Management of *Phragmites karka* invasion in Chilika Lake, Orissa

Background Paper for Consultation Workshop on Management of *Phragmites karka* invasion in Chilika , 17-18 January 2011, Bhubaneswar, Orissa

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Introduction

The ecological character[1] of Chilika Lagoon is influenced by river basin and coastal processes and is vulnerable to changes due to anthropogenic as well as natural factors. One of emerging stresses on ecological character of the wetlands is changes in composition of macrophytes, particularly after the hydrological intervention of 2000. While the opening of new mouth and subsequent changes in salinity regimes have led to drastic decline in area under water hyacinth (*Eicchornia crassipes)*, *Phragmites karka* (locally called Nala dala) has rapidly invaded north and north-western segments of lake. This rapid spread, if not managed with right intervention, is likely to impact lake ecology as well as livelihood of wetland dependent communities. In this light, the participants of the management planning workshop, held on October 2009 at Bhubaneswar recommended adoption of appropriate technologies for control of invasive species, based on assessment on overall ecological productivity of the system.

The problem of management of invasive species is not unique to Chilika Lake alone, but is also shared by a high majority of wetlands in the country. Equally important is the high economic cost that is entailed if management interventions are not designed appropriately and are able to act at multiple scales. Experiences from management of invasive species in Loktak Lake (Manipur), Harike Lake (Punjab) and elsewhere indicate that a holistic management strategy considering the ecosystem complexities and societal interdependence are required for effectively addressing this issue.

The current workshop is aimed at developing an integrated response strategy for managing invasion of *Phragmites karka* in Chilika. This paper presents a background to the current problem, providing an overview of the current status of invasion, likely impacts, proximate factors, management interventions till date and a proposed management strategy.

Invasion[2] of *Phragmites karka* in Chilika

Chilika, a brackishwater coastal wetland located in the Orissa State forms the base of livelihood security of more than 0.2 million fishers and 0.4 million farmers living in and around. Spanning between 906 km^2-1,165 km^2, the wetland is an assemblage of shallow to very shallow marine,

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[1] Wise use of wetlands is defined within the Convention text as 'the maintenance of their ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development'. Ecological character is 'the combination of ecosystem components, processes and benefits / services that characterize the wetland at any given point of time'.

[2] In broader sense, biological invasion is referred to a phenomenon wherein a species enters new environment, establishes itself there and begins to change the populations of species that existed there before, as well as disturbing the balance of plant and animal communities. Invasiveness, or the propensity to become invasive under a range of ideal conditions and ecosystems, can be attributed to a range or combination of characteristics of organisms, which include: a) capacity for rapid growth (and thereby expansion); b) capacity to disburse widely; c) large reproductive capacity; d) broad environmental tolerance; e) effective competition with local species for habitat and growth requirements. However, it is also recognized that species native to a particular area, under the influence of natural events or abrupt changes in ecosystems, can also become invasive.

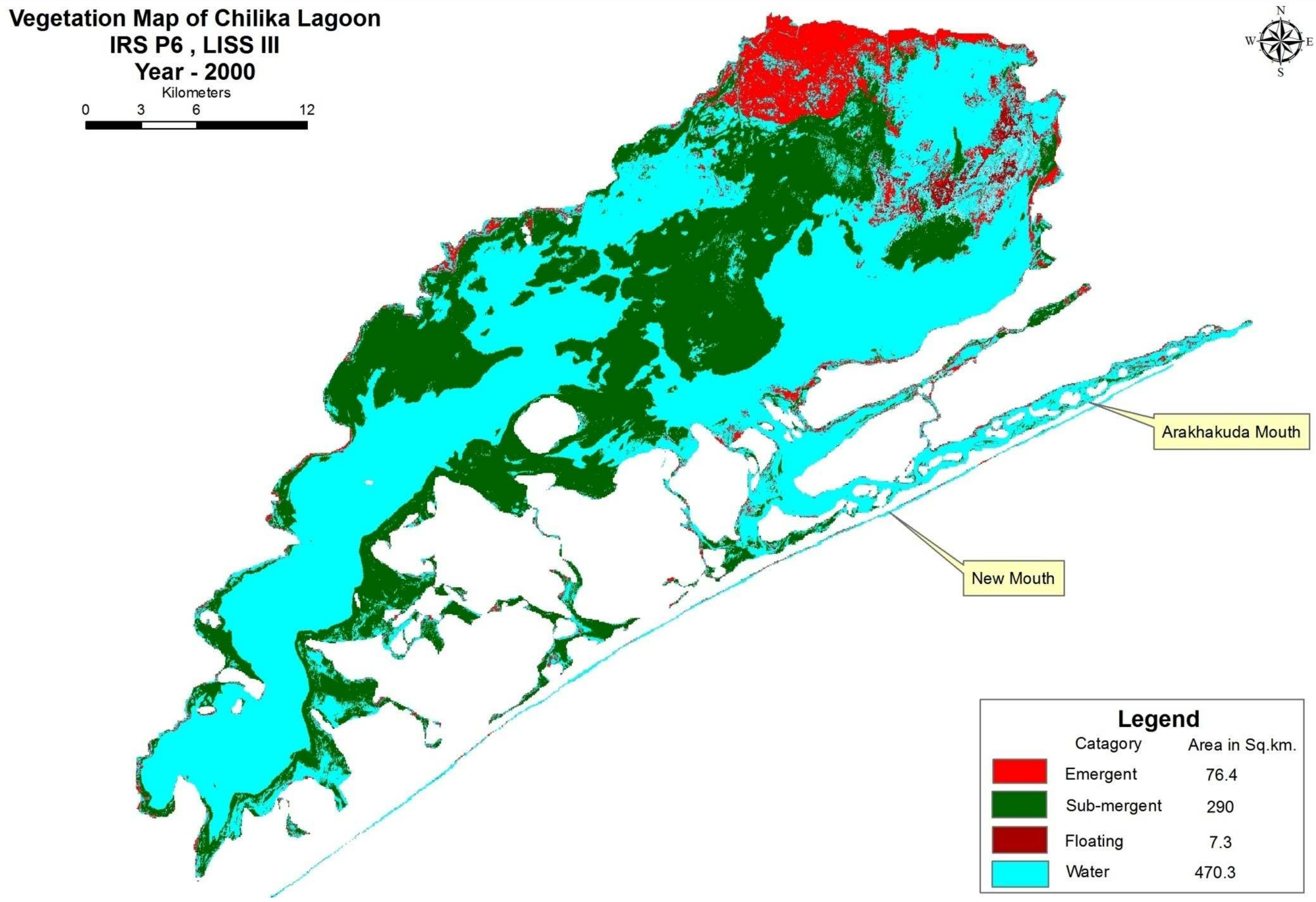
There is a considerable difference in definition 'invasive species'. The National Invasive Species Council (US) explicitly uses non-nativeness as a criterion to define invasive species, and thereby the definition "an alien species whose introduction dies or is likely to cause economic or environmental harm or harm to human health". The definition provided by Australian Government (Department of Sustainability, Environment, Water, Population and Communities) emphasizes on occurrence, and reads as, "an invasive species is a species occurring , as a result of human activities , beyond its accepted normal distribution and which threatens valued environmental, agricultural and other social resources by the damage it causes". The Convention on Wetlands as well as Convention on Biological Diversity retain the focus on alien invasive species.

brackish and freshwater ecosystems and a hotspot of biodiversity. Over one million migratory birds commonly winter here. Chilika is one of only two lagoons in the world that support Irrawaddy Dolphin populations. The lagoon is also inextricably linked to the local culture and belief systems. Based on its rich biodiversity and socioeconomic importance, Chilika was designated as a Wetland of International Importance (Ramsar Site under the Convention on Wetlands) by the Government of India in 1981.

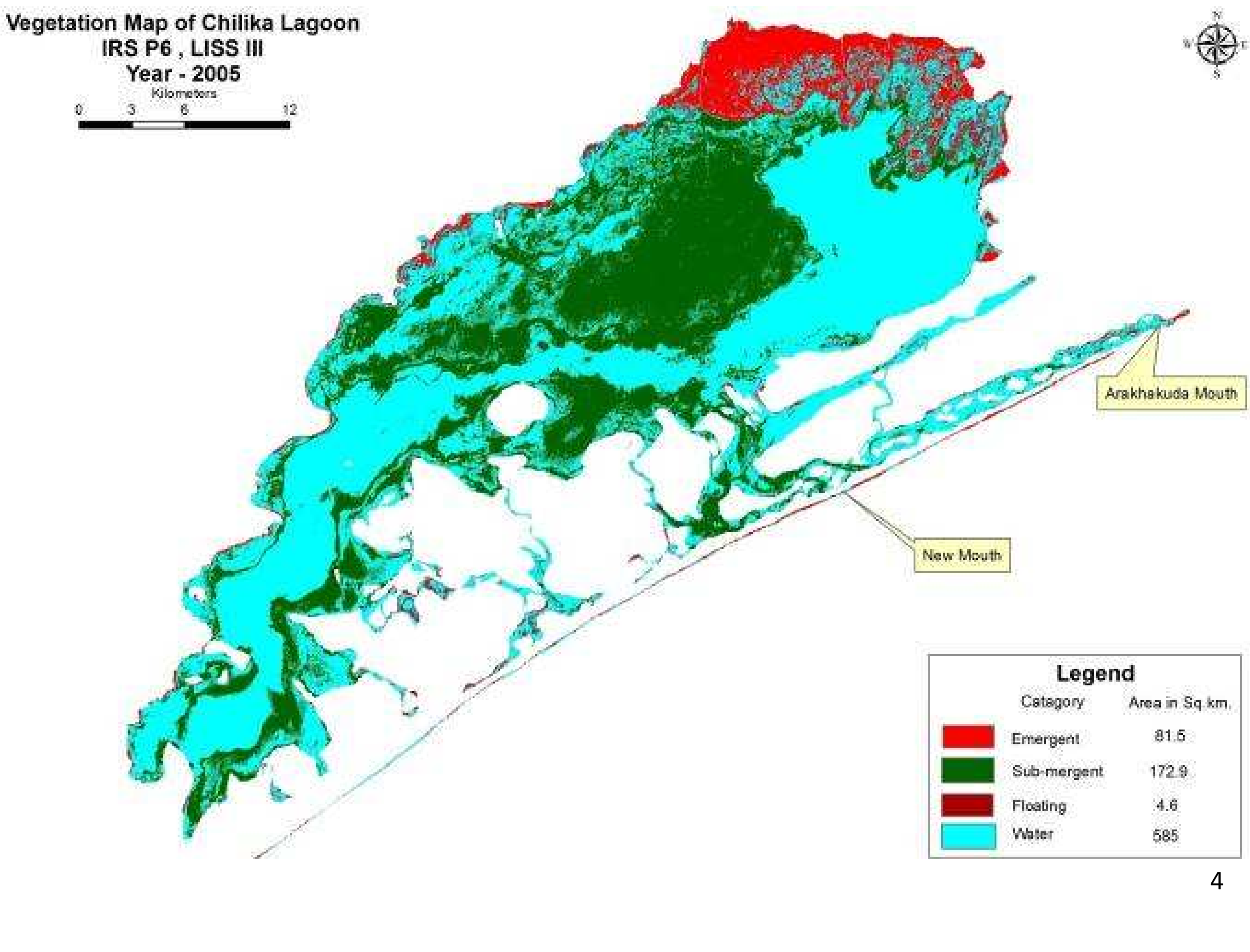
Chilika underwent rapid degradation during 1950 – 2000 owing to increasing sediment loads from the catchments due to change in the land use pattern and reduced connectivity with the sea leading to decreasing salinity. The lagoon fisheries underwent a major decline, invasive weeds proliferated and there was shrinkage in area and volume and an overall loss of biodiversity. This had tremendous impact on the livelihood of communities, especially fishers who depended on lagoon for sustenance. In 2000, opening a new mouth to the Bay of Bengal helped restoration of salinity regime, enhanced fish landing, decrease of invasive species, overall improvement of the lagoon water quality and particularly improved livelihoods of communities. Since then, the Chilika Development Authority, the nodal agency formed by the state government for management of the wetland system, in collaboration with a network of partners, has initiated a series of measures for upkeep of the wetland ecosystem, including catchment area treatment, promoting community led fisheries, ecotourism, and systematic monitoring and evaluation of the various components and processes that sustain the ecosystem.

Salinity is the most dominant factor controlling lake ecology. Chilika has been broadly divided into four sectors primarily on salinity regimes: the northern sector which is predominantly freshwater, the central and southern which are brackish; and, the outer channel which tends towards marine. The aquatic vegetation,represented by submerged, emergent and floating forms, also exhibits changes within the sectors. Northern sector being a freshwater zone is dominated by freshwater species of emergent and submerged type most notably *Phragmites kara, Hydrilla verticillata, Valesneria spiralis*. *Eichorrnia crassipes* which was dominant in the freshwater zone of northern sector is now confined to the river confluence areas. The vegetation of central and southern sectors is mostly submerged brackish water type represented by the dominant genus of *Najas, Potamogeton* and *Halophila*. The outer channel area having marine influence has very less vegetation in comparison to other sectors and is represented by submerged stands of *Potamogeton pectinatus*.

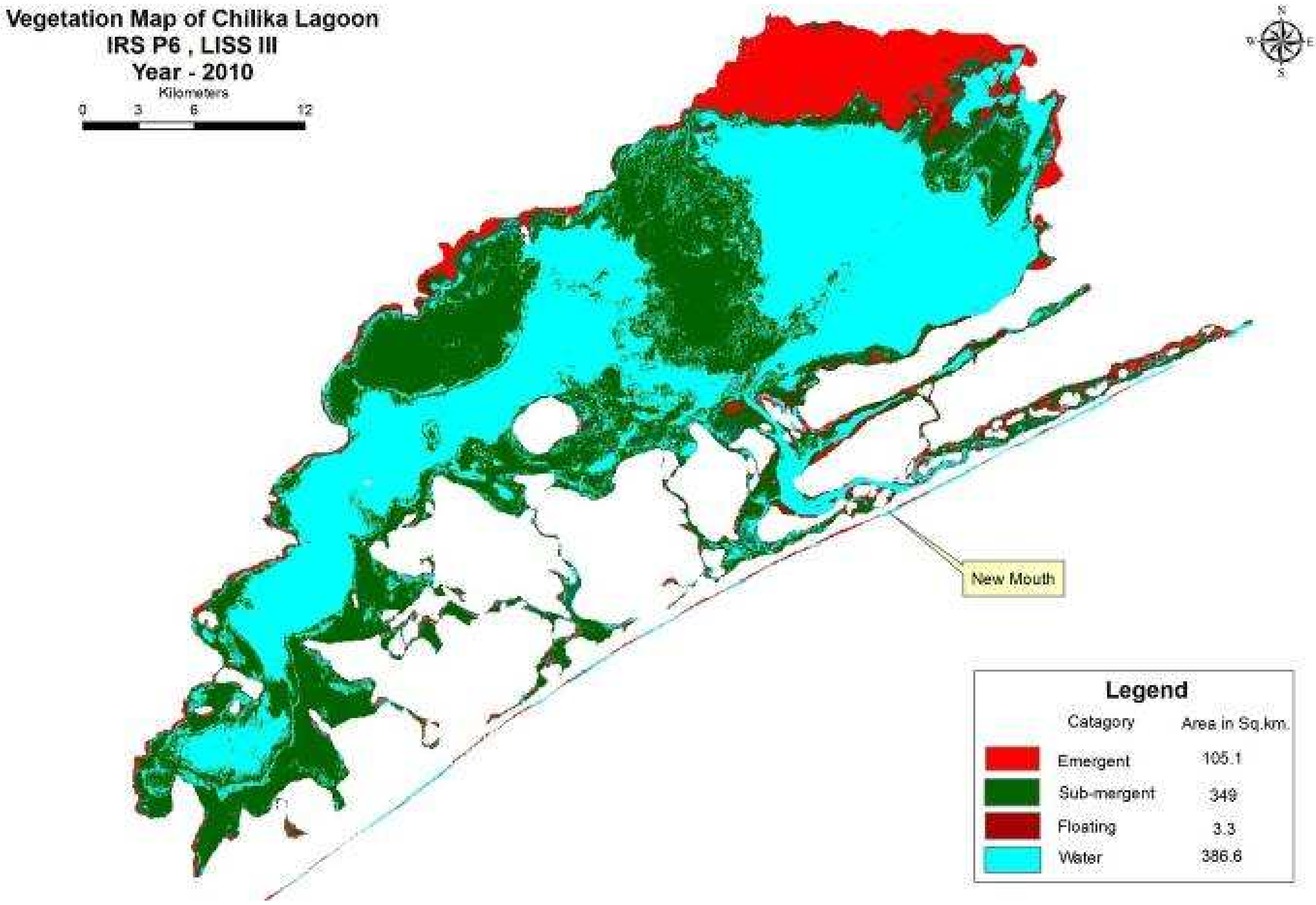
The salinity regimes of Chilika underwent a significant change after the opening of the new mouth. Post intervention, within the northern sector, the salinity remains within 5 ppt during monsoon and winters, but increases during summer to about 15 ppt. This led to significant changes in the aquatic vegetation of the northern sector. Firstly, *Eicchornia crassipes* which had nearly choked the area rapidly declined and presently is confined to the river confluence areas. However, there was a rapid increase in area under *Phragmites* (which is known to tolerate salinity upto 18 ppt, for example see Meyerson, 2009). The area increased from 76.4 sq km in 2000 to 105.1 sq km at present (2010) (Map 1, 2 and 3). Biomass assessments carried on select samples in 1990 and 2001 indicated an increase from 5,068 g/m^2 to 19,040 g/m^2 in the northern sector. Its dispersion also increased from being more dominant in the northern sector to occupying the margins of the central and southern sectors. These findings however need to be followed by deeper analysis.

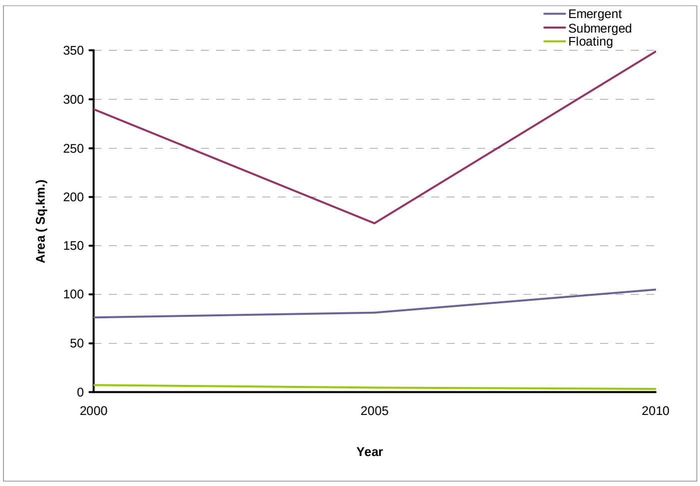


Vegetation Map of Chilika Lagoon
IRS P6 , LISS III
Year - 2000
Kilometers
0 3 6 12
Arakhakuda Mouth
New Mouth
Legend
Catagory
Area in Sq.km.
Emergent 76.4
Sub-mergent 290
Floating 7.3
Water 470.3



Vegetation Map of Chilika Lagoon
IRS P6 , LISS III
Year - 2005
Kilometers
0 3 6 12
Arakhakuda Mouth
New Mouth
Legend
Catagory
Area in Sq.km.
Emergent 81.5
Sub-mergent 172.9
Floating 4.6
Water 585





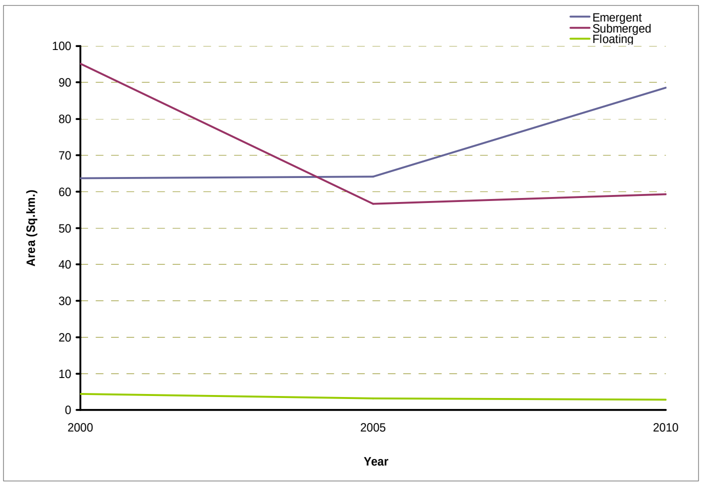


Fig 1 and 2 : Changes in area under vegetation in Chilika Lake and Northern sector respectively

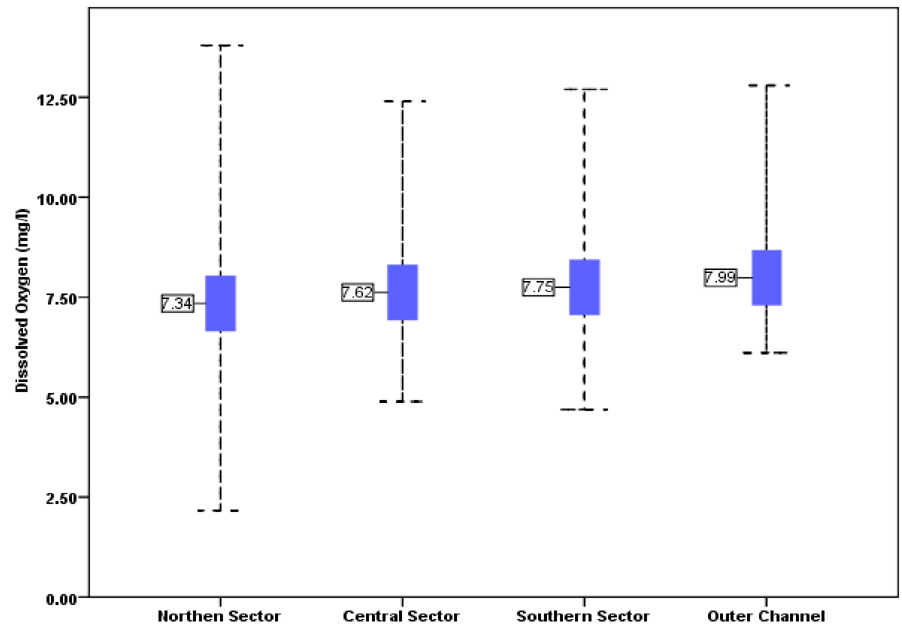


Fig 3 : Dissolved Oxygen fluctuations in various sectors (March 2009 – February 2010)

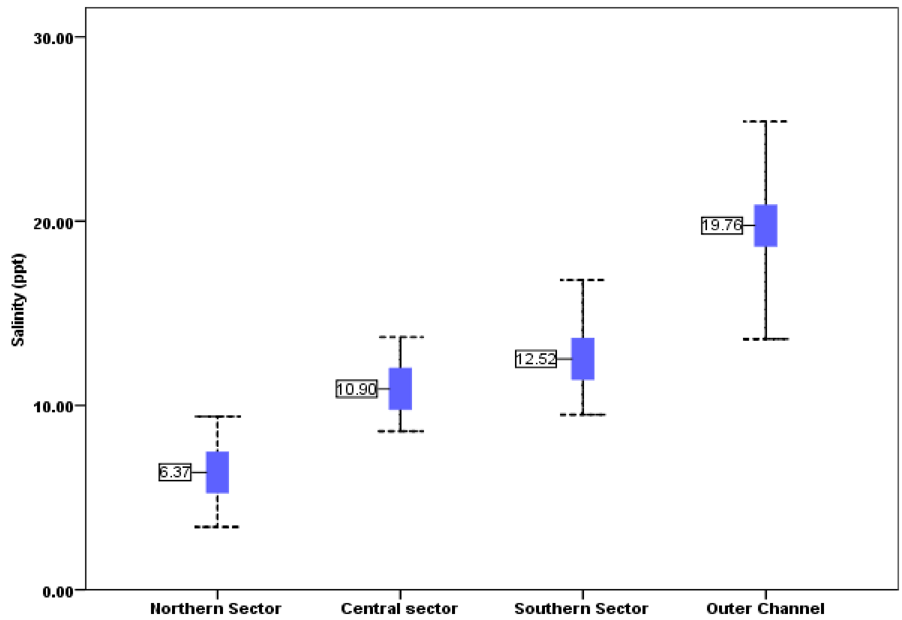


Fig 4 : Average salinity in various sectors of lake (1999 – 2009)

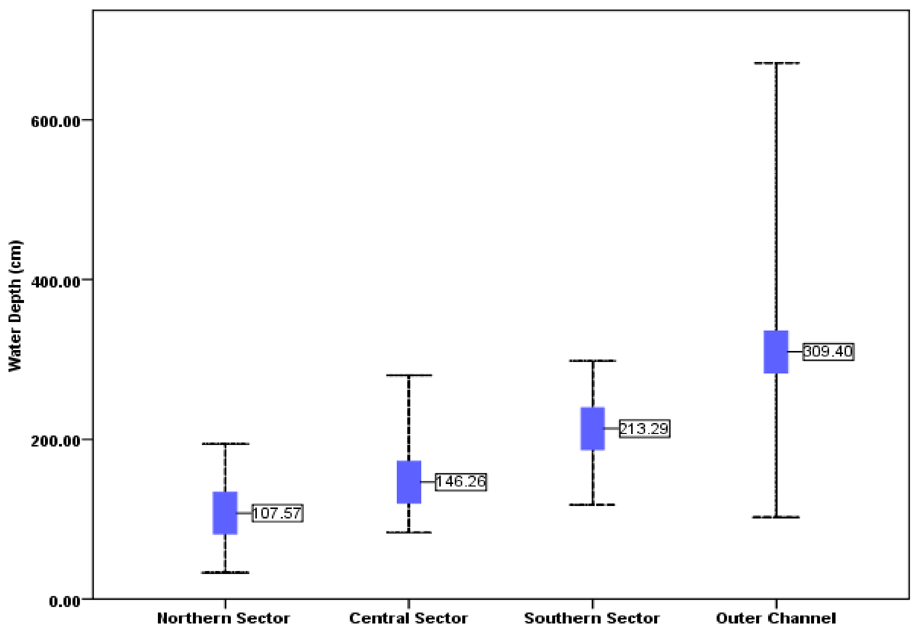


Fig 5 : Water level fluctuations in various sectors (March 2009 – February 2010)

A generic survey of literature conducted on *Phragmites*[3],[4] establishes its high propensity for biological invasion. Its capacity for high growth is indicated by the fact that under optimal conditions, growth in excess of 10 meters is common within a single growing season. Such rapid growth is possible because the horizontal stems of *Phragmites* exhibit strong apical dominance. When the rhizomes and stolons extend to an unfavourable environment where growth of the apical bud is inhibited or the apical bud is damaged, axillary buds along the rhizome axis are released and new photosynthetic stems are produced (Alistock, 2001). *Phragmites* populations can cover an eighth of a hectare in two years (Hocking et al. 1983).

Phragmites is an efficient colonizer of disturbed environments because it seeds profusely and spreads vegetatively by a vigorous system of rhizomes and stolons (Best et al. 1981; Hara et al. 1993; Marks et al. 1994). Primarily it reproduces vegetatively and seeds play an important role in establishing new plants in areas free of vegetation. *Phragmites* is well adapted to a range of salinity, nutrient, and hydrological conditions, and it is able to take advantage of conditions created by human modifications of marsh ecosystems (e.g., Meyerson, Saltonstall, et al. 2000; Meyerson, Vogt, et al. 2000; Warren et al. 2001; Bart and Hartman 2003; Burdick and Konisky 2003; Chambers et al. 2003; Minchinton and Bertness 2003; Silliman and Bertness 2004). *Phragmites* has the potential to establish and spread throughout tidal wetlands occurring in a broad salinity range from 0.5 to 18 parts per thousand (Meyerson, 2009). *Phragmites* has evolved efficient ventilation system that directs oxygen absorbed from the air and channelizes it to its underground structures which aid in colonizing and surviving in conditions which are otherwise inhibiting for other wetland species (Alistock, 2001). The tissue responsible for internal gas exchange, aerenchyma, is abundant in the stems, rhizomes, and roots of *Phragmites*.

Phragmites roots and rhizomes form a densely packed matrix that inhibits growth of other species and accesses additional resources. The slow decomposition of *Phragmites* detritus can significantly reduce the availability of nutrients, light, and space, making the survival or establishment of other species unlikely (Meyerson 2000). *Phragmites* exudes from its roots an acid (3,4,5- trihydroxybenzoic acid, gallic acid) so toxic that it disintegrates the structural protein in the roots of neighbouring plants, thus toppling the competition. *Phragmites* uses this strategy not to keep other plants away but to conquer them and invade new territory (Bais, 2007).

Why is rapid spread of Phragmites a threat to Chilika?

Impacts on hydrological processes

The northern sector of Chilika, owning to its proximity to the delta fraction of Chilika Lake basin, receives the maximum inflow of freshwater, as well as silt. As per assessments during 2001 – 2009, the northern sector received 42,413 Mcum of freshwater inflow from Mahanadi Delta distributaries , which represents 75 % of the overall freshwater inflow received from all surface flow sources (excluding rainfall). Since the delta distributaries also carry the runoff from large drainage basin (the total area of Mahanadi Basin being 141,589 sq km) as well as aggrading channel network (built over long term flood sediment depositional loads) within the delta region, the silt contribution into Chilika is also proportionally high. Assessments of TSS loads indicated that the

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[3] The literature on *Phragmite*s as a genus is quite extensive. However, at species level, the information is largely on *P. australis*, with relatively little documentation on *P. karka*.

[4] There are 8 known species of *Phragmites*, namely *P.australis* (74 varieties), *P.karka* (5 varieties), *P.communis* , *P.altissimus*, *P. berlandieri*, *P. maximus*, *P.vulgaris* and *P.dioicus. Phragmites karka (Retz.) Trin. Ex Steud* has a distribution range within Africa, Asia and Australia. Within Asia, it is found in India sub continent (Bhutan, India, Nepal, Pakistan, SriLanka), Indo China (Cambodia, Laos, Mynamar, Thailand and Vietnam) , Melanesia (Brunei, Indonesia, Malaysia, PNG, and Phillipines), Arabian Peninsula (Yemen, China) and Eastern Asia (Japan, Taiwan)

delta rivers contributed 7.19 million MT which is 74 % of overall silt load into the lake. The northern sector is also comparatively shallower as compared to other parts of the wetland.
The presence of *Phragmites karka* in the northern zone is therefore likely to have an impact on the flushing of sediments thereby leading to sediment accumulation and retention within the northern sector. In the long run, this is likely to impact the water holding capacity of the system.

Assessment of changes in area under vegetation confirms higher contribution of *Phragmites* to the overall increase within the northern sector. This indicates that increase in area of *Phragmites* has led to reduction in open water surface area in the sector, which is critical to overall productivity of the system. (Fig 1 and 2)

The water quality assessments indicate high fluctuation in DO and higher BOD concentrations in *Phragmites* dominated areas which is attributed to photosynthesis as well as higher rates of decomposition and microbial activity. Lower nitrate concentration observed within water samples from this sector may also be attributed to lock up within *Phragmites* stands, but this needs to be ascertained by adequate research (Fig 3).

Impacts on ecological processes
From an ecological perspective, the northern sector serves as breeding ground for several economically important fish species, notably *Eleutheronema tetradactylum*. Juveniles of some important species of minor carps, cat fishes, featherbacks, murrels, *E. tetradactylum, E. suratensis* and *P. canius* are found in sizeable numbers in Northern sector. Spread of *Phragmites* affects fisheries, primarily by creating ecologically stressed environments for juveniles as well as blocking migratory pathways. Annual landing of *E. tetradactylum* has recorded a decline in the period 2001-08 (CDA and DOF, 2009), which could be, amongst several other factors, be attributed to this spread.

Phragmites has also tended to colonize areas previously under submerged vegetation (primarily *Hydrilla, Vallisneria, and Potamogeton*). It has also gradually shifted towards the fringe areas, and as per imageries of 2010, borders the entire lake margin. The northern sector is also important from the perspective of waterbirds. Several species of ducks have been observed to avoid dense stands (BNHS, 2005).

Socioeconomic impacts
The delta communities are primarily agrarian, with agricultural productivity dependant on the flood and sediment enrichment cycles. *Phragmites* is seen to be a causative factor, particularly within the fringe communities for extended periods of waterlogging in agricultural fields. This is also impacting movement within the lake. Dense strands of *Phragmites* are also triggering mosquito breeding and thereby a health hazard. Highly silted up areas create conducive conditions for encroachment of land. The extent of disgruntlement of communities with *Phragmites* has reached to such an extent that some of the political parties have introduced removal of *Phragmites* within their political agendas and have sent delegations to Chilika Development Authority. Some villagers set *Phragmites* stands on fire to vent out their frustration with the invasion.

Proximate reasons for invasion

Changes in hydrological regimes
The changes in salinity regimes induced by the hydrological intervention has led to drastic reduction in area under freshwater invasive, particularly *Eicchornia crassipes*. The new regime favours *Phragmites* which can tolerate higher levels of salinity (Fig 4).

There are also significant changes in land use pattern leading to high siltation rates. The overall area under vegetative cover has declined from 1200 sq km in 1955 to 738 sq km in 2007. Dense forests constituted only 31% of the total forests cover in 2007. Sediment coring studies confirm that the maximum depth of sedimentation is in the northern sector (85 cm as compared to 77 cm and 49 cm in the central and southern sector respectively), and also that much of this has occurred post 1950s. The high rates of sedimentation and constrained flushing make the northern sector shallower as compared to other parts of the lake, which creates conditions conducive to colonization of *Phragmites* (Fig. 5).

Increase in nutrient loading
There have been several changes within the lake basin which create conducive conditions for higher nutrient loading rates. As per remote sensing imageries, agriculture occupies 65% of the total landuse of the basin. There has also been an increase in agricultural productivity (1,968 kgs /ha to 3,164 kg /ha during 2002-2006) as well as a near concomitant increase in consumption of chemical fertilizers (from 51.2 kgs / ha to 65.6 kgs /ha). The overall population living within the delta fraction has also increased rapidly (at a decadal growth rate of 80.13% during 1971-2001). A socioeconomic assessment of villages in and around Chilika indicated that only 16 % of population had access to adequate sanitation and safe drinking water facilities.

Human interference
The northern sector is also very densely populated on the fringes, with communities frequenting the lake as well as river channels for fishing and other purposes. This helps in propagating *Phragmites* rhizomes to other areas.

Management interventions till date

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

CDA in collaboration WISA is also developing an integrated management plan for the wetland system based on an evaluation of hydrological, ecological, socioeconomic and institutional aspects using a consultative approach. Invasion of *Phragmites* has been flagged as one of the key issues that need to addressed for achieving wise use of the system.

Proposed way ahead

Existing Guidelines and Recommendations
The Ramsar Convention Resolution 5.6 on *Additional guidance for implementation of wise use concept* includes reference to taking measures to address problems of invasive species. Resolution VII.14 on *Invasive Species and Wetlands* urges the Contracting Parties to take steps to identify, eradicate and control invasive species in their jurisdictions; to review and as necessary adopt legislations and programmes to prevent the introduction and movement or trade of new and environmentally dangerous alien species into or within their jurisdictions; to develop capacity to facilitate identification and awareness of invasive and alien species; and to share information and experience, including on best practices and management. Subsequently, the Contracting Parties to the Convention also adopted Resolution VIII.18 which emphasized on adoption of integrated approaches to management off invasive species, and application of risk assessment tools using the guidance of Ramsar’s Risk Assessment Framework. The Resolution also noted the climate change dimension, wherein there was an increased likelihood of invasion by alien species into new areas, and species formerly regarded as benign becoming invasive.

The Contracting Parties to the Convention on Biological Diversity adopted the Guideline on Invasive Alien Species with an Annex on Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species. A summary of these guidelines is presented as Table 1.

Developing an Integrated Approach

Building upon the principles laid down in the abovementioned guidance, the strategy for managing invasive macrophytes within Chilika is envisaged to comprise two broad sets of actions: a) controlling the current invasion, and b) enhancing preparedness to manage risks of future invasions within the wetland ecosystem.

Controlling current invasion: This would need to comprise in-situ and ex-situ actions aimed at controlling the rapid spread of *Phragmites* within Chilika, particularly within its northern sector. The options to consider and their likely positive and negative impacts are as follows:

Management Options	Positive implications	Negative implications	Remarks
In-situ			
a) Chemical control (treating with glyphosate product)	Effective on plants, particularly on foliage and rhizome	Can lead to impacts on other biota as glyphosate is not species specific	Current experiment has been limited success
b) Mechanical control / physical control (cutting / mowing the stands to below water level (particularly during summer when water levels are lower)	As most of the food reserves are stored in the upper portion of plants, can knock down the growth	- Expensive, high manpower requirement - Possibility of re-growth from rhizome fragments	
c) Controlled burning	Can greatly reduce the biomass, which can allow other species to germinate	Burning is not species specific and can be dangerous	
d) Biological control			No known options (still need to explore)
e) Harvesting and economic use	Can create incentives for local communities to participate in management	Need to have regulations in place for perverse incentives	Need to invest into technologies and market development
Ex-situ interventions			
f) Manage hydrological regimes (target variables : salinity and sediments) a. Managing higher salinity levels within Northern sector b. Checking sediment inflow and deposition			These investments will form a part of the catchment conservation and water management

particularly in the fringe areas c. Catchment management			action plans within the overall management action plan
g) Manage nutrient enrichment of wetland ecosystem: a. Reduction in chemical Promote organic agriculture – reduction in chemical fertilizer usage b. Enhance sewage and sewerage management within the basin c. Create treatment systems in upstream reaches			These investments will form a part of the water quality management interventions within the management action plan

<u>Enhancing preparedness to manage risks of future invasions within the wetland ecosystem</u>: The focus of this component would primarily be on creating institutional capacities and mechanisms to be able to assess and respond to risks of future invasions. Proposed actions include development and implementation of a risk management framework and enhancing the current research and assessment programmes.

- *Risk assessment framework for Chilika*: The management planning for Chilika aims to promote wise use, which is defined is the Convention text as ‘the maintenance of their ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development’. The risk assessment framework, adopted by the Convention as Resolution VII.10 is aimed at assisting site managers with predicting and assessing changes in ecological character of wetlands, and promotes, in particular, the usefulness of early warning systems. The wetland risk assessment framework is presented as an integral component of the management planning processes for wetlands. A basic model comprises six steps: a) Identification of problem; b) Identification of adverse effects; c) identification of extent of problem; d) identification of the risk; e) risk management and reduction; and f) monitoring. This model would be sufficiently expanded and structured for application in the case of Chilika Lake.

- *Research:* It is also proposed to undertake some targeted research on the following aspects to inform the risk assessment processes and suggest response measures:
  - Characteristics of invasive species, vulnerability of Chilika ecosystem to invasion by alien species
  - Impact of climate change on invasion risks
  - Analysis of pathways for introduction of invasive species
  - Socioeconomic importance of invasive species, particularly implications for local communities and livelihoods
  - Costs and benefits of using biocontrol agents to control invasive species
  - Means to enhance capacity of ecosystems to resist or recover from invasions
  - Priorities for taxonomic research
  - Criteria for assessing invasion risks

- Use of traditional knowledge of communities for management of invasive species

Table 1: Summary of Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species (Convention on Biological Diversity, 2002)

Guidelines	Key implications
General	
Precautionary Approach	▪ Lack of scientific certainty on the various implications of an invasion should not be used as a reason for postponing or failing to take appropriate eradication, containment and control measures
Three stage hierarchical approach: Prevention, Eradication, Containment	▪ Priority to prevention. If eradication is not possible, containment and long term control measures should be implemented , supported by long terms assessment of benefits and costs
Ecosystem Approach	▪ Adoption of an ecosystem approach while formulating a strategy for managing invasive species
Role of State	▪ Cooperation between states to minimize risks of invasion
Research and monitoring	▪ Research on invasive alien species should consider: a) history and ecology of invasion; b) biological characteristics, and c) associated impacts at the ecosystem, species and genetic level and also socio economic impacts, and changes over time
Prevention	
Border Control and Quarantine Measures	▪ Measures to be put in place to minimize accidental / non accidental introduction of species ▪ Measures should be based on risk analysis of the threats posed by alien species and their pathways of entry
Exchange of information	▪ Development of an inventory and synthesis of relevant databases , including taxonomic and specimen databases ▪ Sharing of information at multiple levels
Cooperation , including capacity building	▪ Programmes developed to share information of invasive species ▪ Develop agreements for regulating trade in alien species ▪ Support for capacity building ▪ Cooperative research and funding for identification, early detection, monitoring and control of invasive alien species
Introduction of species	
Intentional introductions	▪ Risk assessment to evaluate whether a particular species should be authorized for introduction ▪ Application of precautionary approach
Unintentional introductions	▪ Strengthening regulatory and statutory measures ▪ Priority attention on common pathways
Mitigation of impacts	
Eradication	▪ Develop early detection systems focused on high risk entry points ▪ Use of community support and consultation based approaches ▪ Consideration to the secondary effects on biodiversity
Containment	▪ Include regular monitoring and link with quick actions to prevent any outbreak
Control	▪ Use of a range of integrated management techniques, including mechanical control, chemical control, biological control and habitat management, implemented according to existing regulations and international codes