Final Report

Conservation of the Kalivelli Wetland Complex

Towards a Comprehensive Management Plan

R. S. Bhalla,
Foundation for Ecological Research, Advocacy and Learning

July, 2011

This report is a compilation of work taken up by FERAL in the Kailvelli region for the past decade and a half. It seeks to provide a scientific framework for the continuous monitoring of environmental, ecological and anthropogenic parameters that affect the functioning of the Kalivelli wetland complex. It is intended to provide a scientific basis for a comprehensive management plan for the wetland complex.

Foundation for Ecological Research, Advocacy and Learning
No.27, 2nd Cross Appavou Nagar
Vazhakulam, Puducherry - 605 012, India
Tel: 91 -413-2671566, 2225441
http://www.feralindia.org

Cover photo: R.S.Bhalla

Acknowledgements

This document is a compilation of work done by various individuals working on a series of projects in the Kalivelli region. These include scientists and field staff who have worked in FERAL over the past decade and a half, all of whose names cannot be listed out. Among the major contributors to this are (in no particular order) Srinivas.V., Dr.Rauf Ali, Dr.Neil Pelkey, Anupama Pai, Sivarajan, Dhandapani, Benjamin Larroquette, Gopinath Srikandane, Gaspard Appavou, Saravanan, Kumaran K, Rajendran K, Sapna Anne, Mahesh and Sohan Shetty. Agencies that have supported this work include various wings of the Dept. of Science and Technology - New Delhi, the India Canada Environment Facility and the United Nations Development Programme - New Delhi.

Contents

Chapter 1 Introduction

Background

The Coromandel Coast of Tamil Nadu is unique in its habitats and endowed with numerous unique features, which include large lagoons and estuaries, mangrove forests and tropical dry evergreen forests (TDEF). Most water bodies along the coast are estuarine and therefore brackish, with one important exception. The Kalivelli lake is a shallow, fresh water lake lying about 10km to the North of Pondicherry in the Villupuarm district of Tamil Nadu. The lake is linked by a long neck, the Uppukalli creek, to an estuarine region called Ediyanthittu and the water body, in its entirety covers slightly over 81.43km^2 with the fresh water comprising about 18.22km^2 during summer and extending to an additional 55.6km^2 during the monsoon (totally 73.81km^2). The brackish portion of the wetland extends to another 7.62km^2 and falls largely under an adjacent watershed in the Kanjeepuram district.

The watershed which drains into Kalivelli lake covers an area of 723.29km^2. It brings in a flow of fresh water along with sediment and associated nutrients and other contaminants during the monsoon months. Thus the wetland as an ecosystem displays a wide range of seasonal variation both in terms of depth and spread of water as well as its physical and chemical properties. The areas adjacent to the water body are largely comprised of an aquatic reed which also exhibits periods of growth which coincides with the winter months and serves as refuge for migratory birds which begin arriving in early November and stay as long as April.

The Kalivelli wetlands are highly influenced and affected by anthropogenic activities. These range from passive influences through transport of sediment and nutrients by surface drainage from agricultural fields, to active interventions such as aquaculture along the water body, removal of reeds, fishing and agricultural encroachments. Another growing issue is the introduction and spreading of exotic and invasive alien species such as *Ipomoea aquatica* and *Prosopis juliflora*.

There is a high dependence of local communities on the lake, both for ecosystem goods such as fodder and reeds, and for services such a ground water recharge. The importance of this landscape for sustaining biodiversity has been recognised by many experts. Unfortunately, the scientific information available for the lake is insufficient for developing a comprehensive management framework for its conservation. This information is largely through publications in local natural history journals and in reports to Indian and multilateral agencies. Gaps in information include:

- topical gaps due to which only specific taxa and few communities around the lake have been studied in any scientific detail.
- temporal gaps which prevent us from fully understanding the seasonality associated with various environmental and ecological processes,
- spatial gaps with only few areas of this vast wetland being monitored.

This study is an attempt to collate the present state of the knowledge about Kalivelli and to put forward and test a methodology which can be pursued to build a suitable database to inform management decision making and conservation of the lake's habitat. It is split into three sections, the present section which introduces the lake and its surroundings, the next section which reviews literature published regarding Kalivell and a final section to propose a sampling framework and parameters to be covered for building a spatially explicit and scientific dataset for the lake.

Location and climate

The Kalivelli wetlands lie roughly between the towns of Tindivannam to the North West, Marakannam to the North East and Pondicherry to its South. The bounding coordinates of the watershed are11°55'N, 79°35'E and 12°10'N, 79°55'E (Fig. 1.1). According to the Watershed Atlas of the Central Ground Water Board (Central Ground Water Board, 2007), Kalivelli is labelled the Nallavur watershed No.4C1D4 and falls under the Pennar basin and Penniyar sub-basin.

The region falls under the South-Eastern Coastal Plains and is climate is characterised by temperatures in the range of 28° and 39°C and humidity levels exceeding 60% for most of the year. The bulk of the 1200mm of average rainfall is received during the North East monsoon during the end of October and November, which signals the onset of the migratory season for the numerous winter migrants to the wetland.

Physiography and landuse

The Kalivelli region is largely flat with a maximum elevation of 45 metres (Fig. 1.2) . The watershed is a predominantly agricultural area with a centuries old tank based irrigation management system, now supplemented with lift irrigation (Fig. 1.3) . Over two hundred of these tanks, many exceeding 200ha in area, are linked by a network of channels which empty themselves into the Kalivelli wetlands. Studies in the region suggest that the total nutrient load carried into the lake in this way is considerable, and that the land use pattern in the larger watershed dictates the nutrient inflow into the wetlands and hence influences its ecology.

Salinisation of aquifers in this region is considered one of the more serious threats and is often attributed to lift irrigation for water intensive cultivation practices. Various watershed development efforts in the region have tried to address this issue through restoration of irrigation tanks and channels and construction of water harvesting structures. Data collected over a period of four years suggests that some of the salinity is local in nature and not linked to intrusion from the Bay of Bengal (Fig. 1.4). Kalivelli has five different geological formations (Fig. 1.5) and six dominant soil types (Fig. 1.6) which have bearing on land use and ground water recharge and exploitation.

Environment

The northern parts of the wetland are increasingly saline, the salinity levels being the highest at the Ediyanthittu salt pans and at the mouth of the estuary near the Alambara fort. The Uppukalli creek is a long neck which joins the southern and western fresh water body with the saline estuarine portion to the north east. Paddy fields along this creek have now been converted to shrimp farms (Fig. 1.7) and

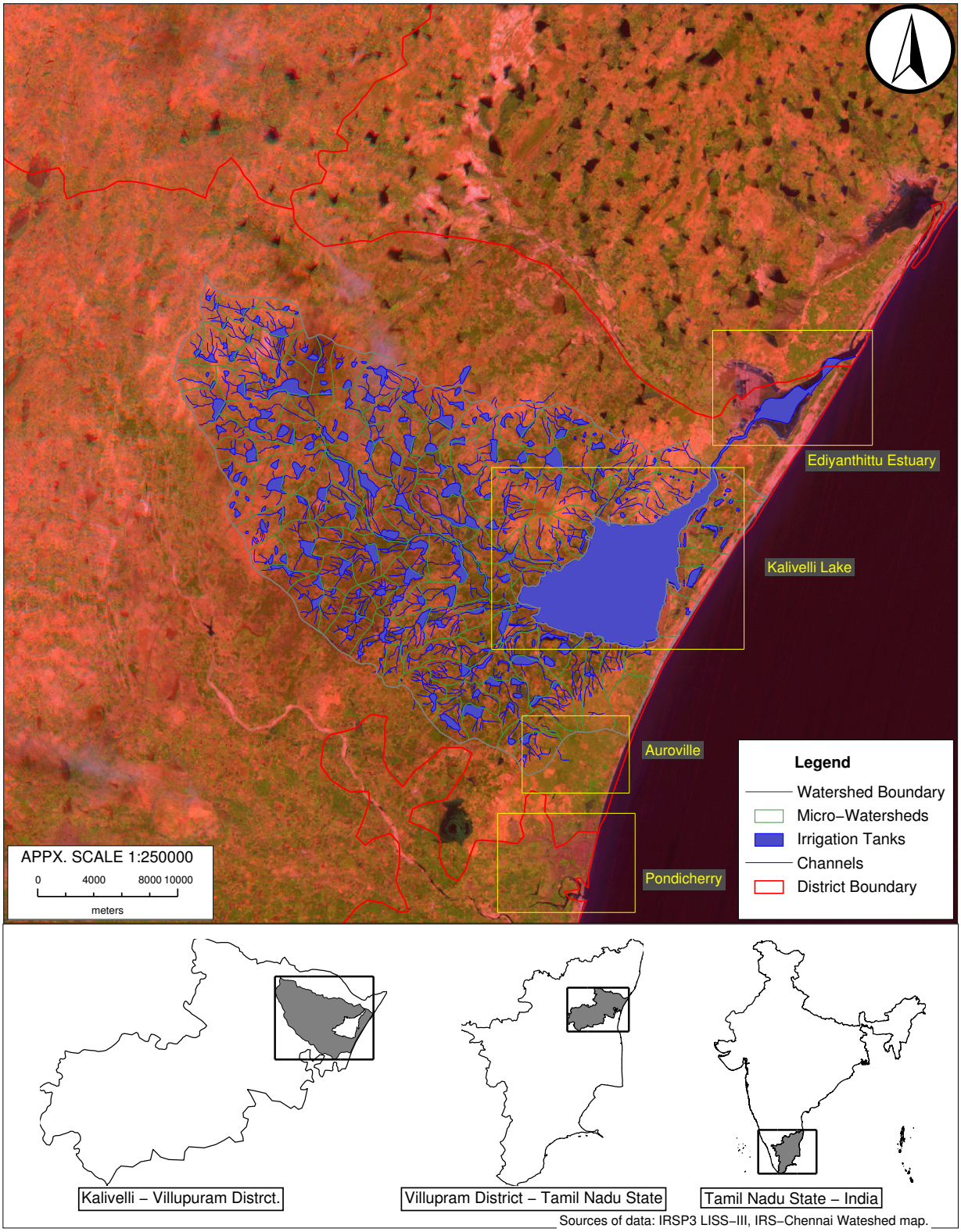


Figure 1.1: Location of the Kalivelli wetlands and watershed with some landmarks.

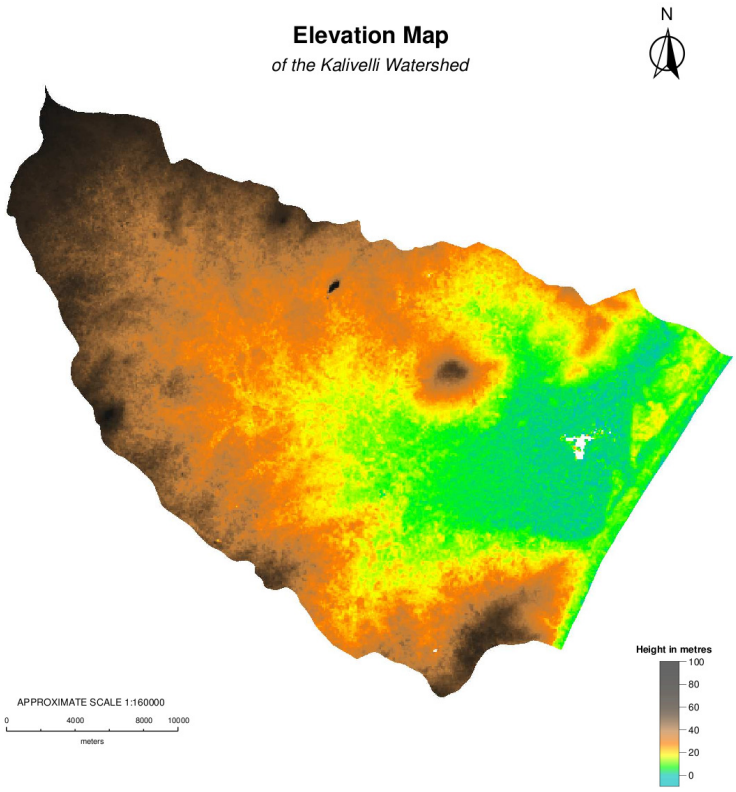


Figure 1.2: Elevations of the Kalivelli watershed, derived from an SRTM digital elevation model.

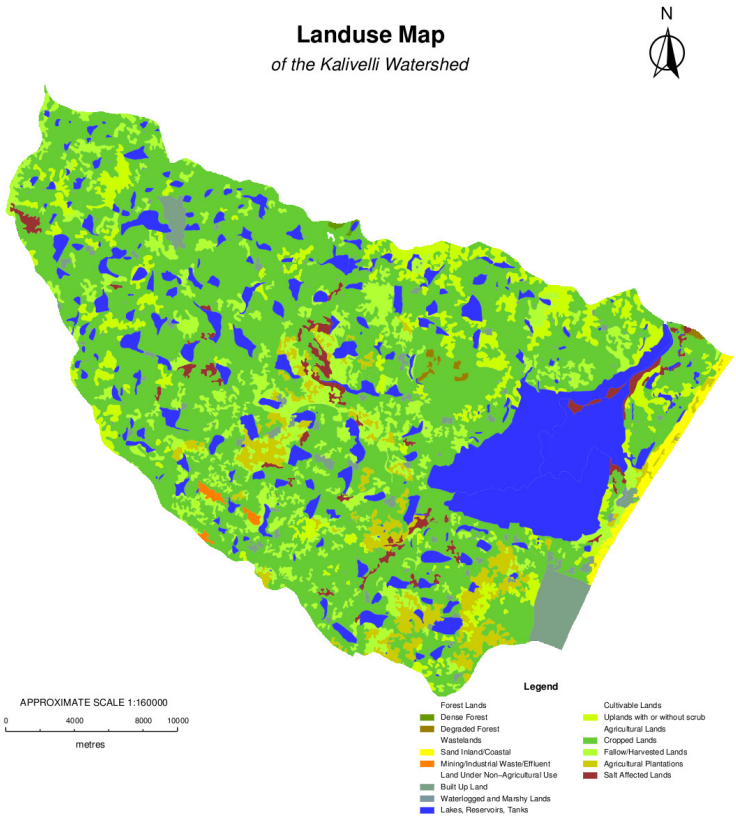


Figure 1.3: Landuse map of the Kalivelli watershed. Source: Institute of Remote Sensing, Anna University, Chennai.

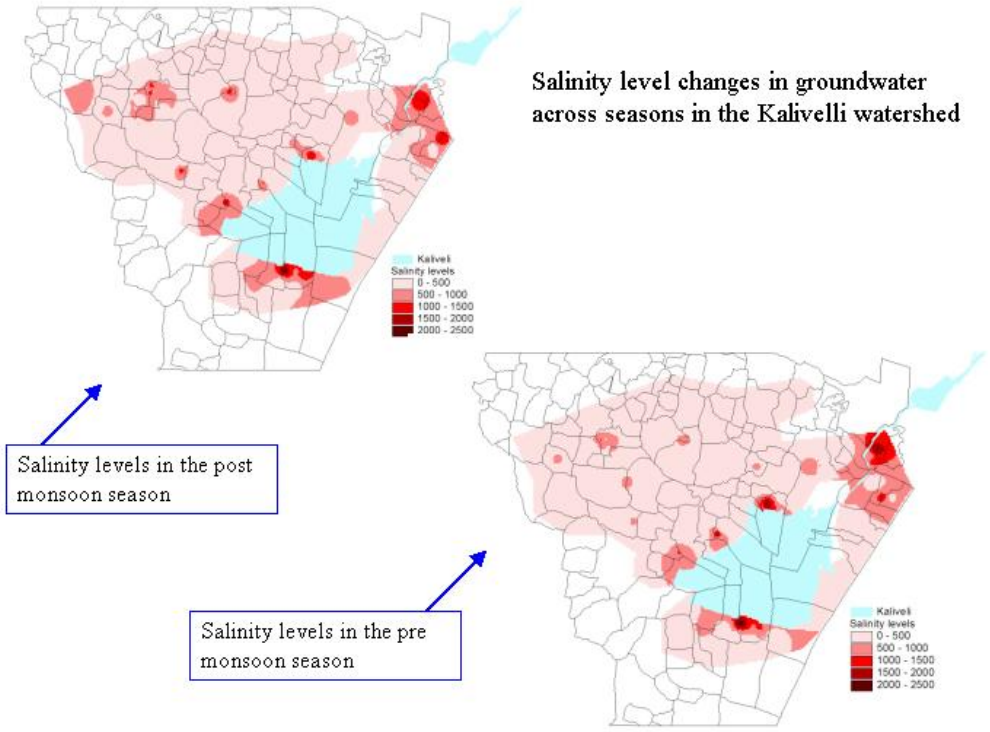


Figure 1.4: Changes in salinity around Kalivelli.

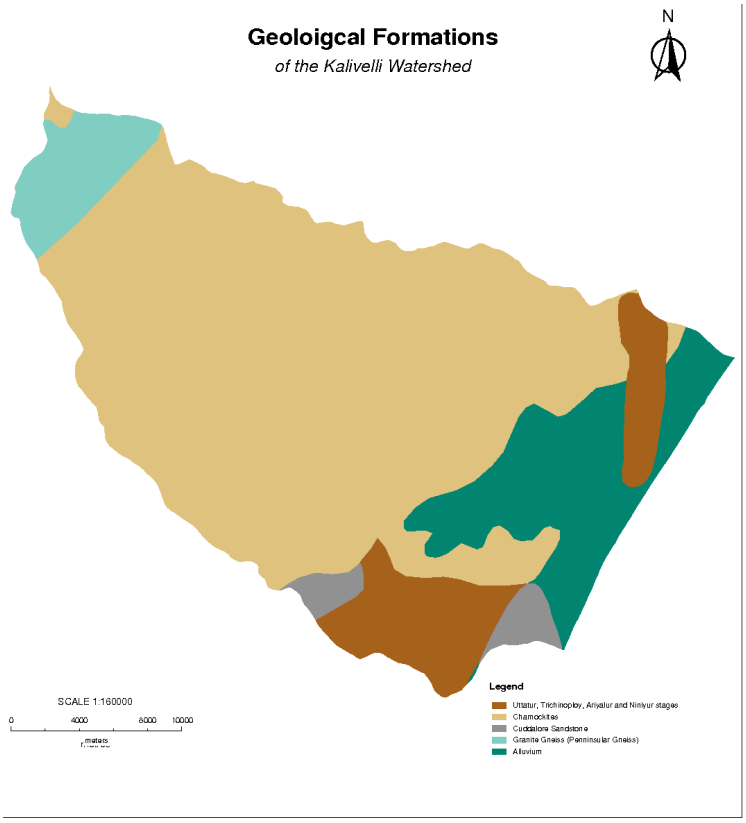


Figure 1.5: Geological formations in the Kalivelli watershed. Source: Geological Survey of India.

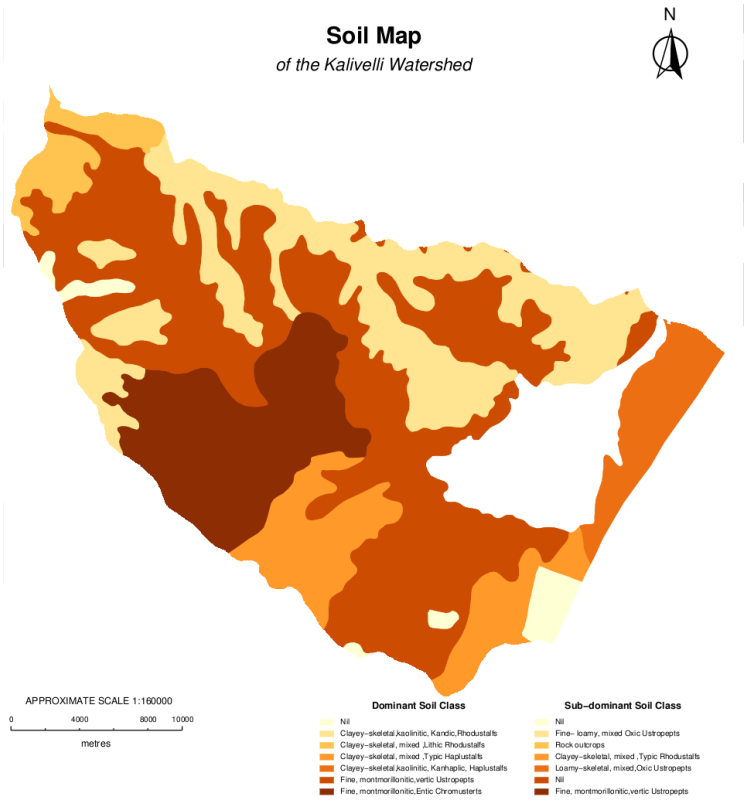


Figure 1.6: Major soil types in the Kalivelli watershed. Source: National Beareau of Soil Sciences and Landuse Planning.

also effect the environmental conditions of the regions nearby. Salinity levels in the wetlands therefore have a gradient from fresh in the south to saline in the north with spikes in the vicinity of aquaculture and salt pans. The levels of salinity increases during the dry season and gets washed out into the estuary and Bay of Bengal during the monsoon.

The area under salt pans in the Ediyanthittu estuary has increased substantially over the years till its present extent, which covers the bulk of the Southern area of the estuary. This has an overwhelming impact on the habitat surrounding the region as demonstrated by the stunted and single species dominated mangroves in the vicinity.

Demography and Resource Dependence

The Kalivelli wetlands are surrounded by a total of 18 villages, which according to the Census of India, 2001, comprised of nearly eight thousand households and a population of forty thousand. (Fig. 1.9 and Table 1.1).

Communities living in the region use a range of resources from the lake. Surveys conducted in an earlier study showed wide ranges being utilised for grazing and reed collection. The various kinds of resources and uses of the wetland with the number of villages involved in the respective resource is summarised in Table 1.2 while the areas observed to be used for grazing and reed collection are presented in figure 1.11.

Table 1.1: List of villages surrounding Kalivelli along with the number of households and total population as per the 2001 census.

Name	Households	Population
Agaram (Vada)	199	899
Anumandai	1199	5644
Chettikuppam	360	1713
Idaichcheri	58	280
Kaluperumbakkam	291	1383
Karattai	344	1568
Kilappakkam	180	999
Kilpudupatti	1304	6427
Kodur	317	1544
Koluveri	383	1866
Komadippattu	145	717
Koonimedu	1341	6651
Pudupakkam	273	1329
Seyyankuppam	299	1472
Singanandai	72	365
Talaiganikuppam	146	705
Uppuvelur	797	3429
Vilvanatham	170	835
Total	7878	37826

Table 1.2: Villages and resources utilised (Source: FERAL, 2001).

Resource/use	Number of villages
Grazing (full year)	15
Grazing (after harvest)	8
Fishing	11
Reed collection	10
Thorn forest	13
Fuel-wood collection	9
Soil collection	10
Paddy (nursery based)	13
Paddy (direct sowing)	3
Aquaculture (shrimp)	3

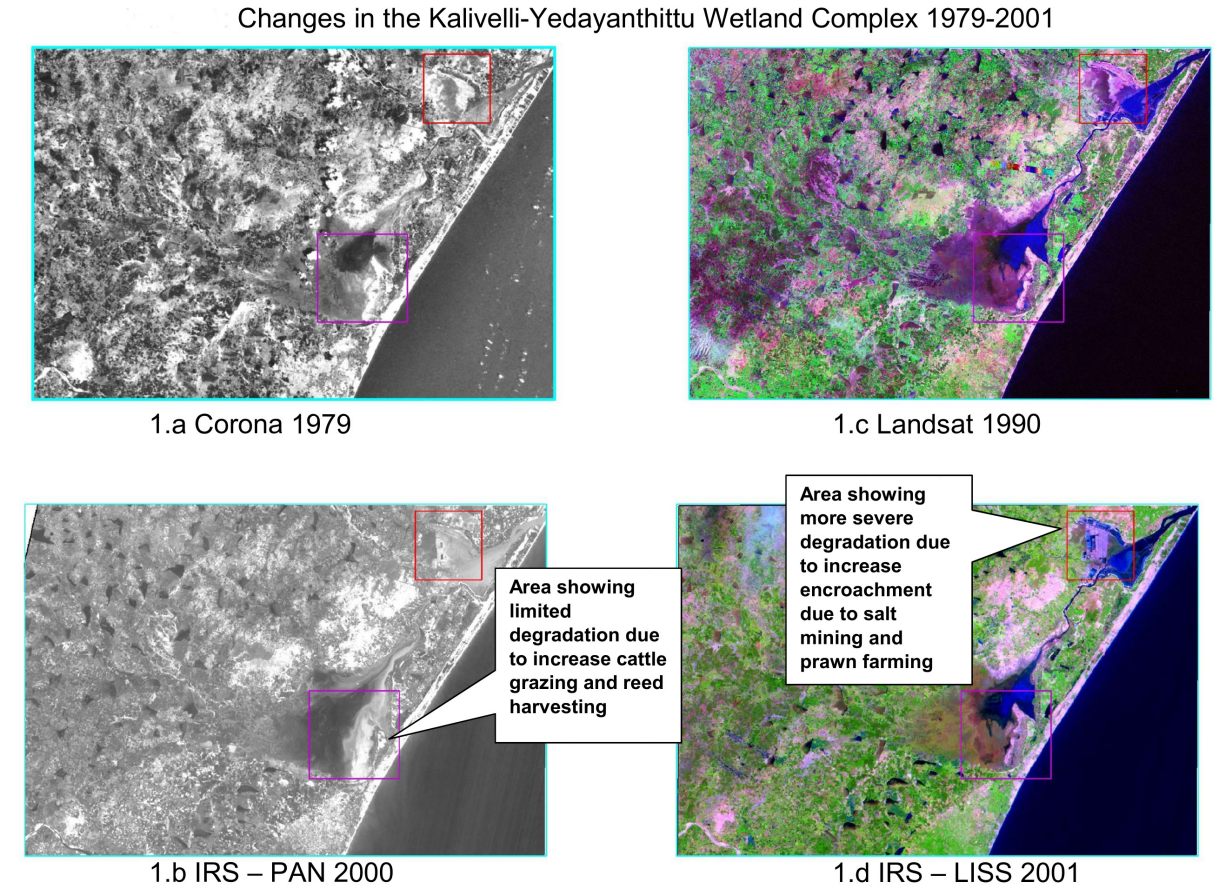
Figure 1.7: The Uppukalli creek joining the Ediyanthittu eastuary to Kalivelli has numerous shrimp farms on either side.

Kalivelli in Literature

Kalivelli is regarded as one of the most important wetlands in Tamil Nadu Perennou (1987), and one that is both nationally (Kaliaperumal and Kalimuthu, 1993; Chari, 1997) and internationally important (Pernetta, 1993). It is listed in the wetland conservation programme of the Government of India (SACON) and finds a place in the national report on the implementation of the Ramsar convention on wetlands (Anony, 2008) as well as in the Ramsar directory of wetlands in India (Woistencroft et al.).

Among the few attempts to consolidate the state of knowledge on Kalivelli was that by Gopinath and Vaidyanathan (2004) following which there have been a series of independent studies on specific aspects or taxonomic groups, most of which are limited to isolated sites and unable to capture the complexity of this complex wetland. The most comprehensive work on the fauna of Kalivelli appears to be that of M.E. Ramanujam and various co-authors, chiefly R. Anbarasan who have published over 7 papers in the period between the year 2000 and 2009 (Ramanujam, 2000; Ramanujam and Kadamban, 2001a; Ramanujam and Verzhutskii, 2004; Ramanujam, 2005; Ramanujam and Anbarasan, 2007, 2008; Ramanujam and Murugavel, 2009). Most this work is observations and compilations of vertebrate diversity in and around the Kalivelli region which recorded 268 vertebrate species including 49 species of fish, 7 amphibians, 37 reptiles, 38 mammals and 137 species of birds. He also records 25 species of aquatic vegetation (Ramanujam and Anbarasan, 2007).

Kalivelli has long been regarded as an important migratory bird stopover and destination (Scott, 1989) in (Pernetta, 1993). Various accounts of birds have been published from the wetlands which include work done by members of the Bombay Natural History Society (BNHS), supported by BNHS or published in its journal by independent workers (Cedex et al., 1990; Balachandran and Hussain, 1998; Sundar, 2000; Kannan and Manakadan, 2005; Balachandran, 2006; Balachandran and Sathiyaselvam,



The satellite imagery presented here shows a somewhat clear picture that the wetland has been reduced in size. It also clearly shows that encroachments are a major phenomenon in the northern section of the wetland. The environmental impacts of these land use changes is unclear. This study will help document these impacts and assess their long term consequences.

Figure 1.8: Development of the Ediyanthittu salt pans over the years.

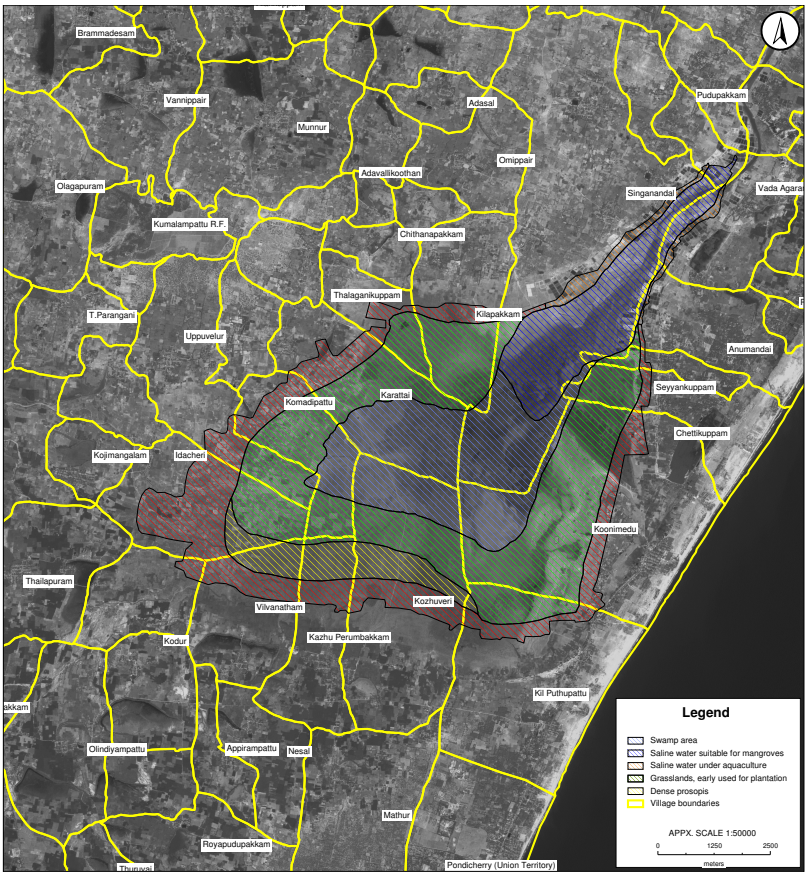


Figure 1.9: Villages around the Kalivelli wetlands.

(a) Ecosystem goods. *(b)* Ecosystem services.

Figure 1.10: Goods and services from the Kalivelli wetlands the local communities depend on. Extraction of reeds, grazing, fishing and a booming salt pan industry are among the major goods. Kalivelli provides biodiversity services ranging from habitat for migratory species, patches of tropical dry evergreen forests and ground water recharge.

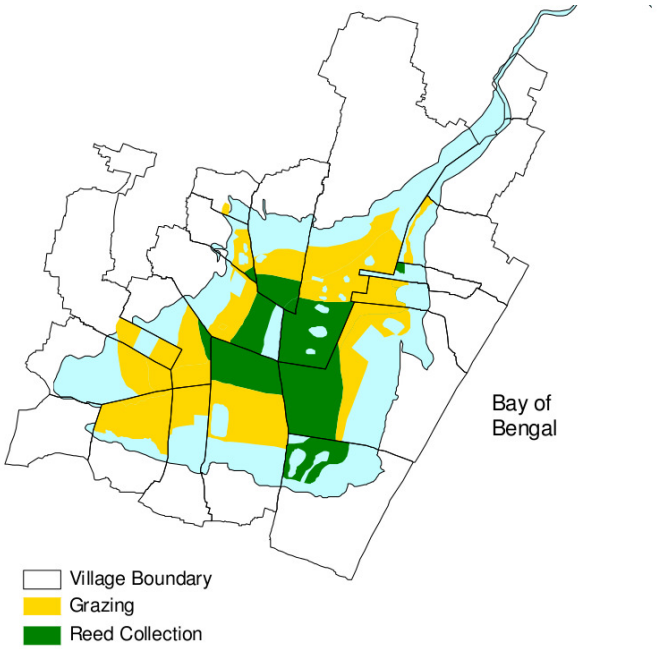


Figure 1.11: Areas used for extraction of reed and for grazing.

2009). The work by Perennou and Santharam (1990) was is particularly significant as it comprised an extensive survey of wetlands along the Coromandel coast and identified Kalivelli as one of the two most important wetlands in the region. Other studies include work on distributions of migratory species (Pittie et al., 2005) and various bird lists and sightings reported in natural history journals (Shantharam et al., 2006; Ramanujam and Murugavel, 2009).

Dr.N Parathasarathy of Pondicherry University is the most published ecologist on this region, with most of his work concerning tropical dry evergreen forests, largely trees and lianas, around the Kalivelli region among which are Puddupet, Oorani and the Marakannam RF. These include both descriptive papers restricted to specific sites as well as site wise and regional comparisons of species diversity, phenology, population and vegetation structure, biomass and productivity between TDEF sites along the Coromandel coast (Parthasarathy and Sethi, 1997; Venkateswaran and Parthasarathy, 2003; Parthasarathy et al., 2004; Selwyn and Parthasarathy, 2006; Mani and Parthasarathy, 2006, 2007, 2009; Udayakumar and Parthasarathy, 2010). Other articles on TDEF in the region include work by Ramanujam and Kadamban (2001a) on Oorani and Olagapuram and on the possible impacts of increased moisture of Kalivelli on fine root production in nearby groves by Visalakshi (1994a). Restoration of TDEF has been another important area of work undertaken in the region Blanchflower (2005); Venugopal et al. (2008). Work done on aquatic plants of the regions include that of Ravikumar and Ganesan (1990a) who worked on Hylophyla and that of Parthasarathy et al. (1991) on sea grasses. Documentation of Macrofungi from the region was also done by Mani and Kumaresan (2009b). There have been few publications on the environmental aspects of Kalivelli. Among these are an analysis of watershed guidelines based on the Kailvelli watershed (Bhalla et al., 2011) and a book on land use and ecological aspects of the Kalivelli watershed (Abbasi, 1997).

The lack of a comprehensive dataset on the wetlands is among the biggest obstacle for its scientific management. Much of the functioning of Kalivelli as an eco-system has not been studied, this includes processes such as nutrient and water cycling which drive the other parameters. Levels of human

dependence, the potential for involving local communities in the management of the wetland and the role of anthropogenic interventions and development in the wetland are still not known.

Chapter 2 Framework for an Ecological and Environmental Baseline for the Kalivelli Wetlands

Introduction

Kalivelli provides a host of opportunities for ecologists and naturalists. A number of fundamental questions on the functioning of this complex wetland system remain unanswered. Systematic research on these issues could play an important role in building a scientific management framework for the wetlands which is sensitive to both the needs of local communities, and to the need for conserving this unique habitat.

Management decisions for conservation areas require a mix of environmental, ecological, and anthropogenic information. A subset of the possible variables are suggested based on their importance, cost of analysis and their ease of collection in terms of effort involved and sample availability. These are:

1. Environmental parameters
    a) Physical variables for water from the wetland including pH, EC/TDS, salinity, turbidity and DO.
    b) Optionally sediment and nutrient content, the latter being NO3 and PO4.
    c) Meteorological variables including maximum and minimum temperatures, relative humidity and optionally light intensity and wind direction and speed.
    d) Optionally, details of ground water based on surveys of existing wells.
2. Ecological parameters
    a) Diversity and abundance of flora (aquatic and terrestrial, not including grasses) and of avifauna (resident and migratory).
    b) Presence and densities of invasive alien species particularly Prosopis juliflora and Ipomoea aquatica
3. Anthropogenic parameters
    a) Resource dependence (ecological goods) on reeds, grazing, fuelwood and other resource extraction.

b) Ecosystem services in terms of ground water recharge through proxy measures such as area under cultivation through lift irrigation.

c) Revenue relations specifically looking at land use into the lake.

Anthropogenic parameters require to be collected from all the villages surrounding the reserved land as shown in figure 1.9. These surveys will need to explicitly accommodate caste and gender issues in their design as resource use patterns and perceptions may differ substantially between social groups and according to gender.

The rest of this section describes the sampling strategy that will be pursued to collect this information and the tools, techniques and specifics of the methods for measuring the variables.

A spatially explicit sampling strategy will be employed for the environmental and ecological parameters. We explored various sampling options and settled on a uniform hexagonal grid across the seven land use type categories provided by the forest department[1]. Within each grid, sampling would be determined by local conditions. For instance, bird counts would be located in the centre of the grid while water samples would be collected wherever water bodies lay. Similarly quadrats for vegetation sampling would be laid based on the cover in each grid with different approaches being used for reeds/herbs, shrubs and trees.

Alternatives included a randomised approach which would have resulted in a lower representation of areas of unique land use, or opportunistic approaches which would ensure a higher number of points per land-use type, but may bring in bias into the observations. The present approach relies entirely on the land use areas defined by the forest department. As shown in figure , these areas could be varied on the ground and while many are highly seasonal in nature. Furthermore, given the relationship between the larger watershed and the estuarine region of Kalivelli, it would be advisable to extend the sampling of some of the parameters to these regions.

There is a substantial variation in the various parameters to be measured across seasons. This is reflected both in terms of the spatial spread of different land-cover and use as well as the variables themselves which often move from one extreme of their range to another. The sampling strategy therefore needs to be cyclical and must be repeated at least thrice per annum (preferably four), to cover the wettest, the driest and one intermittent sample per sampling point each year. Seasonal variations for some of the parameters may be collected by other means. For example water-spread areas of the lake would be better detected using satellite imagery and many anthropogenic parameters could be covered by building in seasonality measures into the questionnaire.

Financial constraints often limit the duration and intensity of sampling efforts, especially when they need to be spatially extensive and to cover a wide range of parameters. Some of these costs can be offset by involving local communities, especially schools, in the collection of some of the parameters such as meteorological measurements and some socio-economic measures. There are various examples of the Forest Department building such a sampling strategy as part of the community outreach or eco-development plans.

Environmental Parameters

These cover measures of water quality and meteorological variables as follows:

[1] The sampling was done using the spsample package which is part of the sp package which provides spatial extensions to the R package for statistical computing

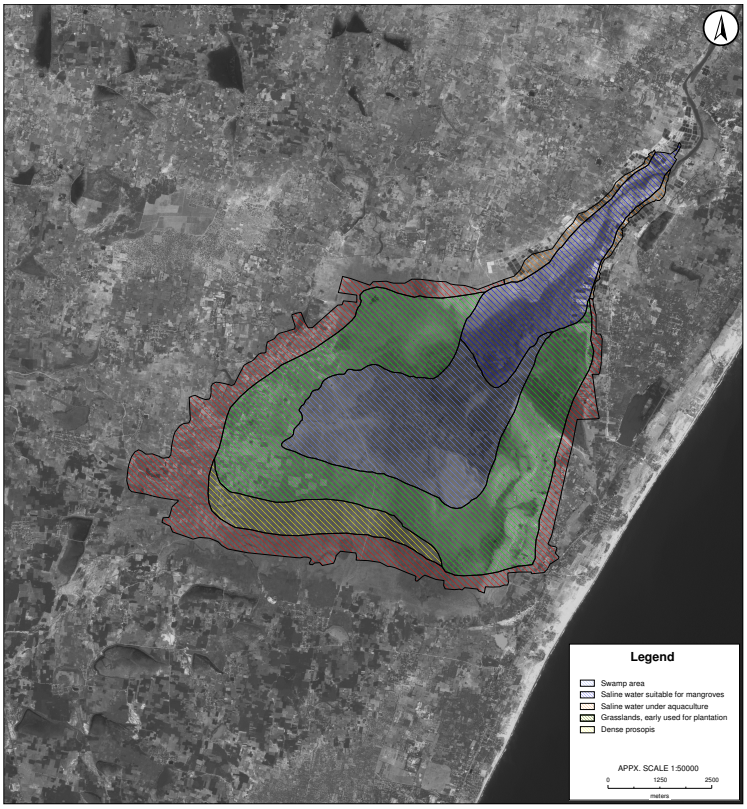


Figure 2.1: Land use around the Kalivelli wetlands as per Forest Department records.

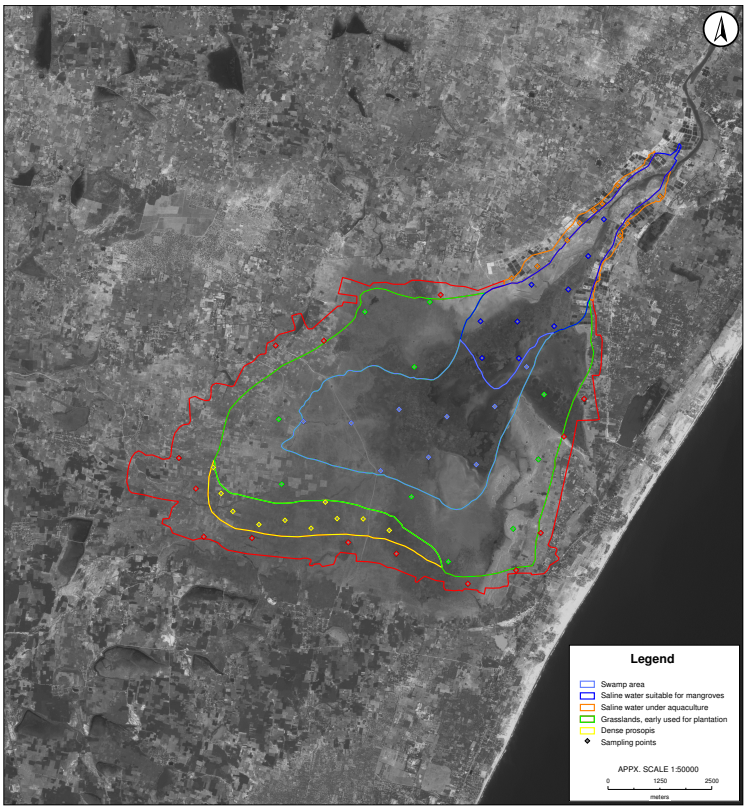


Figure 2.2: Sampling strategy based on a hexagonal grid across the different land use types and areas provided by the forest department. Note that these areas may be increased to accommodate more recent land use changes which will result in additional points.

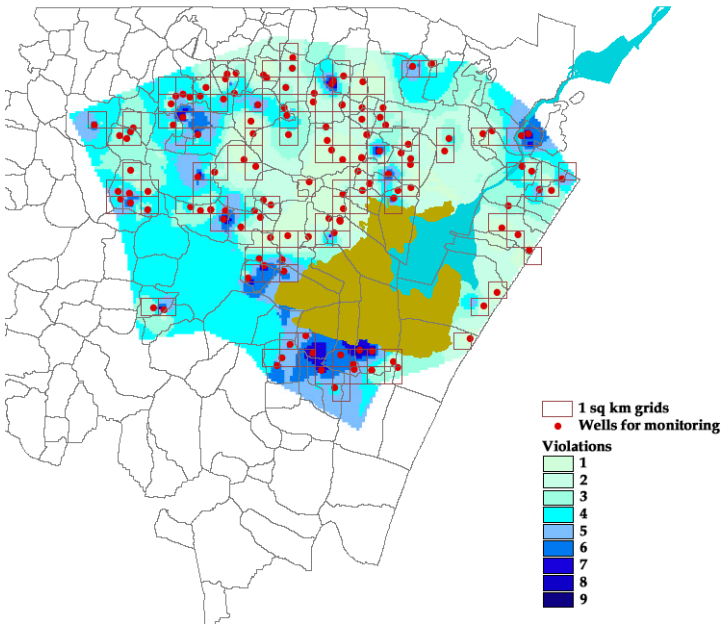


Figure 2.3: Ground water sampling points used during studies conducted by FERAL in the period 1999-2004.

Water Quality and Quantity

Both surface and ground water variables are important from the perspective of conserving and measuring the ecosystems services of Kalivelli.

Surface water quality both in inlets to the lake as well as at various points of the water body are required. Hand held electronic meters can be used to measure physical variables such as pH, EC/TDS and salinity. Turbidity and temperatures at various depths are other important parameters where a Secchi-disk and thermometer is useful. Other parameters that are important are dissolved oxygen and biological and chemical oxygen demand. In terms of nutrients, nitrates and phosphates are among the most important but require a laboratory infrastructure as do DO, BOD and COD.

The quantum of water entering the Kalivelli wetlands determines, among other things, the water spread, the flushing of nutrients and salinity out of the Uppukalli creek and the status of the sand-bar at Alambara fort which can re-form and choke off the mouth of the lake during years of low rainfall.

Ground water quality and extraction rates around the wetland are another set of important variables required to determine the effect of Kalivelli on ground water recharge and quality. Among the largest earlier dataset on the ground water depth and quality is that of FERAL (Fig. 2.3) . The Auroville Water Harvest group has also worked extensively in the southern regions of Kalivelli. Among the parameters that need to be covered are water extraction rates which are a function of time period for which pumps are run and their horsepower. Depth of wells are another important variable which provides information on the aquifer from which water is being drawn. Measures of the physical and chemical that are required include those listed for surface water with the exception of turbidity, DO, BOD and COD.

Meteorological Variables

Habitat suitability and productivity are often driven by daily fluctuations in variables such as precipitation, light intensity, temperatures and relative humidity. Furthermore, the input of water into the lake is directly related to the total precipitation. A grid of automated weather stations, complimented by

manual stations which may be placed in schools and colleges in the region would provide vital information required to model the major hydrological drivers of the Kalivelli wetland. It is suggested that a 10km grid is used for this set-up with a mix of automatic and manually operated weather stations.

Ecological Parameters

Diversity and Abundance of Targeted Taxa

Avifauna

Kalivelli is home to hundreds of resident and migratory species of birds which has led to it being considered internationally and nationally important, and a potential Ramsar site. Unfortunately the vast majority of the bird count data is inconsistent both in terms of methods utilised and period of sampling. There is some progress towards standardised data collection through the efforts of the Bombay Natural History Society (BNHS) and the School of Ecology and Life Sciences at Pondicherry University.

A standardised and publicly available bird record for the lake would greatly enhance our knowledge of its ecological significance. This would require the following:

1. Standardised sampling design - we suggest a uniform point based sampling strategy which covers all the land-use types as described earlier.

2. Fixed periods for sampling to cover all seasonal variation.

3. Linking avifaunal surveys with other assessments such as that of water quality and ground cover.

4. Use of species accumulation curves for each seasonal assessment to determine the sampling size.

Vegetation

Ground cover around the wetland plays an important role in determining the abundance and diversity of other taxa, including Arthropoda and Aves. Furthermore, Kalivelli's surroundings include various patches of TDEF, some of which exhibit a rich diversity and abundance of plant species. The wetland portion of the lake exhibits distinct seasonal variation in productivity and cover which need to be captured. Among the measurements of ground cover and composition required are:

1. Seasonality to cover at least the wet and dry seasons.

2. Structural characteristics: height and biomass.

3. Species composition and abundance using quadrats of suitable sizes - 1x1m for herbaceous vegetation and grasses, 5x5m for shrubs and 25x10m for trees.

4. The number of replicates of each type of sampling needs to be determined through plotting species accumulation curves.

Invasive Alien Species

One of the gravest threats to the ecological integrity of Kalivelli is the invasion of species such as *Prosopis juliflora* and *Ipomoea aquatica* into the wetland and its surroundings. These can alter the habitat of the lake in a short period owing to their aggressive colonisation of both wet and dry portions of the lake. The location and size of patches of these two invasives needs to be tracked on a seasonal basis so that management decisions such as removal and burning can be taken.

We recommend a GPS based survey of the patches to cover the perimeter along with the density of the invasive species using a 25x10 quadrat randomly placed in each patch of *Prosopis sp.* and a 5x5m quadrat randomly placed in each patch of *Ipomoea sp.*

Area of Ecological Significance

The Kalivelli watershed is a landscape of diverse land cover types which provide unique and diverse habitat for a range of species. This includes:

1. Patches of wetland and riparian habitat not just around the lake itself but around the two hundred and odd minor irrigation tanks and ponds that cover the watershed. Some of these tanks are under plantations of *Acacia nilotica*.
2. Riparian regions of these irrigation tanks and other areas of irrigated agriculture and plantations such as coconut, casuarina and coconut.
3. Dryland areas under dryland crops and plantations such as cashew, *Acacia auriculiformis* and casuarina.
4. Barren and rocky areas.
5. Forested areas under natural TDEF and forestry plantations of eucalyptus and
6. Estuarine areas to the North East of the lake.

Some of this landscape harbours patches of high diversity such as the areas under reserve forests, sacred groves, portions of the estuary, the irrigation tanks and the wetland itself. Other landscape features such as channels and bunds of tanks and plantations probably provide connectivity between water bodies and patches of forests for birds, butterflies and small mammals. It is important that the extent and distribution of these areas is mapped and documented. Some of them, such as the reserved forests and a few sacred groves, have well documented diversities and abundances of plants and other groups such as birds and butterflies.

Anthropogenic Parameters and Threats

A range of anthropogenic activities occur regularly in and around the Kalivelli wetlands and have a bearing both directly and indirectly on the lakes functioning. These activities include but are not limited to:

1. Agriculture in the lake foreshore both in private fields and encroachment.
2. Intentional and unintentional introduction of invasive alien species which are spreading in area.

3. Removal of reeds.
4. Grazing.
5. Removal of other usufructs such as clay and fuel.
6. Hunting and fishing.
7. Conversion of areas to aquaculture and expansion of salt pans.
8. Past plantations in the fore-shore by the Forest Department that have reduced the habitat for rare grassland birds such as Indian Courser.
9. Proposed development projects

A large amount of data pertaining to the use of the Kalivelli region as a resource can be collected through participatory exercises such as resource mapping and seasonality, as well as sample based surveys of households. Other data requires quantification of biomass extraction and nutrient removal and cycling which depends on exclusion experiments as well as direct measurements of biomass and nutrient content in biomass.

Agriculture in the lake foreshore and upper catchment

There are large amounts of sediment and nutrients that enter the lake by way of drainage from agricultural fields. Unknown amounts of pesticide are also probably transported similarly in to the water body. Agriculture, particularly paddy cultivation in the lake foreshore may play a more important role in this process.

Other than inputs transported by channels (described earlier) an approximation of nutrient inputs to the foreshore areas could be done through regular water sampling during various stages of paddy cultivation in areas adjacent to paddy fields.

Introduction of invasive species

There is an inadvertent introduction of invasive species, particularly *Ipomoea aquatica* by agriculturists and reed collectors who use it to demarcate boundaries. The sticks of *Ipomoea sp.* used for marking out plots often germinate and grow into clumps of vegetation which are now appearing in more and more places. Clumps of *Prosopis juliflora* have also increased in number and extent. These too were initially a fencing arrangement but are now being dispersed naturally. A regular monitoring of the patches as described earlier needs to be put into place.

Removal of reeds for thatch

Thatch reeds are a traditional resource from the wetlands and are harvested by many villages in the vicinity. Some of the reed harvested is controlled by the Panchayat while in some areas this is done through informal arrangements. In some areas, harvested areas are burnt to encourage the flush of new reeds. Areas being burnt need to be mapped using a GPS unit whenever burning activities are taking place.

Measurement of biomass extraction in the form of weeds could be made by setting up exclusion plots of 10x10m at various locations in the reed collection areas. These would not significantly affect the total extraction yet would provide a reasonable estimate of total extraction. Samples of harvested reeds could be collected for analysis of nitrogen carbon and phosphates.

Grazing

Earlier studies suggested about 35,000 heads of cattle graze in the grasslands in and around the wetland.

Estimates of total biomass extracted through grazing could be made through exclusion plots and weighing of biomass on a regular basis. A spot count of number of cattle grazing during specific seasons would provide an estimate of the total number of heads. Village based surveys of cattle could be used to supplement this information. It should be stressed that the grazing is not necessarily harmful. It introduces a large quantity of nutrients in the form of dung, which probably results in increased fish production as well as water plants and reeds. It also keeps waterways open from weeds for aquatic birds.

Other usufructs

Among the other uses of resources of Kalivelli are extraction of clay, fuelwood and fodder. Earlier surveys suggest that these are low intensity and impact activities. Village based surveys of resource use around the lake could help elucidate the spatial extent, seasonality and quantum of extraction of such usufructs from the wetland.

Hunting and fishing

Sporadic cases of hunting in the lake have been recorded. This includes "hobbyists" from nearby villages, towns and cities as well as harvesting of birds by tribal communities for sale. Given that some of these activities are not permitted, it is difficult to collect accurate data on the same. Fishing is taken up more extensively, mostly in the estuarine regions of the lake. Fishing has also been recorded in the fresh water portion with gill nets being the favoured gear. Again the extent and intensity of this activity has not been recorded and little information is available on the species being harvested and their morphometry. The latter would provide important information on whether the Kalivelli wetlands are nurseries for commercially important marine fish species.

Direct observation of catch has been used for most studies on fishing in the wetland with fewer cases where hunting has been similarly observed. Opportunistic sampling or recording of all observations as they are noticed is probably the most practical means to measure this. This sampling strategy needs to be accompanied with a geo-location (GPS reading) of the site of observation so that parameters such as water quality can be linked with these observations.

Conversion to aquaculture and salt pans

Perhaps the most environmentally disruptive activity taking place around the Kalivelli wetlands is the conversion of fresh water paddies to brackish water aquaculture and that of natural mud flats to salt pans. This has a direct impact on the salinity levels and nutrients and biological waste released from these units could play an important role in shaping the ecology of their surroundings. No studies have

yet been undertaken to determine what the extent of these activities and their impact on the local ecosystem are.

Measurements of physical and chemical parameters as well as biological sampling of benthic and aquatic organisms in affected and comparative natural habitats would provide interesting insights which could guide restoration and management efforts in the affected areas. A historical mapping exercise combined with a rapid GPS survey of the area would serve to develop a perspective on the rate of change and factors affecting the spread of aquaculture and salt pans in the area.

Introduction of trees in the foreshore

About five years ago, the Forest Department undertook intensive planting of various tree species in the foreshore areas of the coastal floodplain of Kalivelli. This was done to help demarcate the area of the wetlands that was declared reserved land. However this area was a natural grassland and inhibited by the Indian Courser which is a rare grassland bird. Changes in land use such as these can have a negative and long term impact on the ecology of the lake and areas thus converted need to be restored to their original status. A landscape level mapping of the entire wetlands would provide an important baseline to ensure that no future modifications of such a nature take place.

Proposed development projects

Towns and cities around the Kailvelli wetlands are rapidly urbanising. This has led to a number of development projects in the vicinity of the wetlands which may have bearing on the health of the ecosystem. These developmental projects include real estate and tourism projects which are mushrooming along the East Coast road as well as larger projects such as a the proposed renovation and extension of the Buckingham Canal under the National Waterways programme. The latter proposed the linking of Kalivelli with the Buckingham Canal which in turn would be linked all the way to the Kakinada canal in Andhra Pradesh. The Pondicherry UT stretch of this waterway proposed to extend upto the village of Kanakachettikulam through the Kalivelli lake.

Projects such as these can have a disastrous affect on the entire Kalivelli wetlands by causing fundamental changes to the water flow regime and by introducing brackish water in the presently fresh water flood plain. It is important that proposed projects of such nature are duly evaluated for their ecological and environmental repercussions through appropriate environmental impact studies.

Chapter 3 Conclusions

This chapter tries to present the way forward for building a comprehensive management plan for the Kalivelli region. It first tries to summarise the major lessons about the watershed and the present areas of concern and then suggests a series of steps which may be taken to pursue additional research to feed into management decisions.

Kalivelli is a complex wetland with multiple levels of feedback and many external drivers: A range of external drivers such as nutrient and sediment inflows which are a function of climatic variables and land use in the catchment, drive much of the nutrient water cycle of the wetlands. Many of these materials make their way out into the Bay of Bengal during the monsoon, however there are additional nutrients and chemical modifications made to the system due to cattle in the coastal plain and aquaculture in the Uppukalli creek and Ediyanthittu estuary. Some nutrients and water are taken out of the system through reed collection, grazing, other biomass extraction and ground water removal for irrigation.

Studies on the hydrological cycle and on sediment and nutrient cycling in the wetland complex are a must to understand its basic functioning.

Kalivelli has a very important place in the livelihoods of communities in its vicinity: Kalivelli provides a wide range of ecosystem goods and services which make a number of communities in its vicinity highly dependent on it. Many of these communities have traditional institutions to manage extraction of certain resources while in other cases, such as ground water extraction, there is no management framework in place. Seasonal encroachments into the flood plain for agriculture and encroachments of a more permanent nature in the creek and estuarine areas are also common.

Management of the wetland complex will require a strong and long term interface with local communities and collaborations and cooperation of other government agencies, and perhaps non-governmental agencies in the region to check the negative repercussions of anthropogenic activities and to manage resources in a sustainable fashion.

The wetland complex has three ecologically distinct aquatic regions each with its unique set of characteristics and problems: The coastal plain of Kalivelli is largely fresh water with increasing salinity along the Uppukalli creek which leads to the hypersaline Ediyanthittu estuary and finally into the Bay of Bengal. While the flood plain is relatively sparsely populated and un-disturbed, the creek and estuary are highly modified by human activities. Salinity levels in these areas determine the composition of flora and fauna. The larger watershed contains sacred groves, some of which are known to have a very high diversity of trees and lianas and are among the few surviving patches of Tropical Dry Evergreen Forests on the Coromandel coast. Birds are attracted to this diverse range of habitats and

land cover making Kalivelli one of the most important wetlands in South India.

Distinct management interventions will be required in the various components of the wetlands if the aquatic and water related biodiversity of the region is to be conserved, which includes the migratory bird populations. Additional measures will need to be put in place to conserve what is left of representative TDEF and coastal scrub and grassland.

The wetland complex is highly dependent on seasonal variations in water availability, temperature and humidity: The highly seasonal nature of the wetland results in the expansion and contraction of the water body, changes in salinity levels throughout the creek and estuarine areas and variations in land cover which changes from being dominated by reeds to a grassland in the coastal plain. This in turn governs the species composition of both migratory and resident bird as well as other motile and non-motile species. Land use in the region changes accordingly with an increase in aquaculture and salt production which peaks during the summer and pre-monsoon while the area under cultivation increasing along with the monsoon and seasonally encroached areas cultivated in the receding waters of the coastal wetlands.

Seasonal variations in species diversity and richness of both migratory and resident species needs to be recorded along with environmental parameters. This needs to be coupled with studies on resource use and extraction as well as on agricultural and industrial activities that occur in the surrounding areas.

Specific threats to the ecosystem need to be dealt with at the earliest: The wetland complex is threatened by the expansion of alien invasive species and encroachments into all its three major components. While many of these problems remain relatively easy to deal with, further delay in containing them may result in the expansion of the problem to much larger areas and irreversible modifications to the ecology of the wetland. Large development projects such as the linking of Kalivelli to the Buckingham canal as part of a national waterway are potentially disastrous and their possible impacts on the ecology and environment of the entire lake need to be studied in detail.

Immediate action is needed to remove exotic invasive weeds from the wetland, specifically Prosopis and Ipomoea sps. There has already been substantial work in demarcation of boundaries of the wetland, particularly in the coastal flood plain. This needs to be extended to other ecologically representative areas in the wetland and similar demarcations need to be made in un-protected community forests with TDEF. Through scientific evaluation of ecological and environmental impacts of development projects such as the proposed National Waterways project needs to be conducted before any large scale modifications of the wetlands takes place.

Bibliography

S. A. Abbasi. Wetlands of india: ecology and threats. vol. 1: the ecology and the exploitation of typical south indian wetlands. *Wetlands of India: ecology and threats. Vol. 1: the ecology and the exploitation of typical South Indian wetlands.*, 1997.

Anony. National report on the implementation of the ramsar convention on wetlands. National report, Ramsar Convention, Republic of Korea, October 2008.

S. Balachandran. Decline of coastal birds along the south-east coast of india. In *National Symposium on Conservation and Valuation of Marine Biodiversity*, page 26–29, 2006.

S. Balachandran and S. A. Hussain. Moult, age structure, biometrics and subspecies of lesser sand plover charadriusmongolus wintering along the South-East coast of india. *Stilt*, page 3, 1998.

S. Balachandran and P. Sathiyaselvam. Expansion of greater flamingo wintering range along the southeast coast of india. *Flamingo*, page 55, 2009.

R. S. Bhalla, Neil W. Pelkey, and K. V. Devi Prasad. Application of GIS for evaluation and design of watershed guidelines. *Water Resources Management*, 25:113–140, 2011. doi: 10.1007/s11269-010-9690-0. URL http://dx.doi.org/10.1007/s11269-010-9690-0. Published online: 30 June 2010.

Paul Blanchflower. Restoration of tropical dry evergreen forest of peninsular india. *Biodiversity*, 6 (3):17–24, 2005. URL http://www.google.com/search?ie=UTF-8&oe=UTF-8&sourceid=navclient&gfns=1&q=Blanchflower%2C+P.+2005.+Restoration+of+tropical+dry+evergreen+forest+of+PeninsularIndia.+Biodiversity+6%283%29%3A+17-24.

F. Cedex, C. Perennou, and V. Santharam. An ornithological survey of some wetlands in South-East india. *Journal of the Bombay Natural History Society*, 87(3):354, 1990.

Central Ground Water Board. Central ground water board - watershed atlas of india. http://cgwb.gov.in/watershed/, 2007. URL http://cgwb.gov.in/watershed/.

K. B. Chari. *A Reconnaissance of the Ecology of Two Wetlands: Ousteri and Kaliveli*. PhD thesis, MS thesis, Pondicherry University, Pondicherry, India, 1997.

S. Gopinath and Srinvas Vaidyanathan. *Kalivelli Wetlands*. Foundation for Ecological Research, Advocacy and Learning, Pondicherry, 2004.

N. Kaliaperumal and S. Kalimuthu. Need for conservation of economically important seaweeds of tamil nadu coast and time-table for their commercial exploitation. *Marine Fisheries Information Service, Technical and Extension Series*, 119:5–11, 1993.

V. Kannan and R. Manakadan. The status and distribution of spot-billed pelican pelecanus philippensis in southern india. *Forktail*, 21:9, 2005. ISSN 0950-1746.

S. Mani and V. Kumaresan. Occurrence of macrofungi on the coromandel coast of tamil nadu, southern india. *Journal of Threatened Taxa*, 1(1):54–57, 2009b. ISSN 0974-7893.

S. Mani and N. Parthasarathy. Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of peninsular india. *Current Science*, 90(9):1238–1246, 2006.

S. Mani and N. Parthasarathy. Above-ground biomass estimation in ten tropical dry evergreen forest sites of peninsular india. *Biomass and Bioenergy*, 31(5):284–290, 2007.

S. Mani and N. Parthasarathy. Tree population and above-ground biomass changes in two disturbed tropical dry evergreen forests of peninsular india. *Tropical Ecology*, 50(2):249–258, 2009.

N. Parthasarathy and P. Sethi. Trees and liana species diversity and population structure in a tropical dry evergreen forest in south india. *Tropical Ecology*, 38(1):19–30, 1997.

N. Parthasarathy, K. Ravikumar, R. Ganesan, and K. Ramamurthy. Distribution of seagrasses along the coast of tamil nadu, southern india. *Aquatic Botany*, 40(2):145–153, 1991. ISSN 0304-3770.

N. Parthasarathy, S. Muthuramkumar, and M. Sridhar Reddy. Patterns of liana diversity in tropical evergreen forests of peninsular india. *Forest Ecology and Management*, 190(1):15–31, March 2004. ISSN 0378-1127. doi: $16/\mathrm{j.foreco.2003.10.003}$. URL `http://www.sciencedirect.com/science/article/pii/S037811270300464X`.

C. Perennou. Two important wetlands near pondicherry. *Blackbuck, Madras Naturalists' Society*, 1987.

C. Perennou and V. Santharam. An ornithological survey of some wetlands in south-east india. *Journal of the Bombay Natural History Society*, 87(3):354–363, 1990.

J. Pernetta. *Marine Protected Area Needs in the South Asian Seas Region: India*. Iucn, 1993. ISBN 2831701759.

Asheesh Pittie, Suhel Quader, and Prakriti Pittie. Distribution of white-winged tern chlidonias leucopterus in india and a new record from andhra pradesh. *Indian Birds*, 1(4):81–83, 2005.

M. E. Ramanujam. An attempt to rationalize on the vocalizations and displays of captive indian eagle owls bubo bubo bengalensis (Franklin). *Zoos' Print Journal*, 15(6):269–274, 2000.

M. E Ramanujam. A preliminary report on the ichthyofauna of kaliveli floodplain and uppukalli creek, pondicherry, india, with some notes on habitat, distribution, status and threats. *ZOOS'PRINT JOURNAL*, 20(9):1967–1971, August 2005.

M. E Ramanujam and R. Anbarasan. A preliminary report on the vertebrate diversity of the kaliveli watershed region. *Zoos Print Journal*, 22(3):2608–2616, 2007.

M. E. Ramanujam and R. Anbarasan. A priliminary report on the ichthyofauna of yedayanthittu estuary (Tamil nadu, india) and rivulets draining into it. *Journal of Threatened Taxa*, 1(5):287–294, 2008.

M. E. Ramanujam and T. Murugavel. A preliminary report on the development of young indian eagle owl bubo bengalensis (Franklin, 1831) in and around puducherry, southern india. *Journal of Threatened Taxa*, 1(10):519–524, 2009.

M. E Ramanujam and B. Verzhutskii. PREY OF THE INDIAN PIPISTRELLE BAT PIPISTRELLUS COROMANDRA (GRAY) AT AUROVILLE, SOUTHERN INDIA. *ZOOS'PRINT JOURNAL*, 1919 (12):1720, 2004.

M. P. Ramanujam and D. Kadamban. Plant biodiversity of two tropical dry evergreen forests in the pondicherry region of south india and the role of belief systems in their conservation. *Biodiversity and Conservation*, 10(7):1203–1217, 2001a. ISSN 0960-3115.

K. Ravikumar and R. Ganesan. A new subspecies of halophila ovalis (R. br.) JD Hook.(Hydrocharitaceae) from the eastern coast of peninsular india. *Aquatic Botany*, 36(4):351–358, 1990a. ISSN 0304-3770.

SACON. National sites for wetlands of india. http://www.wetlandsofindia.org/wetlands/nationalram.jsp. URL `http://www.wetlandsofindia.org/wetlands/nationalram.jsp`.

D. A Scott. A directory of asian wetlands. *IUCN The World Conservation Union, Gland, Switzerland*, 1989.

M. Arthur Selwyn and N. Parthasarathy. Reproductive traits and phenology of plants in tropical dry evergreen forest on the coromandel coast of india. *Biodiversity and Conservation*, 15(10):3207–3234, July 2006. ISSN 0960-3115. doi: 10.1007/s10531-005-0035-x. URL `http://www.springerlink.com/content/kg3jl07012501004/`.

V Shantharam, Rauf Ali, and Paco Prieto. Grey-headed lapwings vanellus cinereus extend range into coastal tamil nadu, india. *Indian Birds*, 2(6):172–173, 2006.

K. S. G. Sundar. The greyheaded lapwing, vanellus cinereus (Blyth) in kaliveli tank, tamil nadu. *JOURNAL-BOMBAY NATURAL HISTORY SOCIETY*, 97(2):277–277, 2000. ISSN 0006-6982.

M. Udayakumar and N. Parthasarathy. Angiosperms, tropical dry evergreen forests of southern coromandel coast, india. *Check List*, 6(3), 2010.

R. Venkateswaran and N. Parthasarathy. Tropical dry evergreen forests on the coromandel coast of india: structure, composition and human disturbance. *Ecotropica*, 9:45–58, 2003.

P. D Venugopal, S. Ram, and M. Anbarashan. Restoration of tropical dry evergreen forests. *Studies on Vulnerability and Habitat Restoration along the Coromandel Coast., eds. Bhalla, RS, Ram, S., and V. Srinivas. 1st ed. Pondicherry, India*, 2008.

N. Visalakshi. Fine root dynamics in two tropical dry evergreen forests in southern india. *Journal of Biosciences*, 19(1):103–116, 1994a. ISSN 0250-5991.

James A. Woistencroft, S A. Hussain, and C. K. Varshney. *A Directory of Wetlands in India*. Ramsar Sites Information Service.

About FERAL

The Foundation for Ecological Research, Advocacy and Learning (FERAL), is a non-profit trust founded in July 1997. FERAL comprises of a small team working on various aspects of applied research on ecological and environmental issues. The key areas of work include conservation, ecological restoration, environmental and natural resource management and training and capacity building in these areas.

Visit the FERAL web page, `http://www.feralindia.org`, for more information about ongoing activities and projects.