamomeus* (Gmelin, 1789)
39. *Egretta garzetta* (Linnaeus, 1766)
40. *Egretta gularis* (Bosc, 1792)
41. *Mesophoyx intermedia* (Wagler, 1829)
42. *Butorides striatus* (Linnaeus, 1758)
43. *Nycticorax nycticorax* (Linnaeus, 1758)
44. *Dupetor flavicollis* (Latham, 1790)

Artamidae

45. *Artamus fuscus* (*Vieillot, 1817)*

Apodidae

46. *Apus affinis* (Gray, 1830)
47. *Apus pacificus* (Latham, 1802)
48. *Tachymarptis melba* (Linnaeus, 1758)
49. *Hirundapus giganteus* (Temminck, 1825)
50. *Cypsiurus balasiensis* (Gray, 1829)

Bucerotidae

51. *Ocyceros griseus* (Latham, 1790)

Campephagidae

52. *Tephrodornis pondicerianus* (Gmelin, 1789)
53. *Coracina macei* (Lesson, 1831)
54. *Coracina melanoptera* (Rüppell, 1839)
55. *Pericrocotus cinnamomeus* (Linnaeus, 1766)
56. *Pericrocotus flammeus* (Forster, 1781)

Charadriidae

57. *Pluvialis fulva* (Gmelin, 1789)
58. *Pluvialis squatarola* (Linnaeus, 1758)
59. *Charadrius dubius* (Scopoli, 1786)
60. *Vanellus malarbaricus* (Boddaert, 1783)
61. *Vanellus indicus* (Boddaert, 1783)
62. *Charadrius alexandrinus* (Linnaeus, 1758)
63. *Charadrius mongolus* (Pallas, 1776)

64. *Charadrius leschenaultii (*Lesson, 1826)

Ciconiidae
65. *Mycteria leucocephala* (Pennant, 1769)
66. *Anastomus oscitans* (Boddaert, 1783)
67. *Ciconia episcopus* (Boddaert, 1783)

Columbidae
68. *Columba livia* (Gmelin, 1789)
69. *Stigmatopelia chinensis* (Scopoli, 1786)
70. *Chalcophaps indica* (Linnaeus, 1758)
71. *Ducula badia* (Raffles, 1822)
72. *Treron pompadora* (Gmelin, 1789)

Coraciidae
73. *Coracias garrulus* (Linnaeus, 1758)
74. *Coracias benghalensis* (Linnaeus, 1758)

Corvidae
75. *Dendrocitta vagabunda* (Latham, 1790)
76. *Corvus splendens* (Vieillot, 1817)
77. *Corvus macrorhynchos* (Wagler, 1827)

Cuculidae
78. *Clamator jacobinus* (Boddaert, 1783)
79. *Cuculus micropterus* (Gould, 1837)
80. *Eudynamys scolopaceus* (Linnaeus, 1758)
81. *Centropus sinensis* (Stephens, 1815)
82. *Clamator coromandus* (Linnaeus, 1766)
83. *Hierococcyx varius* (Vahl,1797)
84. *Cacomantis passerinus* (Vahl, 1797)

Capitonidae
85. *Megalaima viridis* (Boddaert, 1783)
86. *Megalaima haemacephala* (Müller, 1776)

Caprimulgidae
87. *Caprimulgus atripennis* (Jerdon, 1845)

Chloropseidae
88. *Chloropsis cochinchinensis* (Gmelin, 1788)
89. *Chloropsis aurifrons* (Temminck, 1829)
90. *Aegithina tiphia* (Linnaeus, 1758)

Cisticolidae
91. *Prinia hodgsonii* (Blyth, 1844)
92. *Cisticola juncidis* (Rafinesque, 1810)
93. *Prinia socialis* (Sykes, 1832)
94. *Prinia inornata* (Sykes, 1832)
95. *Acrocephalus dumetorum* (Blyth, 1849)
96. *Acrocephalus stentoreus* (Ehrenberg, 1833)
97. *Orthotomus sutorius* (Pennant, 1769)
98. *Phylloscopus trochiloides* (Sundevall, 1837)
99. *Phylloscopus magnirostris* (Blyth, 1843)

Dicruridae
100. *Dicrurus macrocercus* (Vieillot, 1817)
101. *Dicrurus leucophaeus* (Vieillot, 1817)
102. *Dicrurus aeneus* (Vieillot, 1817)
103. *Dicrurus paradiseus* (Linnaeus, 1766)

Dicaeidae
104. *Dicaeum erythrorhynchos* (Latham, 1790)

Estrildidae
105. *Lonchura striata* (Linnaeus, 1766)
106. *Lonchura punctulata* (Linnaeus, 1758)
107. *Lonchura malacca* (Linnaeus, 1766)

Falconidae
108. *Falco tinnunculus* (Linnaeus, 1758)
109. *Falco peregrinus* (Tunstall, 1771)

Glareolidae
110. *Glareola lactea* (Temminck, 1820)

Hirundinidae
111. *Hirundo rustica* (Linnaeus, 1758)
112. *Hirundo daurica* (Linnaeus, 1771)
113. *Hirundo smithii* (Leach, 1818)
114. *Hirundo fluvicola* (Blyth, 1855)
115. *Hirundo tahitica* (Gmelin, 1789)
116. *Riparia diluta* (Sharpe & Wyatt, 1893)

Jacanidae
117. *Hydrophasianus chirurgus* (Scopoli, 1786)
118. *Metopidius indicus* (Latham, 1790)

Laniidae
119. *Lanius cristatus* (Linnaeus, 1758)
120. *Lanius schach* (Linnaeus, 1758)

Laridae
121. *Sterna aurantia* (Gray, 1831)
122. *Larus ichthyaetus* (Pallas, 1773)
123. *Larus brunnicephalus* (Jerdon, 1840)

124. *Larus ridibundus* (Linnaeus, 1766)
125. *Gelochelidon nilotica* (Gmelin, 1789)
126. *Sterna caspia* (Pallas, 1770)
127. *Sterna bengalensis* (Lesson, 1831)
128. *Sterna bergii* (Lichtenstein, 1823)
129. *Sterna albifrons* (Pallas, 1764)
130. *Sterna fuscata* (Linnaeus, 1766)
131. *Chlidonias hybrid* (Pallas, 1811)
132. *Chlidonias leucopterus* (Temminck, 1815)

Meropidae
133. *Merops orientalis* (Latham, 1802)
134. *Merops philippinus* (Linnaeus, 1766)
135. *Merops leschenaulti* (Vieillot, 1817)

Monarchidae
136. *Terpsiphone paradisi* (Linnaeus, 1758)
137. *Hypothymis azurea* (Boddaert, 1783)

Motacillidae
138. *Motacilla alba* (Linnaeus, 1758)
139. *Motacilla flava* (Linnaeus, 1758)
140. *Motacilla cinerea* (Tunstall, 1771)
141. *Anthus rufulus* (Vieillot, 1818)
142. *Dendronanthus indica* (Gmelin, 1789)
143. *Motacilla citreola* (Pallas, 1776)
144. *Motacilla maderaspatensis* (Gmelin, 1789)

Muscicapinae
145. *Muscicapa dauurica* (Pallas, 1811)

Nectariniidae
146. *Nectarinia asiatica* (Latham, 1790)
147. *Nectarinia zeylonica* (Linnaeus, 1766)
148. *Nectarinia lotenia* (Linnaeus, 1766)

Oriolidae
149. *Oriolus oriolus* (Linnaeus, 1758)
150. *Oriolus xanthornus* (Linnaeus, 1758)
151. *Oriolus chinensis (*Linnaeus, 1766)

Passeridae
152. *Passer domesticus* (Linnaeus, 1758)
153. *Petronia xanthocollis* (Burton, 1838)

Pelecanidae
154. *Pelecanus philippensis* (Gmelin, 1789)

Phalacrocoracidae
155. *Phalacrocorax niger* (Vieillot, 1817)
156. *Phalacrocorax fuscicollis* (Stephens, 1826)
157. *Phalacrocorax carbo* (Linnaeus, 1758)

Pittidae
158. *Pitta brachyura* (Linnaeus, 1766)

Ploceidae
159. *Ploceus philippinus* (Linnaeus, 1766)
160. *Ploceus manyar* (Horsfield, 1821)

Podicipedidae
161. *Tachybaptus ruficollis* (Pallas, 1764)

Psittacidae
162. *Psittacula krameri* (Scopoli, 1769)
163. *Psittacula cyanocephala* (Linnaeus, 1766)
164. *Loriculus vernalis* (Sparrman, 1787)

Paridae
165. *Parus major* (Linnaeus, 1758)

Picidae
166. *Dendrocopos nanus* (Vigors, 1832)
167. *Dendrocopos mahrattensis* (Latham, 1801)
168. *Dinopium benghalense* (Linnaeus, 1758)
169. *Celeus brachyurus* (Vieillot, 1818)

Pycnonotidae
170. *Pycnonotus jocosus* (Linnaeus, 1758)
171. *Pycnonotus cafer* (Linnaeus, 1766)

Rallidae
172. *Amaurornis phoenicurus* (Pennant, 1769)
173. *Porzana pusilla* (Pallas, 1776)
174. *Gallicrex cinerea* (Gmelin, 1789)
175. *Porphyrio porphyrio* (Linnaeus, 1758)
176. *Gallinula chloropus* (Linnaeus, 1758)
177. *Fulica atra* (Linnaeus, 1758)
178. *Rallina eurizonoides* (Lafresnaye, 1845)
179. *Gallirallus striatus* (Linnaeus, 1766)
180. *Porzana fusca* (Linnaeus, 1766)

Recurvirostridae
181. *Himantopus himantopus* (Linnaeus, 1758)

Rostratulidae
182. *Rostratula benghalensis* (Linnaeus, 1758)

Rhipiduridae
183. *Rhipidura aureola* (Lesson, 1830)

Scolopacidae
184. *Limosa limosa* (Linnaeus, 1758)
185. *Numenius phaeopus* (Linnaeus, 1758)
186. *Tringa erythropus* (Pallas, 1764)
187. *Tringa totanus* (Linnaeus, 1758)
188. *Tringa stagnatilis* (Bechstein, 1803)
189. *Tringa nebularia* (Gunnerus, 1767)
190. *Tringa ochropus* (Linnaeus, 1758)
191. *Tringa glareola* (Linnaeus, 1758)
192. *Actitis hypoleucos* (Linnaeus, 1758)
193. *Calidris minuta* (Leisler, 1812)
194. *Calidris temminckii* (Leisler, 1812)
195. *Calidris subminuta* (Middendorff, 1853)
196. *Calidris ferruginea* (Pontoppidan 1763)
197. *Philomachus pugnax* (Linnaeus, 1758)
198. *Gallinago gallinago* (Linnaeus, 1758)
199. *Numenius arquata* (Linnaeus, 1758)

Strigidae
200. *Otus bakkamoena* (Pennant, 1769)
201. *Athene brama* (Temminck, 1821)
202. *Ketupa zeylonensis* (Gmelin, 1788)
203. *Strix ocellata* (Lesson, 1839)
204. *Glaucidium radiatum* (Tickell, 1833)
205. *Ninox scutulata* (Raffles, 1822)

Sturnidae
206. *Sturnus malabaricus* (Gmelin, 1789)
207. *Sturnus pagodarum* (Gmelin, 1789)
208. *Acridotheres tristis* (Linnaeus, 1766)
209. *Acridotheres fuscus* (Wagler, 1827)
210. *Sturnus blythii* (Jerdon, 1845)
211. *Sturnus roseus* (Linnaeus, 1758)

Threskiornithidae
212. *Plegadis falcinellus* (Linnaeus, 1766)
213. *Threskiornis melanocephalus* (Latham, 1790)
214. *Platalea leucorodia* (Linnaeus, 1758)

Timaliidae
215. *Turdoides striata* ((Dumont, 1823)
216. *Turdoides affinis* (Jerdon, 1845)

Tytonidae
217. *Tyto alba* (Scopoli, 1769)

Turdidae
218. *Zoothera citrina* (Latham, 1790)
219. *Copsychus saularis* (Linnaeus, 1758)
220. *Saxicoloides fulicata* (Linnaeus, 1758)
221. *Saxicola torquatus* (Linnaeus, 1766)
222. *Saxicola caprata* (Linnaeus, 1766)
223. *Luscinia svecica* (Linnaeus, 1758)

Upupidae
224. *Upupa epops* (Linnaeus, 1758)

Zosteropidae
225. *Zosterops palpebrosus* (Temminck, 1824)

(Sivaperuman and Jayson, 2000; Jayson and Easa, 2000; Narayan et.al., 2011; Kottayam Nature Society, 2011; IUCN Red data list 3.1 accessed on 13 November 2013)

Mission:

To sustain and restore wetlands, their resources and biodiversity

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