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Ecological Status and Management of Dr. Salim Ali Bird Sanctuary and Estuarine Areas of Chorao Island:
A Desk Review

March 2015

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Indo-German Biodiversity Programme
Conservation and Sustainable Management of Coastal and Marine Protected Areas

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03

Indo-German Biodiversity Programme
Conservation and Sustainable Management of Coastal and Marine Protected Areas

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List of Acronyms

Al	Aluminium
BOD	Biological oxygen demand
CMPA	Coastal and Marine Protected Areas
Cr	Chromium
Cu	Copper
DBH	Stem diameter
DO	Dissolved oxygen
Fe	Iron
GBH	Trunk girth at breast height
HT	High tide
ICPOES	Inductively coupled plasma-optical emission spectrometer
IUCN	International Union for the Conservation of Nature
LT	Low tide
Mn	Manganese
MoEFCC	Ministry of Environment, Forests and Climate Change
MPAs	Marine protected areas
MT	Mid tide
Ni	Nickel
NOAA	National Oceanic and Atmospheric Administration
OC	Organic carbon
OM	Organic matter
Pb	Lead
PRIMER	Plymouth Routines In Multivariate Environmental Research
S.A.B.S.	Dr. Salim Ali Bird Sanctuary
SPM	Suspended particulate matter
TC	Total carbon
TN	Total nitrogen
Zn	Zinc

Executive Summary

Dr. Salim Ali Bird Sanctuary is an estuarine mangrove swamp located in North Goa. It is bounded by two rivers, the Mandovi and the Mapusa. The sanctuary is part the Chorao Island, which has natural forests as well as areas under agriculture and aquaculture. Mangroves and *khazans* are the major ecosystems to be found Chorao Island. The sanctuary has been selected as a pilot site for implementing the Coastal Marine Protected Area (CMPA) Project in to strengthen conservation efforts and sustainable use of the biodiversity. The ecosystems of the island, i.e., mangrove and *khazan* ecosystems, are very important both ecologically and economically. These ecosystems are now threatened by changes in land use, urbanization and its consequences, with the anticipated dangers of climate change looming in the background. In order to identify and formulate future interventions that will help the conservation and management of these ecosystems, it was proposed to conduct a detailed desk review that would assess the existing information on the ecological status of the sanctuary and estuarine areas of Chorao Island as well as the existing management and conservation plans.

The literature review highlights the existing information on the ecological status of the sanctuary and estuarine areas of Chorao Island, and identifies the gaps in the base line data. Several ecological studies have been conducted across the Mandovi estuary, with a single sampling location at Chorao. Besides, studies that involve Chorao focus on the estuarine ecosystem, without notable attention given to the marshy sections of the island. The physico-chemical properties of the sediments of Chorao have been determined in three separate studies. The flora and fauna of Chorao range from mangroves-associated species to algae, seaweeds, sea grasses, mammals, birds, reptiles and amphibians, benthic macrofauna, meiofauna, zooplankton and

microorganisms. A study was reported on the frequency of occurrence of marine fungi in the vicinity of the two common mangrove species of Chorao, *Rhizophora mucronata* and *Avicennia marina*. The meiofauna and macrofauna of Chorao have been studied, of which Nematoda and Harpacticoida are the dominant meiofaunal taxa, with Polychaeta and Oligochaeta being dominant among the macrofauna. The literature survey indicates that the number of studies carried out that focus on the island is limited Lacunae were found in the data available for the mangrove ecosystems as well as for the *khazan* ecosystems.

In addition, the report also highlights the existing management and conservation plans and identifies the gaps in the management and conservation of the estuarine areas of Chorao Island. The existing management plan, which has been instituted for the mangrove ecosystem, involves zonation of the sanctuary and institution of protective and tourism-related measures, but its implementation is weak. The other estuarine ecosystem reviewed, i.e., the *khazan* system, occupies a specialized ecological niche. It has experienced changes in the post-colonial period of Goa, and as a result, the modes and effectiveness of its management have weakened.

A mode of participatory management has been suggested for the island estuarine ecosystem that includes three different processes, namely, planning, establishment of institutions and community participation. Participatory management of the island's estuarine resources is therefore necessary, and a mode of executing the same has been proposed.

Chapter 1

Introduction

Chorao, an estuarine island located in the backwaters of the Mandovi River, lies between the coordinates 15°25'N and 15°30'N between 73°45'E and 73°59'E. It is the largest of the riverine islands of Goa. The mangrove cover in the Mandovi estuary starts at the head of Chorao and extends upstream for a distance of 34 km. On the western tip of the island lies the state's only protected area of estuarine status – the Dr. Salim Ali Bird Sanctuary. The sanctuary, with an area of 1.8 km^2, was established in 1988 and is open to visitors throughout the year. It is home to a multitude of coastal resident and migratory birds as well as a wide assortment of terrestrial and marine life (Harding 2003; Abram 2004; Untawale 1973; Dhargalkar 2014; Department of Tourism - Government of Goa 2015; Goa Prism 2015; Goa Tourism, 2015; Wikipedia 2015). Below is a map of Chorao Island highlighting Dr. Salim Ali Bird Sanctuary (Figure 1). Chorao is divided by creeks and backwaters that have tidal variations, a network formed from the Mandovi and Mapusa rivers and the Cumbarjua canal. Access to these channels by motor boat is restricted to high tides alone, but the channels are accessible by canoe even during low tides (Department of Tourism - Government of Goa 2015; Forest Department – Government of Goa 2015; Goacom 2015).

The ecosystem of Chorao is fragile. The regional map of Chorao Island obtained from the State Town and Country Planning Department indicates that naturally occurring forest cover is also to be found at Chorao, as are areas under agriculture and aquaculture in the form of paddy fields, *khazans*, orchards and fish farms (Figure 2). Natural mudflats are found along the banks of the river Mandovi. The two major ecosystems of Chorao are the mangroves and the *khazans*. Rich mangrove forests exist within the wildlife sanctuary at Chorao, which support a diversity of life forms, both migratory species and ones that are endemic to Goa's coast. The *khazans* are reclaimed wetlands, saltmarshes, and mangrove areas that are used for agriculture, aquaculture and salt panning purposes (Sonak 2012; Sonak 2014b; Sappal 2014; Department of Tourism - Government of Goa 2015; Forest Department – Government of Goa 2015; Goacom 2015). These ecosystems will be elaborated in

Figure 1
Map of Chorao Island Showing Dr. Salim Ali Bird Sanctuary

Source: Google Earth

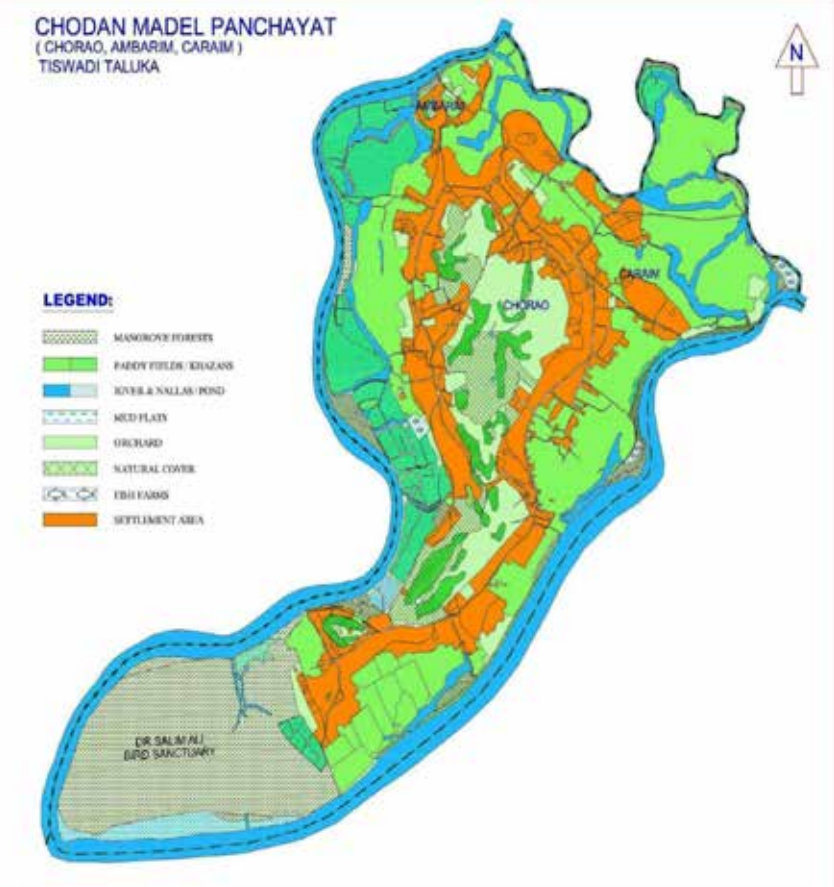
subsequently the review. Both these ecosystems are now under threat from changes in land use, urbanization and its consequences, and climate change. There is an urgent need to establish a suitable framework for their management and strengthen the management activities that have already been put in place.

Mangrove Ecosystem and Its Ecological and Economic Importance

The island of Chorao harbours an estuarine wetland ecosystem in the form of mangrove swamps. Mangrove ecosystems are one of the major specialized ecosystems along the country's west coast. They are complex in nature, in the confluence of land, sea and fresh water, and form ecotones between the land and sea. Mangroves in the intertidal regions along sheltered sea coasts and estuaries support a varied fauna and play a significant role in estuarine and coastal food webs (Untawale and Parulekar 1976; Harikrishnan 1999; Mchenga and Ali 2003; Goa Forest Department, 2004 Alongi, 2008; Kumar and Khan 2013; Bassi 2014; Dhargalkar 2014).

Mangroves establish cover in harsh conditions, under tidal regimes, and are subjected on a daily basis to changes in temperature, water and salt exposure and changing levels of anoxia. Mangrove forests are thus highly stable ecologically. These tidal forests are often important as nursery and breeding grounds for birds, mammals,

Figure 2
Map Showing Habitats of Different Estuarine Ecosystems of Chorao Island

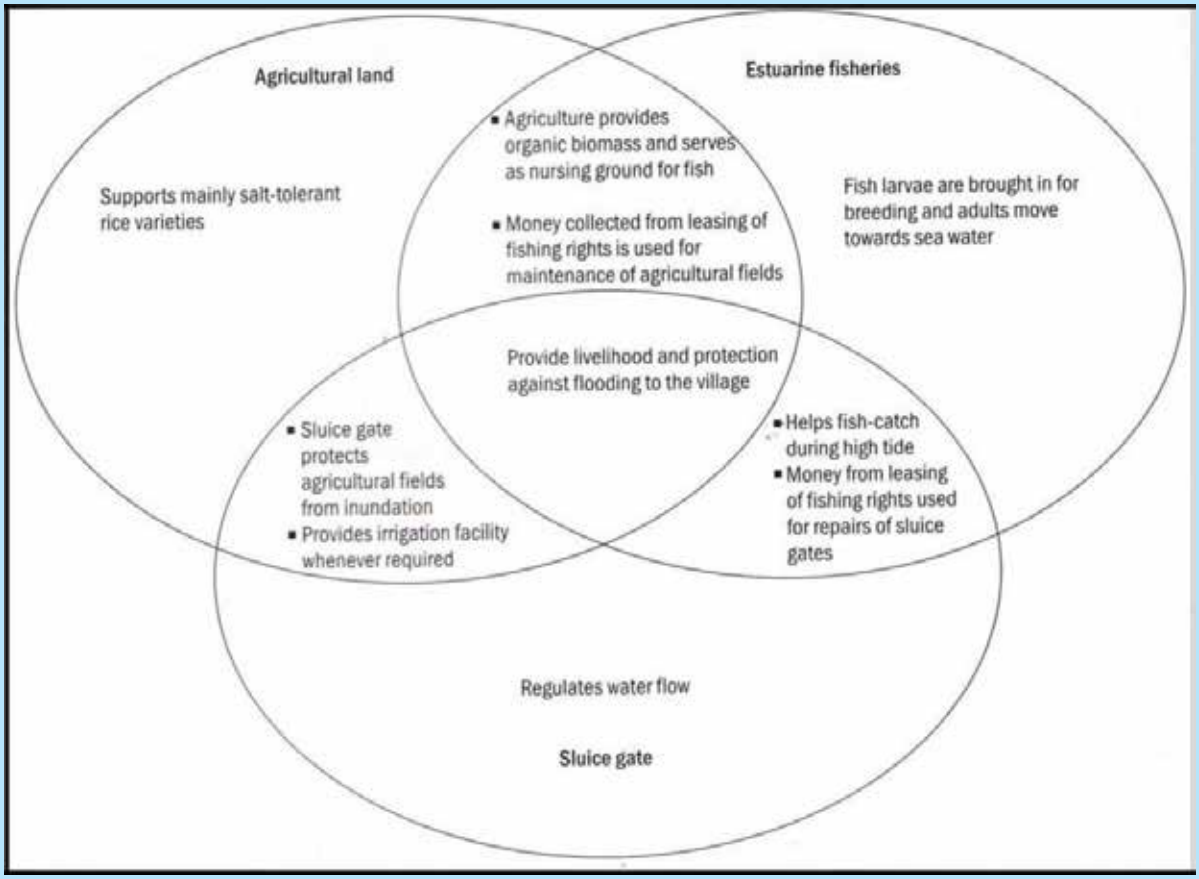


fish, crustaceans, shellfish, and reptiles; a renewable source of wood; and as sites where the accumulation of sediments, nutrients, and contaminants occurs (Alongi 2008; Dhargalkar 2014).

Mangrove ecosystems produce a lot of litter, the decomposition of which leads to an increase in the production of dissolved organic matter as well as the recycling of nutrients in both the mangroves and the adjacent habitats. The detritus and nutrients could eventually support fishery resources (Kathiresan and Bingham 2001; Dhargalkar 2014). Mangrove forests have stronger trophic linkages with epibenthic invertebrates and fish living in the mangroves or associated habitats, such as seagrass beds. Mangroves make significant contributions towards the estuarine carbon budget but not much to its nitrogen and phosphorus budgets. The mangrove environment may therefore be a sink for carbon and nutrients, rather than a source of the same for the habitats adjacent to it (Untawale and Parulekar 1976; Kathiresan and Bingham 2001).

Mangroves and the ecosystems associated with them are, for these reasons, recognized as being among the most biologically important ecosystems. They are ecologically indispensable. They have socio-economic importance and aesthetic attractiveness (Pattanaik and Prasad 2011). They are of critical importance as nursery habitats for important marine species (Kathiresan and Bingham 2001; Goa Forest Department 2004), and a positive correlation has been observed between near-shore coastal shrimp and fish catches and mangrove forest cover. Mangroves have the potential to be developed as sources of high-value commercial products and fishery

Figure 3
Components of the *Khazan* Ecosystem and Their Interactions



Source: Sonak et al, *2005*

wealth, and as sites for an expanding ecotourism industry through the indigenous biodiversity, which is very attractive to tourists (Goa Forest Department 2004; Dhargalkar 2014). To obtain and retain all these benefits, it is necessary that this resource be understood, carefully managed and protected.

Khazan Ecosystem and Its Ecological and Economic Importance

'*Khazan*' is a word that stands for saline lands, and it denotes reclaimed wetlands, salt marshes and mangrove areas. *Khazan* lands have been put to several productive uses like agriculture, aquaculture and salt panning. They are the result of the conversion of natural estuarine ecosystems but do not greatly alter its physical or living components. The range of agricultural species and varieties in *khazan* ecosystems adds to the diversity of the estuaries and is a feature that is not found in many modern forms of agriculture (Sonak 2012; Sonak 2014 2014b; Goa Foundation 2015). The *khazan* technology of Goa safeguards agricultural fields and villages from the entry of tidal waters, inundation and floods via an established system of outer protective dykes, inner embankments and sluice gates. The dykes prevent saline estuarine waters from coming up to the land, and the sluice gates regulate its flow. The shutters of the sluice gates can be operated manually or automatically to permit the entry of the necessary volume of estuarine water into the *khazan* lands (Sonak 2012; Sonak 2014 2014b).

Typically, a *khazan* ecosystem has an inner canal connected to the estuary that drains the agricultural fields. Located immediately upstream of the sluice gate is a pit, locally called a '*poiem*', which has a depth lower than that of

the water at low tide. The pit acts as a reservoir for water and as a suitable environment for the eggs and larvae of aquatic fauna. During high tide, fish and prawns swim to waters with lower salinity to spawn. The larvae grow in the *khazan* fields, where the water is high in nutrient content from the organic biomass of the paddy straw of the agricultural fields. The adult fish are captured at the sluice gate when they return from the '*poiem*' to waters with higher salinity. This process ensures a good yield, at the same time providing protection in general to the fish and prawn/shrimp populations (Sonak 2014a). Crabs, prawns and shellfish such as mussels, clams and oysters are harvested seasonally. The fish and shellfish sustain a large population of resident and migratory birds and marsh crocodiles, or 'muggers' (Goa Foundation 2015). Salt-tolerant varieties of rice are the crops customarily grown in *khazan* fields. Winter crops are also grown in those areas that are not influenced by salinity (Sonak 2014 2014b). *Khazan* ecosystems thus occupy a special ecological niche. They have multiple uses and provide more than the usual complement of services contributed by wetland ecosystems. (Table 1 lists the different ecosystem services of *Khazan* ecosystems) The *khazan* technology utilizes tools in water management, such as the canals, *poiem*, and sluice gates, which improves the availability of water during erratic monsoon seasons, thus providing regulatory services. *Khazans* are a repository of genetic resources, such as endemic salt-tolerant rice varieties, fish and halophilic plants and animals. *Khazans* contribute highly important ecosystems services such as the cycling of nutrients, and they are breeding and feeding grounds for fish and other marine fauna. They provide refuge to birds and aid soil formation, cycling of water and photosynthesis by plants and halophilic microorganisms (Sonak 2014b).

Table 1
Different Ecosystem Services Provided by *Khazans*

Service	Application to *khazan* ecosystem
Cultural services –the nonmaterial benefits people obtain from ecosystem services	
Ethical values	Most *khazans* have a holy cross near sluice gates; however, often Hindu rituals are followed.
Existence values	*Khazan* are part of endemic culture of Goa. The origin of *khazan* dates back to the pre-Christian era.
Recreation and ecotourism	This potential of *khazans* is underutilized
Supporting services - underlying processes that are necessary for the production of all other ecosystem services	
Nutrient cycling	carry out nutrient recycling.
Breeding ground	*Khazans* serve as excellent breeding ground for fish and penaeid prawns that migrate to less saline water for breeding
Refugia for bird	Migratory birds take shelter in the khazan wetland ecosystem in water
Soil formation	*Khazan* soils are rich in organic material
Primary production	*Khazan* land serve as feeding grounds for fish and prawns, and the use of paddy straw as organic material by juvenile fish helps convert inedible protein into edible protein.
Photosynthesis	Carried out by photosynthetic plants in *khazans.* Photosynthesis is also carried out by halophilic micro flora from *khazan* soils.
Water cycling	Highly structured system for water cycling
Provisioning services - the goods or products obtained from ecosystems	
Food	Rice, vegetables and some horticulture plants; fish, shellfish, crabs prawn
Fuel	Salt extracted from *khazans* in dry months paddy straw
Fresh water	Water channels, sluice gates
Genetic resources	Fish, salt- tolerant rice, halophilic plants and animals
Biochemicals	Lime from shells of shellfish from *khazan* lands
Regulating services - the benefits obtained from an ecosystem's control of natural processes	
Water regulation	Excellent water regulation through sluice gates, *poiem* and water canals
Erosion regulation	Through a system of smaller as well as protective dykes
Natural hazard regulation	Allows water and prevents flooding of villages and fields. Accommodates saline tidal water during high tides. Dykes built using traditional technology protect coastline.
Water purification and waste treatment	*Khazan* wetlands remove harmful pollutants from water by trapping metals and organic materials. Soil microbes degrade organic waste, rendering it less harmful.
Disease regulation	Salt water reduces breeding area for mosquitoes, thus reducing the incidence of diseases
Pest regulation	Saline water inundation controls pests.
Pollination	Birds and bees from *khazan* fields pollinate crops.

Source: Sonak (2014b)

Chapter 2

Ecological Status of Mangrove Ecosystem of Chorao Island

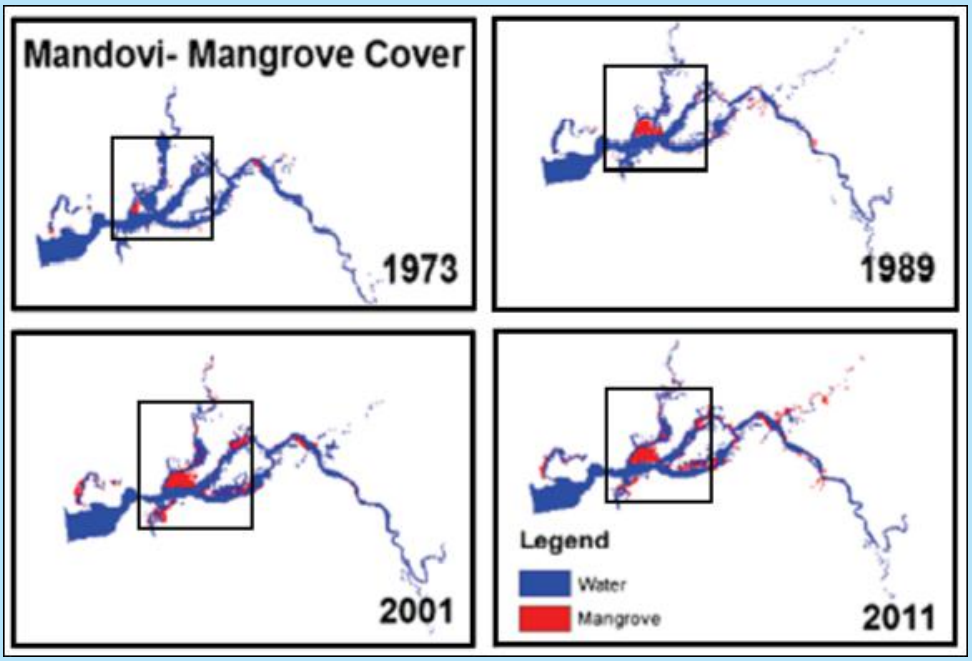
The Mandovi estuary has an average water column depth of ~4 m. Tidal currents exert influence on the estuary, which is characterized by mixed diurnal tides. Shetye (1995) have reported that both diurnal and semidiurnal tides are propagated at a speed of 6 m s^{-1}. This speed remains constant over a range of 40 km from the mouth, and the current velocity reaches a maximum of 1.1 m s^{-1}. The Mandovi is classified as a macrotidal and monsoonal estuary, with spring tides > 2 m. (Shetye 1995). The runoff of the Mandovi during the period of June–October, at the head of the river, was measured to be ~258 m3 s^{-1}, and that during the period of November–May was ~ 6 m3 s^{-1}. Shetye (2007) have noted that the volume of the estuary is, on average, exceeded by the volume of fresh water that flows through the river Mandovi in one year by a factor of 40. The efflux of fresh water that takes place during the months of June–October is over 95 per cent, making the water of the estuary limnetic from head to mouth during the monsoon season.

The island of Chorao, in the Mandovi, as per the observations of Kunte and Wagle (1994), is probably a rocky exposure that has extended peripherally due to heavy siltation. Dhargalkar (2014) have elaborated this point, indicating that Chorao is a natural island formed through the sedimentation of the Mapusa river, Norora creek and Mandovi estuary. It is essentially a projection of basalt wherein the land surface has become extended peripherally as a result of heavy siltation up to the current edge of the estuarine water. Upon establishment of mangrove swamps, the root system trapped fine sediments, and in this manner, land was built up along low coasts (Mascarenhas and Chauhan 1998). The mangroves have gradually overgrown areas that were earlier utilized for paddy cultivation and fish farming, making the land unsuitable for agriculture in recent times. Established mangrove vegetation occupies about 2.5 km^2. of the island.

Distribution of Mangroves

It has been reported by Misra (2015) that in 2004 there was a 44.9 per cent increase in the mangrove cover in Goa. Chorao Island

Figure 4
Temporal Changes in Mangrove Distribution at Chorao



Source: (Misra, 2015)

is one of the contributors of mangroves in the Mandovi, where the cover has increased during 1989-2001 (Figure 4). The afforestation programme of the Goa Forest Department ascertained an increase of 876 ha of mangrove cover by the end of 1996–1997, shedding light on the importance of awareness and the need for the active involvement of the state forest department, and stressing the significance of *in situ* conservation in the preservation of mangrove habitats.

The coastal habitat of the Mandovi estuary is under severe pressure from threats the increasing population, tourism, mining and urban development. Changes in the mangrove forest cover thus require to be monitored constantly. Mapping and analysis of the land use/land cover of an area are essential in order for assessing the trends of change, particularly from the angle of policy making, planning, and implementation of natural resource management (Misra 2015).

Physico-Chemical and Geochemical Characteristics

Physico-chemical characteristics have a significant effect on the species diversity, pattern of diversity and spawning, breeding, and metabolic activities. The major factors that influence the biotic components of the mangrove system are physico-chemical parameters, such as temperature, pH, salinity, dissolved oxygen levels, tides, precipitation, wind and nutrients. For instance, temperature and salinity are the factors that determine the composition, distribution and zonation of species, and the landward extension of mangroves is dominated by tidal amplitude and topography (Dhargalkar 2014). Table 2 indicates the values of various physico-chemical parameters of the Mandovi estuary off the island of Chorao.

Sediment geochemistry. The soils in mangrove forests are formed through the aggregation of sediment derived from the erosion of coasts or river banks or from erosion of soils from

Table 2
Physical and Chemical Parameters (of the Water) of the Mandovi Estuary off Chorao Island

Sr. No.	Parameter	Value/Range	Reported by
1	Tidal range(m)		
	Spring tide	2.3	Prajith 2015
	Neap tide	1.5	
2	Maximum current velocity ms^{-1}	1.1	Gonsalves 2009
3	Temperatur e^0C	26 –33	Gonsalves 2009
4	pH	6.99 – 8.79	Jagtap 2006
5	DO mL L^{-1}		
	May	2.3	Jagtap 2006
	Post-Monsoon	5.64	
6	Salinity (per mil)		
	Pre-Monsoon	35.65	Jagtap 2006
	Monsoon	0	
	Pre-Monsoon	29 – 36	Gonsalves 2009
	Monsoon	0.0 – 10	
	Post-Monsoon	17 – 31	
	Average Salinity (per mil)		
	Wet season	1.9	Shynu 2015
	Dry season	30.4	
7	Nitrite (NO2-N L^{-1}) (µg)	0.12 – 1.04	Jagtap 2006
8	Nitrate (NO3-N L^{-1}) (µg)	1.2 – 6.72	Jagtap 2006
	Premonsoon spring tide (04/2002) (µM L^{-1})	0.75	Sardessai and Sundar
	Pre-Monsoon neap tide (05/2002) (µM L^{-1})	1.1	
	Monsoon (09/2002) " (µM L^{-1})	4.8	
	Premonsoon (03/2003)	0.8	
9	Phosphate (PO4-P L^{-1}) (µg)	0.021 – 1.96	Jagtap 2006
	Premonsoon spring tide (04/2002) (µM L^{-1})	0.2	Sardessai and Sundar
	Premonsoon neap tide (05/2002) (µM $L^{-1)}$	0.5	
	Monsoon (09/2002) (µM L^{-1})	0.55	
	Premonsoon (03/2003) (µM L^{-1})	0.25	
10	Suspended particulate matter (SPM) (g m^{-2})		
	Pre-Monsoon	0.03 – 0.7	Gonsalves 2009
	Monsoon	0.62 – 2.53	
	Post-Monsoon	0.05 – 0.29	
	Average SPM (mg L^{-1})		
	Wet season	12.2 l	Shynu 2015
	Dry season	10.9	

Table 2
Physical and Chemical Parameters (of the Water) of the Mandovi Estuary off the Chorao Island (*Contd...*)

Sr. No.	Parameter	Value/Range	Reported by
11	Particulate organic carbon (POC) (mg m^{-2})		
	Pre-Monsoon	0.8 – 7.8	Gonsalves 2009
	Monsoon	2.6 – 17.9	
	Post-Monsoon	3.5 – 6.6	
	Wet season	0.112	Shynu 2015
	Dry season	0.101	
12	Particulate organic nitrogen (PON) (mg m^{-2})		
	Premonsoon	0.2 – 1.6	Gonsalves 2009
	Monsoon	0.6 – 2.5	
	Postmonsoon	0.2 – 1.3	
13	Chlorophyll a (mg m^{-3})	0.5 – 11.3	Verlencar 1984
		0.01 – 4.33	Krishna Kumari 2002

higher areas that is transported downstream. Mangrove soil comprises coarse sand (3.9 4 per cent), fine sand (38.2 - 38.6 per cent), silt (29.5 - 33.1 per cent), and clay (3.9 - 4.3 per cent). In broad terms, the substratum in mangrove forests is typified by a low oxygen content, high salinity and fine grain sediments containing high levels of organic matter (Dhargalkar 2014).

The sedimentary geochemistry of Chorao, as determined by Sappal (2014), indicates that the sediments are rich in quartz. The uniformity of the quartz content in collected core samples is signified by the consistency of its silica (Si) concentration with a mean concentration of 31.92 per cent, aluminium concentration a mean value of 12.5 per cent and the Si : Al ratio a mean value of 2.9, which serves as an indicator of the extent of the maturity of the sediment indicates that the sediments are well weathered and mature with higher Si content (Sappal 2014).

The carbon biogeochemistry of sediments is governed by factors such as decomposing organic matter and the prevalent sedimentary environment. Sappal (2014) recorded a total-carbon mean concentration of 3.94 per cent in the Chorao Island sediments, and organic carbon 2.77 per cent. Organic carbon made up nearly 70 per cent of the total carbon. The biological productivity of the mangroves is a critical contributor to the organic content of the sediments (Sappal 2014).

Phosphorus (P) is a limiting nutrient in aquatic ecosystems. Sappal (2014) recorded total P concentrations in the sediments of Chorao ranging from 0.7 per cent to 1.1 percent, and the values decreased with depth. Sulphur (S) is very important in marine sediments due to the central role of sulphate reduction in anaerobic respiration, which produces authigenic sulphide minerals (Sappal 2014). They reported that the average S concentration was 0.3 per cent, and gradually increased with depth due to the prevalent reducing conditions.

Heavy metals such as manganese (Mn), chromium (Cr), lead (Pb), copper (Cu), cobalt (Co) and zinc (Zn) were recorded on Chorao Island by Sappal (2014) and Veerasingham (2015)(Table 3).

Biodiversity of Mangrove Ecosystems

The elements of biodiversity in a mangrove ecosystem are singular and considerable since they are inclusive of structural niches, sources of food and protection to several vertebrate and invertebrate species (Dhargalkar 2014).

Table 3
Physico-Chemical Properties of Mangrove Sediments of Chorao Island

	Parameter	Value/Range	Reported by
1	**Sediment grain size and composition**		Prajith 2015 (Lower Mandovi estuary off Panaji)
	Sand, 63mm	15–60 per cent	
	Silt 4 , 4–63 mm	15–90 per cent	
	Clay, <4 mm	75–90 per cent	
2	**Sediment colour**		
	Brown	0–27 cm	
	Brown (loose sediment)	27–38 cm	
	Dark brown	38–60 cm	
3	**Sedimentation rate (cm/year)**		
	Between 8 cm and 20 cm	0.1	
	Between 20 cm and 60 cm	1.24	
4	**Mineralogy of sediments (0 - 14cm depth)**		Sappal 2014 (Chorao Island)
	Silica (Si)	25.9-37.2 per cent	
	Aluminium (Al)	4-18 per cent	
	Si/Al ration	07-Feb	
	Total carbon	3.56-4.53 per cent	
	Organic carbon	2.48-3.28 per cent	
	Total nitrogen	0.39-0.56 per cent	
	Total phosphorus	0.7-1.1 per cent	
	Total sulphur	0.3 per cent (average)	
	Iron	15,500-18,500 mg/kg	
	Manganese	1000-2750 mg/kg	
	Chromium	10-80 mg/kg	
	Lead	250-1500 mg/kg	
	Zinc	2-25 mg/kg	
	Iron	20.35 per cent	"Veerasingham 2015 (Chorao Island)"
	Manganese	1539 µg g-1	
	Copper	39.23 µg g-1	
	Chromium	146.93 µg g-1	
	Cobalt	22.45 µg g-1	
	Lead	22.62 µg g-1	
	Zinc	71.15 µg g-1	

An understanding of the structure of benthic faunal communities in mangrove ecosystems relative to impacts of pollution is important in monitoring changes in such ecosystems (Kumar and Khan 2013). The health of benthic communities is related to the water quality conditions in the surrounding communities, such as mangroves. Varying levels of aquatic salinity could be a limiting factor in the distribution of living organisms. Salinity in combination with temperature affects the dissolution of oxygen. These environmental conditions have an effect on the composition, distribution and growth of biota. Low population densities may be observed during the monsoon season, due to the effect of heavy rainfall (Kumar and Khan 2013;

Pravinkumar 2013). The variations in biotic and abiotic properties within the wetlands make for differentiated niches and habitats with distinct environmental features along the intertidal zone for the settlement of macrofaunal species (Safahieh 2012).

Benthic invertebrates play a vital role in the sedimentary environment, where their feeding, burrowing, and ventilator activities have critical effects on nutrient cycling within the overlying water column (Roberts 2006; Pravinkumar 2013). The distribution of macrobenthos in the muddy sediments of mangrove ecosystems is governed by the sediment grain size, salinity and groundwater. The abundance and variations in the benthic faunal species is dependent primarily on the detrital biomass, especially its source and age, and secondarily on the composition of the sediment (Netto and Gallucci 2003).

Assessments made by ENVIS of mangrove ecosystems in the country indicate that 100 per cent of mangrove species, 92 per cent of other flowering plants, 60.8 per cent of the seaweeds, 23.8 per cent of the marine invertebrates and 21.2 per cent of the marine fishes are threatened. Habitat-specific studies indicate that in spite of mangroves having a protected status, local communities have encroached upon them. Although mangroves are largely resistant to high levels of organic pollution, it has been observed that excessive quantities of waste negatively affect mangrove species diversity (Das Gupta and Shaw 2013). The maintenance of near-shore marine habitats is the prevalent and most essential function of mangrove ecosystems. The multiple functions characterizing these ecosystems bring about the high primary and secondary productivities of tropical estuaries (Dhargalkar 2014).

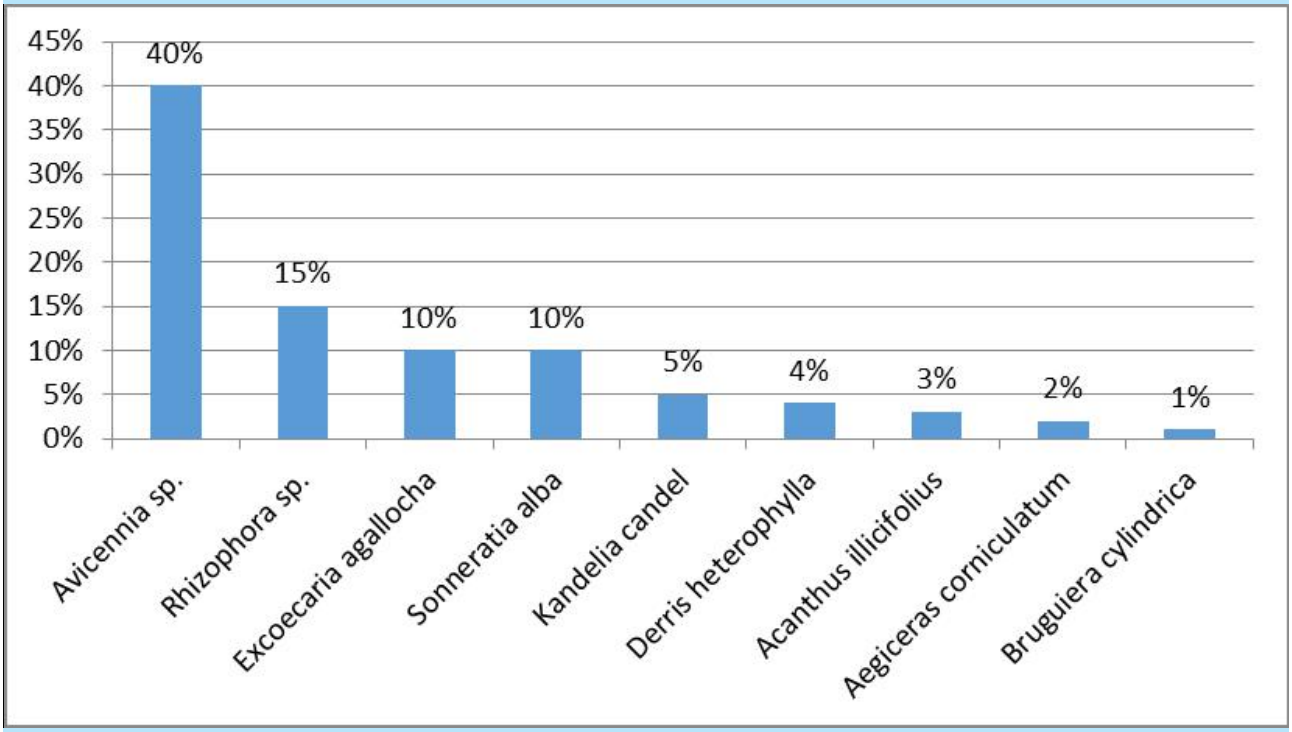
Mangroves and Associated Species

Mangroves possess high genetic diversity due to the existence of both aquatic and terrestrial species and their ability to adapt to a wide range of salinity values, tidal amplitudes, winds, temperatures and muddy and anaerobic soil conditions. The main species of mangrove found on the island of Chorao are *Avicennia officinalis* and *alba* (40 per cent), *Rhizophora mucronata* & *R. apiculata* (15 per cent), *Sonneratia alba* (10 per cent), *Exocaria agallocha* (10 per cent), *Kandelia candel* (5 per cent), *Derris heterophylla* (4 per cent), *Acanthus illicifolius* (3 per cent), *Aegiceras corniculatum* (2 per cent), *Bruguiera cylindrica* (1 per cent), and other species constitute 10 per cent of the mangrove diversity (Untawale 1973; Goa Forest Department, 2004; Forest Department – Government of Goa, 2015), with the dominant species being *A. officinalis, R. mucronata* and *S. alba* (NIO Report, 2002; Jagtap and Singh 2004; Kumar and D'Souza, 2013; Goa Foundation 2015; Wikipedia 2015) (Figure 5). *Kandelia candel*, an uncommon species on the country's west coast, is plentiful in the Mandovi river (Goa Forest Department 2004). *Xylocarpus moluccensis* is a species that has been newly introduced in Dr. Salim Ali Bird Sanctuary. The island of Chorao has one of the best mangrove forests in the state and is home to practically all the species of mangroves found along Goa's coast (Goa Forest Department 2004; Dhargalkar 2014).

Succession of Species in Mangrove Establishment

Establishment of mangroves on river banks and islands, and species succession occurs with the initial entrenchment of the red mangrove *Rhizophora mucronata*, which is the first species encountered in mangrove swamps towards the waterfront. They attain a height of 6–8 m and their fleshy leaves form a dense canopy. The establishment of *R. mucronata* creates the appropriate environment for the black mangroves, *Avicennia officinalis*, which later develops a horizontal system of roots called pneumatophores. This root system occupies a large area and traps silt, and this accretion aids in the formation of a suitable substratum. The canopy of *A. officinalis* is also dense, and decayed leaves are important for the enrichment of the substratum. The extensive root systems of *Rhizophora* species and *Avicennia* species provide support to the plants, and allow them to

Figure 5
Mangrove Species Distribution in Chorao Island



Source : (Kumar and D'Souza 2013)

withstand the action of high waves and therefore prevent erosion (Untawale 1973; Untawale and Parulekar, 1976). The distribution of mangroves within the estuary occurs according to the salinity gradient (Untawale 1982). When these mangrove species are established, shrubs, herbaceous species, and climbers become lodged. *Brugueira conjugate* and *B. parviflora* develop characteristic knee roots that arise from the substratum. The root systems of all these species are submerged during the high tide and completely exposed during low tide. In the profile depicting the mangrove distribution along the Mandovi estuary (Figure 6), Chorao falls in the polyhaline zone of the estuary, where *Avicennia* sp. and *Sonneratia alba* are dominant species.

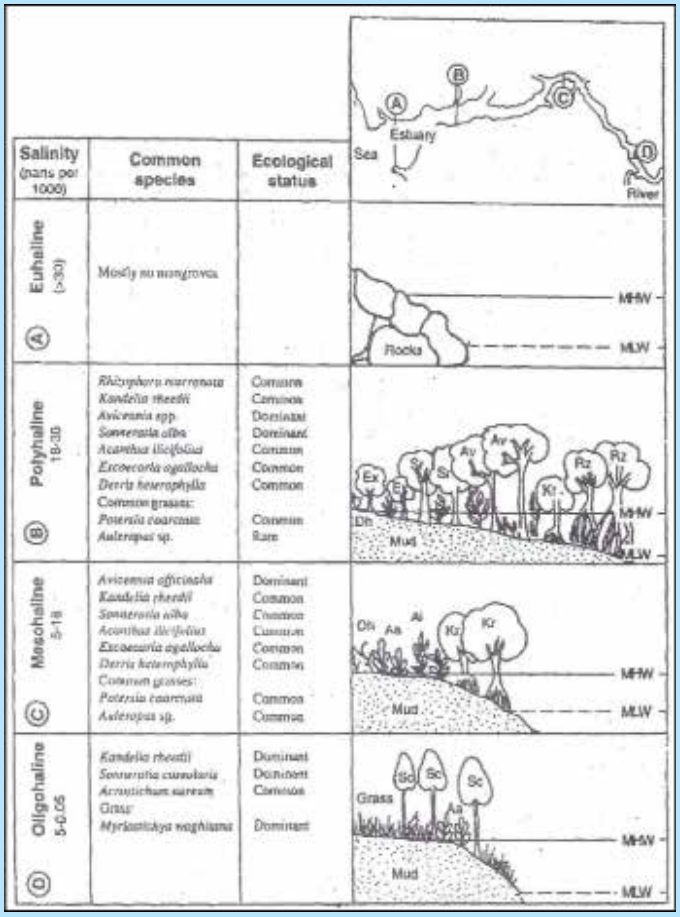
Algae and Seaweeds

Several estuarine and marine species feed on micro- and macro-algae that flourish in mangrove areas. Micro-algae are epiphytes that adhere to the aerial roots of the mangroves and surfaces of sediments (Dhargalkar 2014). Untawale and Parulekar (1976) observed three peaks in the distribution of phytoplankton as cell counts, in the months of May, June and October, and counts were low in August, September and November. Diatoms are the largest group of micro-alga found in the mangrove community and are important bioindicators of water quality and ecosystem health.

Coscinodiscus, Cyclotella, Flagilaria, Gyrosigma, Navicula Nitzschia are the most abundant ecosystems (Dhargalkar 2014; Goa Foundation, 2015). Phytoplankton recorded by Jagtap et al, 2009 in the mangrove habitats in the Mandovi estuary are listed in the Table 4.

Macro-algae, or seaweeds, occur as epiphytes on stems and roots or other substrata when associated with mangrove ecosystems. A few are unique to particular mangrove habitats, and an understanding of their biodiversity and biomass may provide indications of mangrove

Figure 6
Profile of Distribution of Mangrove Species along Mandovi Estuary of Goa



Source: Jagtap and Singh, 2004

health. *Bostrychia, Caloglossa, and Catenella,* among others, are found on India's west coast (Dhargalkar 2014). Muddy mangrove areas are the habitats of green algae such as *Enteromorpha, Cladophora, Rhizoclomium, Bryopsis, Ulva, Monostroma, Avrainvilles Caulerpa* and brown algae such as *Ectocarpus, Hydroclathratus, Dictyota and Padina*. These seaweeds flourish on mudflats by getting attached to any solid material that gets embedded in the mud. The great number of Chlorophyta species in these ecosystems is attributed to the presence of domestic and industrial effluent (Dhargalkar 2014).

Seagrasse

Seagrasses are angiosperms that live in submerged saline habitats. Seagrass beds provide shelter and are an important food source for fishes and crabs. Fishes also use sea grass beds as nursery grounds. The dense roots of seagrasses secure shorelines, and they also improve the quality of the water. *Halophila beccarii* and *Porteresia coaretata* has been observed in the mudflats of the Mandovi, and *H. ovalis* has been observed in the pre- and post-monsoon season in the sublittoral swamps of the river (Dhargalkar 2014; Goa Foundation 2015). The biomass and growth of *P. coarctata* also appeared to be strongly influenced by rich nitrite and nitrate contents and lower salinity (Jagtap 2006).

Micro-organisms

Free-living bacteria, fungi and yeasts have been described as having notable roles to play in detritus formation in mangrove ecosystems. Mangrove environments harbour mainly Gram-

Table 4
Phytoplankton Species of Mangrove Habitat in Mandovi Estuary
(Figures in Percentages)

Sr. No.	Species	Seasonal occurrence
1	*Pleurosigma elongatum*	15
2	*Pinnularia* sp.	10
3	*Gyrosigma balticum*	8.34
4	*Coscinodiscus* sp.	8.34
5	*C. eccentricus*	8.34
6	*Pleurosigma* sp.	8.34
7	*Diploneis robustus*	6.66
8	*Pinnularia alpinia*	6.66
9	*Cymbella marina*	6.66
10	*Rhizosolenia alata*	5
11	*D. smithii*	3.34
12	*Amphora lineolata*	3.34
13	*Cocconeis pediculus*	3.34
14	*Chaetoceros* sp.	1.66
15	*P. angulatum*	1.66
16	*Leptocylindrus danicus*	1.66
17	*Asterionella japonica*	1.66

Source : Jagtap et al, 2009

positive bacterial strains, predominantly those of the *Micrococus, Brevibacterium and Kurthia genera* (Dhargalkar et al, 2014; Goa Foundation, 2015). A new bacterial species *Agromyces indicus* sp. nov. was recorded from Chorao by Dastager et al (2012). Mangrove fungi decompose vegetative material, and through this process, allow its colonisation by bacteria and yeasts that further decompose the organic matter.

Sarma and Raghukumar (2013) have reported 45 different marine fungal species that were found to colonise decomposing substrata in the vicinity of *Rhizophora mucronata* and *Avicennia marina* in the mangrove ecosystem of Chorao belonging to *Ascomycota* (31 species), *Basidiomycota* (2 species) and asexual fungi (12 species) (Table 5). *Aigialus grandis* (15.3%) species occurred most frequently.

Zooplankton

The zooplankton diversity in mangroves is composed of 12 groups, comprised of 52 species. The majority of these species come from copepod genera, namely *Protozoa*, *Coelenterata* and *Cladocera*. The onset and prolonged southwest monsoon brings about extreme changes in the hydrographical conditions of the mangrove ecosystem, as a result of which there are great variations in the abundance and distribution of zooplankton in this community (2014).

Benthic Meiofauna

Benthic meiofauna are abundant in the benthos in terms of numbers and diversity, and have an important role to play in mangrove ecosystems by causing remineralisation of organic matter and stimulating microbial activity that provides sustenance to the mangrove food web. *Meiofauna* are preyed upon by juvenile fish and *benthic macrofauna*. *Nematoda* (76.1%) and *Copepoda* (7.2%) were the taxa found to be most dominant by Ansari and Parulekar (1993) in the Mandovi estuary off Chorao Island. Other taxa that were recorded by Ansari and Parulekar (1993) in the same location are *Turbellaria* (4.5%), *Polychaeta* (2.8%), *Ostracoda* (3%), and others (6.2%). *Nematoda* and *Harpacticoida*

Table 5
Manglicolous Fungi from Chorao and Frequencies of Occurrence

Sr. No	Species	Percentage	Sr. No.	Species
	Very frequent (above 10 per cent)			
1	Aigialus grandis	15.30	23	*Aniptodera chesapeakensis*
	Frequent (5 - 10 per cent)		24	*A. haispora*
2	*Trichocladium achrasporum*	8.60	25	*Calathella mangrovei*
3	*Morosphaeria ramunculicola*	6.70	26	*Cytospora cf. rhizophorae*
4	*Halorosellinia oceanica*	6.30	27	*Halosarpheia fibrosa*
5	*Rimora mangrovei*	5.10	28	*H. minuta*
6	*Dactylospora haliotrepha*	5.10	29	*Hysterium* sp. 2
	Infrequent (1 - 5 per cent)		30	*Massarina* sp.
7	*Rhizophila marina*	4.70	31	*Payosphaeria minuta*
8	*Aniptodera mangrovei*	4.40	32	*Pedumispora rhizophorae*
9	*Halocyphina villosa*	4.30	33	*Periconia prolifica*
10	*Saagaromyces ratnagiriensis*	3.90	34	*Phaeosphaeria oraemaris*
11	*Phoma* sp.	3.50	35	*Phomopsis mangrovei*
12	*Hydea pygmea*	3.10	36	*Phomopsis* sp.
13	*Marinosphaeria mangrovei*	3.10	37	*Saccardoella marinospora*
14	*Verruculina enalia*	3.10	38	*S. rhizophorae*
15	*Cirrenalia basiminuta*	2.30	39	*Sporidesmium* sp.
16	*Massarina velatospora*	2.00	40	*Stagonospora* sp.
17	*Savoryella paucispora*	1.60	41	*Tirispora mandoviana*
18	*Savoryella lignicola*	1.60	42	*Helenospora varia*
19	*Trimmatostroma sp.*	1.60	43	*Halosarpheia cf. minuta*
20	*Leptosphaeria australiensis*	1.20	44	*Hypoxylon* sp.
21	*Hysterium* sp. 1	1.20	45	*Savoryella longispora*
22	*Lulworthia* sp.	1.20		

Source : Sarma and Raghukumar, 2013

were found by Sahoo et al (2013) to be the dominant meiofaunal taxa in the vicinity of different vegetation types in Chorao, found in the top 10 cm of soil (Table 6).

Benthic Macrofauna

Benthic fauna, a major link in the food chain, are composed of filter feeders like bivalves and sponges, and deposit feeders such as molluscs and shrimp. Seasonal variations occur in their abundance as a result of rapid changes in salinity. Benthic fauna get depleted during the monsoon season and maximum numbers are observed from October to January, with a gradual decrease from February to May. Invertebrates that are found in mangrove habitats are worms, clams, crustaceans, crabs, bivalves, sponges, juvenile fish, and other tiny organisms that live in the bottom sediments (Untawale and Parulekar, 1976 Dhargalkar 2014). The vast mangrove root system, muddy benthos, and open water are habitats favoured by invertebrates that feed on leaf litter, detritus, plankton, microorganisms, and small animals. Some benthic fauna reside in the mangroves, others visit for breeding and feeding, while yet others visit seasonally (Untawale and Parulekar, 1976; Dhargalkar 2014). Macrofauna of Chorao were reported by Gaunkar et al (2013) to be dominated by Polychaeta (76 per cent), Oligochaeta (10 per cent), Crustacea (6 per cent), Bivalvia (3 per cent), Gastropoda (2 per cent), and other minor fauna groups that contributed 3%.

Table 6
Meiofauna from Chorao Island in the Sediments of Different Mangrove Species

Sr. No.	Taxa	*Sonneratia*	*Rhizophora*	*Avicennia*	*Bruguiera*
1	*Nematoda*	369.71 ± 199.93	249.10 ± 158.89	150.80 ± 49.44	126.79 ± 33.96
2	*Harpacticoida*	37.36 ± 50.24	59.65 ± 90.55	37.28 ± 5.66	15.16 ± 10.72
3	*Foraminifera*	54.41 ± 53.72	3.28 ± 2.27	4.00 ± 1.49	4.00 ± 1.49
4	*Turbellaria*	7.21 ± 6.98	1.31 ± 1.14	0.00 ± 0.00	0.00 ± 0.00
5	*Oligochaeta*	39.99 ± 20.40	20.32 ± 18.30	5.27 ± 5.06	15.37 ± 14.00
6	*Nemertinea*	4.92 ± 4.92	0.00± 0.00	1.68 ± 1.19	1.47 ± 1.49
7	*Polychaeta*	4.26 ± 4.09	8.85± 10.27	4.84 ± 5.06	2.53 ± 1.79
8	*Oribatida*	0.33 ± 0.57	0.00± 0.00	0.00 ± 0.00	0.00 ± 0.00
9	*Rotifera*	0.00 ± 0.00	0.33± 0.57	0.00 ± 0.00	0.00 ± 0.00
10	*Bivalvia*	0.00 ± 0.00	0.66± 1.14	3.37 ± 1.79	0.84 ± 0.60
11	*Ostracoda*	0.00 ± 0.00	0.00± 0.00	0.42 ± 0.00	0.21 ± 0.30
12	*Unidentified* sp.	1.31 ± 2.27	0.00± 0.00	0.42 ± 0.00	0.21 ± 0.30

Polychaetes play a significant role in the functioning of benthic communities. They exhibit a diversity of feeding modes and are many times the macrobenthic taxon that is numerically dominant. The distribution of this species has an important link with sediment particle size in soft-bottom habitats. Giangrande et al (2005) have reported that polychaetes are among the best indicators of environmental disturbance, as both sensitive and tolerant species are present in this taxon in a range of habitats from pristine to heavily disturbed. *Capitella capitata*, the most common species are known to display high tolerance to hydrocarbons and other pollutants that are toxic to most other fauna. *Syllis prolifera* is another species whose abundance increases with increase in environmental stress. Syllids are appropriate candidates as bioindicator species as they are very sensitive to disturbance and are also a taxonomically well-known family (Giangrande 2005; Sivadas 2010). Polychaete species such as *Nereis diversicolor, Neanthes arenaceodentata, Glycera alba, Tharix marioni* and *Nephtys hombergi* have been reported by Salas et al (2006) and considered capable of accumulating toxic substances. Some polychaete species that have been reported from the Mandovi estuary by Gaunkar et al (2013) are *Nereis* sp., *Glycera alba, Mediomastus* sp., *Prionospio* sp., *Paraprionospio* sp., and *Terebellidae* sp (Annexure I).

Bivalves are important elements of coastal ecosystem as large quantities of suspended matter from the water are removed through their filter-feeding activities followed by excretion of copious amounts of reactive nutrients. They are a notable food resource for human consumption, and serve as prey for several predators (Dame, 1993). Biomonitoring of environmental change, including pollution can be achieved by determining heavy metal accumulation in the soft tissues of bivalves. The sessile nature of molluscs, their wide geographical occurrence, and the ability to detoxify when pollution stops have caused bivalves of the genera Mytilus, Cerastoderma, Ostrea, and Donax to be considered ideal in many cases to detect the environmental concentration of a toxic substance (Salas et al, 2006). Molluscs, including bivalves, found in the Mandovi estuary include *Telescopium telescopium, Paphia malabarica, Martesia striata, Mytilus viridis* and *Modiolus* sp. (Parulekar 1980; Gaunkar 2013; Annexure II). Bivalves like *Meretrix casta, Velorita cyprinoids, Polymesoda erosa* are found in the Mandovi-Cumbarjua canal-Zuari estuarine system. *Polymesoda erosa* is a clam species that has been reported by Ingole et al (1994), ENVIS

(2002), Ingole (2002), and Dhargalkar (2014). In Goa, four species of bivalves are commercially expolited – *Meretrix casta, Paphia malabarica, Villorita cyprinoids* and *Katelysia opima*. (Ingole et al, 2002; Dhargalkar 2014).

The mud clam *Polymesoda erosa* (Solander, 1876) is very abundant in the benthos of the mangrove forests of Chorao, and has ecological and economic importance. Clemente and Ingole (2011) reported the post-larval settling occurred during the month of September. In the landward zone, the density of adult clams was noted to range between 7-12 no. m^2, while adults were completely absent in the seaward region during the low tide. A larger number of juveniles were noted at the low- to mid-tide levels. Frequent inundations occur at these levels and this was assumed to be the cause, as these conditions would allow the juveniles to attain the critical size by feeding adequately. At levels of high tide, the mortality of the settlers may be accounted for by an increase in desiccation. Within the Chorao mangrove ecosystem, *P. erosa* is a major bioturbator and it is expected that it is important in nutrient recycling this clam species has potential as an indicator organism.

Crustaceans play an important role in the dynamics of mangrove ecosystems and are also important in the trophic food web. Their burrowing activities permit the transport of organic matter from lower strata of the benthos to the surface and also aerate the soil. This action lowers the levels of sulphide in the soil and has a positive influence on the productivity of the mangroves (Dhargalkar et al, 2014). Among the crustacea reported from the Mandovi by Parulekar (1980) are *Metapenaeus monoceros, Fabricius, and Scylla serrat*e (Forskal). Six crab species are commercially important, of which Scylla serrata, Thalamitta crenata, and Portunuss anguinolentus are caught in large quantities (Dhargalkar 2014; Goa Foundation, 2015). The fiddler crab species *Uca* and various species of *Sesarma* are common inhabitants of the intertidal mangrove zones, found throughout the Indo-Pacific region (Dhargalkar 2014; Goa Foundation, 2015).

The most prevalent prawn species are the giant freshwater prawn *Macrobrachium rosenbergii* and the marine penaeid prawns *Penaeus indicus, P. merguiensis, P. monodon, and Metapenaeus brevicornis* (Dhargalkar 2014; Goa Foundation, 2015). Juvenile shrimps spend 3-4 months in the mangrove estuaries, and then migrate to shallow coastal waters where maturity occurs. The principal spawning migrations start in June and continue into late January. Spawning of Penaeid shrimp has been observed to peak during May-July and October-December. These periods coincide with the arrival of the monsoon season (Dhargalkar 2014).

Gastropods have been reported by McQuaid (1996) to have immense influence on the structure of intertidal and shallow marine ecosystems. Species of gastropods with strong direct effects on the distribution and abundance of other organisms in the ecosystem are detritivores and epiphytic grazers, whereas macroalgal grazers and epilithic grazers have weak direct effects. *Umbonium vestiarum*, an intertidal gastropod, has been reported by Sivadas et al (2012) to be a species that is sensitive to turbidity caused from activities such as mining, where increased turbidity may interfere with feeding and result in mortality or a reduction in rate of growth. The habitat selection by this species is fastidious, which makes them very vulnerable to any changes in their habitat, leading to mortality and a decrease in abundance.

Other species of molluscs and crustaceans are also known for their wood-boring activities, and have been reported to attack live but injured trees. Species such as *Martesia, Nausilora hedleyi* and a member of *Sphaeroma terebrans* are noted to have destroyed species of *Avicennia* along the coast of Goa (Dhargalkar 2014).

Fishes

The mangrove ecosystem is a detritivorous based ecosystem and supports a large variety of organisms that inhabit it. Fish of marine, estuarine, and backwater species, as well as some freshwater species are found here. More

than 120 fish species have been found among mangroves, mostly of brackish water and estuarine species. Among the commercially important species are mullets *(Mugil cephalus)*, snappers, milk fish *(Chanos chanos)*, sea bass *(Lates calcarifer)*, and tilapia. The most discernible fish is the mudskipper *(Periophthalmus* sp.*)* that is native to the mangroves, and lives on the mudflats associated with this ecosystem. This fish is suited to alternating periods of exposure to air and submersion (Dhargalkar 2014).

Reptiles and Amphibians

Reptiles such as snakes, turtles, and crocodiles are commonly observed in mangroves, with crocodiles being some of the most notable reptiles that are natural inhabitants of marine and estuarine environments. The fresh water crocodile *Corcodylus palustris* has become so adapted to saline conditions that it can survive for an indefinite period in a wide range of salinity, and feeds on fishes, birds, and other animals (Kumar and D'Souza, 2013; Dhargalkar 2014) (Figure 7).

The widely distributed lizards in the bird sanctuary in Chorao are the garden lizard *(Calotes versicolor)*, and water monitor lizard *(Varanus benghalensis)*. Not much research has been conducted regarding lizards that inhabit mangrove ecosystems (Kumar and D'Souza, 2013; Dhargalkar 2014).

An abundance of snakes are also to be located in mangrove areas, especially on the landward fringe. They are salt tolerant, and have diving ability and breath-holding capacity. Three species of snakes, that is the beaked sea snake *(Enhydrina schistose)*, wart snake *(Acrochordus granulatus)*, and the dog-faced water snake (Cerberus rynchops) have been reported from the mangrove regions of Goa (Dhargalkar et al, 2014). Arboreal snakes like bronze backed tree snake, and green whip snake are sighted in the mangrove areas of Chorao; aquatic snakes like checkered keelback, dog faced water snake are commonly sighted in the Dr Salim Ali Sanctuary waters; and terrestrial snakes like cobras, rat snakes, and Russel's vipers have been observed in the sanctuary (Kumar and D'Souza, 2013).

Mammals

Mammals that are generally observed on Chorao are the Common Indian field mouse *(Mus booduga)*, bandicoot *(Bandicoota indica)*, smooth Indian otter *(Lutrgale perspicillata)*, flying foxes *(Pteropus giganteus)*, and jackals *(Canis aureus)* (Kumar and D'Souza, 2013).

Birds

Birds are prominent in mangrove forests and are usually present in big numbers. Approximately 109 species of resident and migratory birds can be found in these forests (Annexure III & Annexure IV). Shallow waters and exposed mudflats of the mangrove regions serve as abundant feeding grounds for many large birds. Species of birds such as ducks *(Dendrocygna javanica)*, egret *(Egretta gularis, E. garzetta)*, kingfishers (Halcyon smyrensis, H. pilenta, H. capensis)*, kites (Haliastur indicus, Milvas migrans)*, cormorants *(Phalocrocorax niger, P. carbo)* have been noted in the mangrove habitat. Some are resident species, while others are migratory. The natural habitat of some species of birds, like the Collared kingfisher, is restricted entirely to mangrove areas (Dhargalkar 2014).

The mangrove cover in the Dr Salim Ali Bird Sanctuary is an ideal breeding ground for raptors, and mangrove species in bloom attract nectar feeding birds. The sanctuary is also home to other wetland birds and woodland or forest bird species. Smaller insectivorous birds are also found here. Migratory birds, including birds of prey, visit the sanctuary (Goa Forest Department, 2004; Kumar and D'Souza, 2013; Goa Tourism, 2015; Wikipedia 2015; Wildlife in India, 2015; Wildlife of India, 2015).

Status of Chorao Island Vertebrate Species

Certain species of vertebrates have been assessed for their global status by the IUCN Red List and their protection status in India has been determined as per the Wild Life (Protection) Act of 1972.

Table 7
Benthic Macrofaunal Density in the Mandovi Estuary

Sl. No.	Taxa	Mean macrofaunal density (individuals m^{-2})		
		May-02	Sep-02	Apr-03
1	Polychaeta	485	300	716
2	Bivalvia	60	290	134
3	Amphipoda	444	40	59
4	Gastropoda	22	10	19
5	Decapoda	25	5	25
6	Cumacea	6	20	50
7	Oligochaeta	9		34
8	Isopoda	9		25
9	Tanaidacea	69		
10	Nemertea	16		
11	Nematoda		5	3
12	Sipunculida	6		
13	Echiurida	6		
14	Echinodermata			6
15	Harpacticoidia			4

Figure 7
Marsh Crocodile *Crocodylus Palustris* in Chorao Island

Source : Dhargalkar 2014

The list is given in Annexure V. Among the reptiles of Chorao, *Crocodylus palustris* is accorded the global status of 'vulnerable'. Among the bird species that are present within the sanctuary, *Ciconia episcopus, Leptoptilos javanicus* and *Aquila clanga* are vulnerable, while *Anhinga melanogaster, Threskiornis melanocephalus, Numenius arquata* and *Sterna aurantia* are near threatened. None of these species are protected in India under the Wildlife (Protection) Act, 1972. Under this Act, the Common Water Monitor (Varanus salvator), the Golden Jackal (Canis aureus), and the Brown-headed Gull (*Larus brunnicephalus*) have been accorded protected status.

Chapter 3

Management of Mangrove Forest

Legislation, Policies and Regulation for Mangroves

The Ramsar Convention of 1971 and the Convention concerning the Protection of the World Cultural and Natural Heritage of 1972 were the two conventions that lead to steady initiatives on conservation that restricted mangrove deforestation. Das Gupta and Shaw (2013) have reported that under the Ramsar Convention on Wetlands, several mangrove areas have been nominated as Ramsar sites or National Parks, Reserves, or Wildlife Sanctuaries. Large-scale initiatives for conservation of forest resources were addressed after the Stockholm Declaration of 1972. Following the Stockholm Declaration, the Indian constitution was amended to take into account the guidelines stipulated within it (Das Gupta and Shaw, 2013).

The National Mangrove Committee, an advisory body to the Indian government, was formed for further conservation of mangroves in the country. Based on the recommendations made by the National Mangrove Committee, the Ministry of Environment, Forests and Climate Change introduced a scheme on the Conservation and Management of Mangroves and Coral Reefs in 1986 – 87. The aim of the scheme was to develop degraded mangrove areas, maintain and enrich their biodiversity, and promote public awareness for protection of these ecosystems at the provincial level. The implementation of the scheme on a national level has on the whole been successful (Das Gupta and Shaw, 2013).

Legislative protection in India, as observed by Das Gupta and Shaw (2013), is conferred to mangroves under the Indian Forest Conservation Act, 1980, and the Wildlife (Protection) Act, 1972. These acts fundamentally categorise the forests with respect to their ecological importance. The Coastal Regulation Zone (CRZ) Notification under the Environment Protection Act, 1986, declares coastal regions of seas, bays, estuaries, creeks, rivers, and backwaters, that are under tidal influence in the landward side up to 500m from the high tide line and the land between the low tide line as Coastal Regulation Zone (CRZ). National and State Coastal Zone Management Authorities were formed for

Table 8
Secondary Legislations for Mangrove Protection

Sl No	Acts	Year	Key features in Mangrove protection
1	Indian fisheries act	1897	Regulates the uses of dynamites and explosives for fishing, control of fishing in eco-sensitive areas.
2	Indian Port act	1908	Regulates the port, movement of vessels & safety.
3	Coast guard act	1950	Responsible for controlling of water pollution in marine & estuarine environment, controls of illegal poaching & intrusion
4	Merchant shipping act	1958	Regulates and controls shipping pollution in marine environments
5	water(Prevention & control of pollution) act	1974	Control discharge into marine environment (from Land).
6	Maritime zone act	1976	Describes various zones such as the EEZ, continental shelf etc
7	Marine fishing regulation act	1978	Provides guidelines to regulate fishing in territorial waters, regulate mesh sizes, zones for fishing sectors.
8	National environmental tribunal act	1995	Provision of compensation for damaging life, property & environment due to the use of hazardous substance and their release in environment
9	Coastal pollution regulation zones (COPOCS Program)	1982	Assess pollution status in coastal area.
10	Coastal ocean monitoring and prediction systems (COMAPS)	1991	Assess the health of coastal waters, pollution monitoring, regulation & legislation recommendation
11	UNCLOS	1995	Provides legal framework for issues related to oceans and seas
12	Coastal aquaculture authority act	2005	Regulates development of aquaculture pond in coastal areas
13	CRZ notification		Incorporation of more integrated and scientific management of coastal Zones

Source: Das Gupta and Shaw, 2013

enforcing and monitoring the CRZ notification. The Environment Protection Act also controls activities that may negatively affect sensitive ecosystems through the Environmental Impact Assessment (EIA) notification of 1994. The Coastal Aquaculture Authority Act, 2005, has been developed recently for the protection of mangroves (Das Gupta and Shaw, 2013) (Table 8).

At the state level, Misra et al (2015) have reported that the Forest Department of Goa has issued a notification under the Goa, Daman, and Diu Preservation of Trees Act, 1984, that bans the felling of the major species of mangroves. The State Forest Department is the nodal agency for mangrove-related activities (Goa Forest Department, 2004). Chorao Island was declared a Reserved Forest under the Indian Forest Act, 1927, for the protection and conservation of mangrove forests (Misra 2015).

Over the last decade, initiatives for restoration have gained strength across the main mangrove habitats in the country. There is however, a minimal level of framework for safeguarding existing mangrove cover from pollution resulting from upstream anthropogenic activities. Significant challenges for restoring ecological services of mangroves are posed due to the increasing levels of salinity and severe reductions in flow of fresh water (Das Gupta and Shaw, 2013).

Mangrove Forest Management at Chorao

Colonial Period

Kumar and D'Souza (2013) have reported that during Portuguese colonisation of Goa, the forest management came under the Department of Agriculture, under the general department 'Directorate of Economy'. The forests were not handled systematically during the colonial period. The trend of shifting cultivation at the

time caused the most damage to the forests of Sattari and Sanguem. Aires Miranda classified the forest in 1945 into 3 types based on their luxuriance – from the most luxuriant type A, through type B, and poorest type C. The local population was allowed benefits in type C forests, and areas of this type of forest were leased out for cultivation. The Legislative Diploma no. 644 of 30th March 1933 was the only rule relevant to forest management, but was insufficient for successful administration. Poaching of wildlife occurred indiscriminately and rules were not put in place to check these occurrences (Kumar and D'Souza, 2013).

Post Colonial Period

The Forest Department came into being as a full-fledged government department in 1963. Two divisions of the forest area, as noted by Kumar and D'Souza (2013), were made - the North Goa division and the South Goa division. These were further subdivided into 10 ranges - 5 in the North Goa division, 3 in the South Goa division, and 1 each in Daman and Diu. Exposed forest areas were restocked artificially with tree species like cashew, teak, and eucalyptus.

The critical step attained in forest management in Goa was the extension of the Indian Forest Act to the state on 1st February 1965, which brought Goa into parity with the rest of the country in terms of forest legislation. Prior to this, wildlife in the state was threatened and numbers were decreasing. The Goa, Daman and Diu wild Animals and Birds Protection act bans hunting without a legitimate license. Restrictions on methods for hunting have also been stipulated. Five types of licenses are issued under the Act: small game license, big game license, special big game license, pet animals (possession license), and pet and other animals (trapping license). Licenses are also issued under this Act for hunting for scientific research and collection of wildlife specimens for zoological gardens and museums, as well as for the destruction of animals and birds that pose a serious threat to human life and property. For this purpose, animals have been classified into four schedules: Schedule I – vermin, Schedule II – small game, Schedule III – big game, Schedule IV – special big game (Kumar and D'Souza, 2013).

Strategies Practiced for Management of Mangroves at Chorao (2013 - 24)

Current Strategies: The Goa Forest Department (2004) has recorded that the activities currently occurring at Chorao for its maintenance and management are:

- The establishment of a nursery of mangrove species for afforestation. The species used for plantation are mainly all 3 species of Avicennia, Rhizophora mucronata, Bruguiera cylindrica, Ceriops tagal, Kandelia candel, and other species to a small extent.
- Enrichment of old mangrove plantations.
- Awareness programmes for students and the general population.
- A Mangrove Interpretation Centre where people can acquaint themselves with the species to be found on the island. Details of various species are displayed at the Centre by way of drawings and text.

Proposed strategies: Strategies that have been proposed for the management of Chorao over a period of the next 10 years have been recorded by Kumar and D'Souza (2013) as follows:

Zonation

Zonation of the protected area has been carried out as part of the management plan for Chorao for the next 10 years as a means of attaining the predetermined wildlife management objectives. The strategies for habitat management will include all human interventions that are deemed necessary for the facilitation of growth and propagation of the flora and fauna of the area. The sanctuary has been divided into the core, tourism, and buffer zones.

The core zone makes up the largest portion of the sanctuary that has heavy mangrove cover, except for the southern area where the walkway, jetty and watchtowers are located. The core zone is the inner sanctuary of the protected

Figure 8
Zonation Map of Dr. Salim Ali Bird Sanctuary, Chorao Island

area where minimal interference will be allowed. The purpose of the core zone is to maintain the ecosystem and improve the suitability of the habitat for resident and migratory birds. There is need for the preservation of habitat features to ensure the success of the management strategies and that of the resident and migratory species.

The walkway along the southern boundary of the bird sanctuary provides access on foot within the protected area, and the tourism zone is constituted of this area. This zone is made up of representative areas of the sanctuary that are more easily accessible, and permits tourists to observe and understand the island's ecology.

A section of the sanctuary on its eastern boundary adjacent to the fishponds and reception office has been designated as a buffer zone for the sanctuary.

Maintenance of Mudflats

Mudflats are essential as foraging grounds for migratory and resident birds. It has been observed that the mudflats have been gradually colonised by the mangroves, which is detrimental to the birds that are dependent on these regions. It is proposed to keep the mudflats free of mangrove growth that may occur naturally or through artificial means.

Management of Bunds

The bunds are ideal habitats for lower faunal species and as nesting sites for some species of birds. Damage to the bunds occurs on a regular basis as a result of wave action and the burrowing activities of crabs. Maintenance of the bunds without concretisation is aimed for, and repair will be carried out by placing mud on the bunds every post-monsoon season.

Traditional Fishing within the Protected Area

A positive association exists between traditional fishing and bird life, as the fish discarded by the traditional fisherman is not of exceeding large quantities, and is consumed by the birds. Motorboats and mechanised means of fishing should be prohibited within the protected area, and solely traditional fishing practices should be allowed to continue.

Management of Plastic and Garbage

Plastic material in the form of bottles, bags, and others enters the backwaters during the high tide and gets lodged in the root systems of the mangroves. The manual collection of this plastic material is the only feasible means of removal of such waste. The use of large mesh nylon nets at the entry points of the creeks would restrict the entry of plastic material into the backwaters, and the large mesh size would not hinder the entry of fish. The collected plastic is to be disposed off in a responsible manner outside the protected area.

Management of Creeks

The constant growth of the mangroves on the banks of the creeks has reduced the width of the creeks, causing restrictions in the movements of boats. The trimming of the branches as required has been proposed, to open the creeks for regular and easy passage of the field staff, via dugout canoes, in the protected area.

Conservation of the Habitat of Fruit Bats within the Protected Area

Apart from resident and migratory birds, the sanctuary is home to a population of fruit bats. It has been noted that the bats live on a few trees within the protected area. The plan in this case is to survey the area and mark and protect these trees.

Ecotourism

Ecotourism involves travel to natural areas in a responsible manner, in an approach that conserves the environment and improves the welfare of local communities. Ecotourism necessitates a multidisciplinary approach, attention to physical and managerial planning, guidelines, and rules that will be enforced in order to achieve sustainable tourism. The management of the impacts caused by visitors is needed to ascertain the long-term protection of natural and cultural resources, and also uninterrupted enjoyment and use by visitors. The activities that are to be taken on under this banner are boat rides, bird watching, mangrove walks, and guided tours into the creeks of the protected area.

An interpretation center is utilised as a tool to create awareness among the public about the natural wealth and resources of a region. The construction of a permanent interpretation centre in the protected area is not feasible due to the marshy nature of the terrain. The aim is to utilise the mangrove walkway for displays indicating the floral and faunal features of the area. Nature camps, snake shows, screening of wildlife films for school children and the general public, and other activities will be taken up by the sanctuary staff to increase levels of awareness. The publication of brochures and the availability of souvenirs also aids in creation of awareness. Thus the management will have to undertake suitable steps to provide education and awareness within society.

Research, Monitoring, and Training

Research and monitoring are essential portions of any management plan. Scientific direction is impeded by the lack of baseline data. The development of a database is necessary in the long term to determine the outcomes of implemented prescriptions, following which remedial measures can be adopted, as required.

The building up of a programme of monitoring, including that of physical and biological changes, is needed. The protected area also needs a database system for continuous analysis and assessment of information obtained from the field. The periodic analysis of the information in the database system will allow for planning in perspective. Prey-predator population dynamics provides a general idea of the need for management interventions.

The park management team will be unable to conduct research projects on the species level, and it is therefore proposed that university and other research scholars be encouraged to carry out such research. Collaborative studies between the Forest Department and Goa University will facilitate the understanding of the biodiversity and the interaction of fauna and flora within the protected area.

Wild animals that stray into human habitation are rescued by the staff of the protected area, given medical treatment if necessary, and are released back into the natural habitat once they are fit. A 24-hour rescue centre is in operation, situated from the Range headquarters in Campal, Panaji.

Wildlife management requires skill and experience, and this can be strengthened through capacity-building trainings and workshops for personnel. Staff should be dispatched for such training and their skills and knowledge should then be utilised in the protected areas.

Chapter 4

Management of *Khazan* Lands

Pre-colonial Period

The Gaudas were the first settlers in Goa who were not nomadic and were into growing food. The Gaudas developed the 'jonn' system of shares and dividends and the produce from the property was shared among all the members of the village (Sonak, 2014b).

In time, other groups arrived in Goa – the Kshatriyas and Brahmins. The Brahmins learned from Gaudas how to regulate the tides and applied this knowledge in reclaiming mangrove lands for agricultural purposes. Land was collectively owned and profits were shared among individual members. Gaunkari was applied to khazan lands, which belonged primarily to the Brahmins (Sonak, 2014b).

Khazans were leased out to one of the gaunkars, who further sublet it to individual cultivators. The individual cultivators managed the khazan ecosystem and tasks were clearly delegated to particular persons. They were responsible for the maintenance of the bunds and sluice gates of the khazans and breaches had to be repaired within 24 hours (Sonak, 2014b).

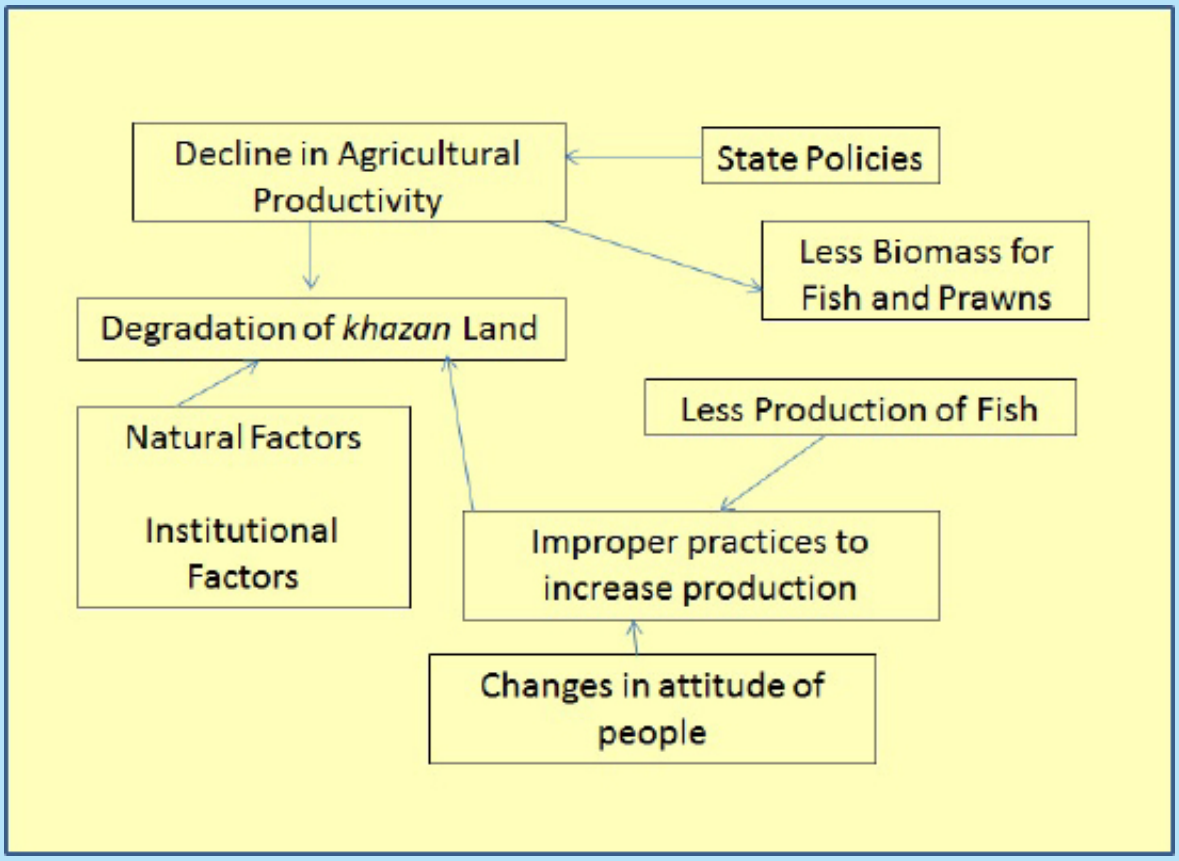
In latter periods, Goa was ruled by several dynasties, some of which allowed lands to be maintained tax-free by the Brahmins, on condition that they prevented the intrusion of saline water into the fields by means of dykes.

Colonial Period

By the mid-1520s, the gaunkari system was re-organised on a major scale and renamed as communidades. The rules and regulations of the communidades were organised for the first time into the Code of the Communidade, through which this institution was regularised and attained legitimacy. The communidade became an institution that owned all the land in a village that was not privately owned (Sonak, 2014b).

The communidade maintained the khazan ecosystem through the association of farmers, as was done in the gaunkari system. The association was responsible for the maintenance of the dykes

Figure 9
Dynamics of *Khazan* Ecosystem Management



Source : Sonak 2005

and sluice gates of the khazans and breaches had to be repaired within 24 hours. Money for this purpose was collected by auctioning rights of cultivation to farmers and leasing fishing rights to fishermen (Sonak, 2014b).

Post-colonial Period

Through the constitution of India, a series of legislative actions were established to bring about social equity and distributive justice. This included agrarian reforms (Sonak, 2014b). The Goa Agricultural Tenancy Act of 1964 initially provided a guarantee of land tenure to agricultural tenants and the formation of tenants' associations. In 1976, an amendment to the act conferred the lands to the tenants who actually cultivated them. In 1975, Joint Responsibility of Tenants Rules was legislated that transferred the responsibility of management of the khazans to the tenants (Sonak, 2014b).

These changes contributed to making the gaunkari or communidade system insignificant, and the tenants became the expected purchasers of the agricultural and khazan lands. These lands then became owned individually though they were managed jointly, and this decreased the income to the tenants' association. Due to the lowered sources of income and decreased weight of membership, the income to the communidade for maintenance of khazan lands reduced (Sonak, 2014b).

Given the above scenario, the revenue obtained by the tenants' associations is now insufficient for maintaining the khazans, and the associations are currently dependent on subsidies from the state for this purpose. Additionally, the official posts in the tenants' associations are honorary and the employees are not paid. These notable factors in conjunction with low business for sale

of agricultural produce caused negative stimulus for cultivation (Sonak, 2014b).

Changes over Time: The following changes have been reported by Sonak et al (2005) in the khazan ecosystem over a period of time (Figure 9)

- Non-residents of the village are permitted to participate in the auction so that auction prices can be raised as a means of bringing in more income for maintenance
- The current outline of events has been low productivity and a declining fish yield, but high commercial demand for fish
- The land area occupied by mangroves has increased gradually
- Auction prices have increased progressively
- There has been a decrease in the availability of help for skilled and agricultural occupation
- The degree of membership of the association, as well as the revenue, has reduced with time
- Regular de-silting of the poiem, or reservoir, is not carried out
- There has been an increase in the number of fields left fallow, which is significant for agricultural and fish productivity
- Remunerations for labour were earlier made in cash and kind
- The process for repair and maintenance of bunds has been altered in recent times: a designated contractor is given the responsibility for a period of 3 years, for which he receives remuneration. Additionally, he also receives the lease for fishing rights for 3 years.

Indigenous Practices of Managing *khazan* Ecosystems

Role of Communities

Traditional communities have been recorded to have a close relationship with their environment and have a comprehensive approach towards resource management. Regular maintenance and timely repairs by the traditional communities has helped in keeping this important legacy operational for several generations. A close and devoted relationship with ancestral lands and values that acknowledge the strength and spirituality of nature have allowed traditional communities to live harmoniously with nature for several thousands of years (Sonak, 2014b).

Indigenous Indicators

Indigenous communities have been noted to utilise ecological events as indicators to predict events that concerned natural resources – their food supply and other useful resources that are often essential. Any conspicuous changes were reported to peers and elders of the village, examined, and decisions were made and implemented. The prompt assessment and application of remedial action aided indigenous communities in the retention of ecosystem stability before degradation could occur. The inclusion of indigenous indicators in the present approaches to resource management may be of notable effectiveness in ecosystem health monitoring (Sonak, 2014b).

Indigenous Ecological Calendars

Sonak (2014b) has reported that many years of observing physical and biological events and judgments obtained from physical and biological occurrences – ecological time and ecological events – formed the bases of ecological calendars. Incorporation of such calendars in management approaches may provide great benefit, especially in monitoring ecosystem health and in the construction of area-specific schedules for extraction of resources and harvests, and other resource management processes.

Eco-friendly Traditional Resource Management Practices

A thorough knowledge of the terrain and its profile, hydrogeography, hydrochemistry, tidal and other events is involved in the designing and positioning of the sluice gates, which ascertains the automatic opening and closure of the shutters with tidal force. In this manner, the water reservoir or 'poiem' occupies a certain location in the khazan for collection of excess water with slow release as necessary. The reproductive and growth cycles of fish are recognised, and patterns of fishing are based on

local tidal cycles, which serve to maximise fish yield naturally (Sonak, 2014b).

Utilisation of Locally Available Resources

Sonak (2014b) noted that extensive local knowledge augmented with simple technology, sturdy tools, plentiful resources that are locally available, and simple and unsophisticated procedures went into the construction of khazans.

Sustainable Resource Extraction and Harvesting

A variety of shrimp, fish and crabs are caught in the khazan ecosystem. Fish that migrate from waters of high salinity to those of lower salinity are allowed to spawn in the khazan lands. The juveniles will grow in the khazan lands, which are rich in organic biomass sourced from the paddy straw of the agricultural fields. After their growth to adulthood, the fish start to migrate back to more saline waters to be recruited to the adult stock. These fish are caught at the sluice gates. This process has been recorded by Sonak (2014b) to assure a high yield while protecting the larvae for the next season.

Integrated Resource Management Systems

Khazan systems are merged agriculture-aquaculture systems that effectively utilise the waste generated by one system to augment the other. For example, paddy straw was used as feed for aquaculture species, and organic manure made from fish residue was used to fertilise the rice fields and other crops (Sonak, 2014b).

Role of Indigenous Institutions

Sonak (2014b) noted that in the traditional management process, all members were familiar with the ecosystem, though individual tasks were allotted to specified persons. These communities relied heavily on the ecosystem for their sustenance and livelihood, and this made the welfare of the individual very closely linked with the welfare of the ecosystem. The communities were self-regulated and fishing and cultivation rights were auctioned and kept exclusively within the community. Fishing was banned during the breeding season as a means of regeneration of species (Sonak, 2014b).

Role of Religious Culture

Sonak (2014b) has elaborated that the monsoon fishing in Goa has been kept in control by important religious feasts of both Hindu and Catholic fishermen. These feasts indicate the end of one fishing season, and celebrate the start of the next fishing cycle. The time is also marked by important religious celebration – the Narali Purnima puja during the full moon of Shravan is celebrated by Hindu fishermen, and the feast of São Lourenço celebrated by Catholic fishermen is the time for the fishing boats to be blessed by the village priests. These festivities fall in the month of August of the Gregorian calendar. Before the advent of mechanised fishing, such religious or informal law was highly effective in the protection of marine fauna during the critical spawning season by assuring that fishermen would not enter the seas due to fear of its roughness and of incurring the fury of the deities (Sonak, 2014b).

Other religious practices that respect the natural environment are the following: The first harvests of rice of good quality are worshipped by both Catholic and Hindu communities of Goa. Harvesting of new crops requires ceremonial blessings from the priests in both communities. 'Manage thapani' is a special ritual performed in the khazan ecosystems of some coastal villages that involves the appeasement of the marsh crocodile, *Crocodylus palustris*, found in Goan coastal marshes and creeks (Sonak, 2014b).

Current State of the Natural Environment

During colonial times, the embankments were maintained by the Portuguese, but in the years following liberation, development within the villages on the island had led to the deterioration of the bunds. Some facts associated with the present use of khazan ecosystems are (Sonak et al, 2005):

- Upon closure of the sluice gates, coconut fronds are utilised so that fish will travel to cooler regions, and the yield can be increased
- There have been reports of dynamite fishing

and deliberate breaching of the bunds. Such methods allow the entry of larger volumes of water, thus increasing the fish catch

- In the past few years, people from outside the village fish in the khazan lands
- Before the commencement of the auction, potential bidders are paid off to prevent their participation in the auction and in this manner, ascertain a lower price
- Salinisation of water and land has been reported
- Operators of the sluice gates pay the auction figures in instalments, and these are often waived off by the managing committee or the Tenants' Association
- Oil lamps are used to increase the catch of fish by interrupting their migration
- The rate used by the state government to estimate expenses for repairs of bunds is lower than the actual cost of labour in Goa
- The fishing regulation that allows fishing rights exclusively to the sluice gate operator within 100 - 150 mt of the gate is not put into operation.

Chapter 5

Threats and Gaps in Management of Mangroves and *Khazans*

Mangroves – Man-made Hazards

In Goa, mangrove forests have been cleared and the land reclaimed to set up infrastructure for housing, industry and tourism. Mangrove forests have been noted to be constantly under threat, despite being under the protection of various rules and regulations.

Urbanization

Mangrove areas and khazan lands are under threat from conversion of these areas for housing, and other developmental activities. Reclamation causes damage to mangrove saplings and small plants (Goa Forest Department, 2004; Dhargalkar et al, 2014).

Illegal Felling of Mangroves

The felling of mangrove trees for timber is an illegal activity that damages mangrove cover and the ecosystem (Goa Forest Department, 2004; Dhargalkar et al, 2014).

Fishing

The collection of clams and crabs by local fishers from the interior regions of the mangroves results in the trampling of seedlings and this activity may uproot or damage the young crop.

Barge Traffic

Increasing activities for fishing and bird watching with motor boats in and around the creeks within the mangrove regions cause generation of strong wave action resulting in the uprooting of young plants and saplings and also cause disturbance in the settling of seedlings into the sediment.

Inadequate Infrastructure for Protection

The limited staff and resources of the state forest department pose difficulties in extending protection to mangrove forests found all over Goa (Goa Forest Department, 2004).

Sewage and Industrial Effluent Pollution

Untreated wastewater from municipalities and industries is discharged directly into rivers as a result of coastal development activities, causing increased accumulation of pollutants in the mangrove ecosystem (Dhargalkar et al, 2014).

Oil Pollution

Since 1970, there have been over 70 cases of oil spills, both large and small, along the country's west coast. The spilled oil that reaches the mangroves has severe effects on the ecosystem – defoliation of trees, mortality of sessile and benthic organisms, and other damage to life that depends on this habitat (Dhargalkar et al, 2014).

Sand and Iron Ore Mining

Rejects from the upstream mining belt affects estuarine water quality and topography, resulting in the formation of mud flats. The formation of the new island between Chorao and Divar has occurred as a result of this effect (Dhargalkar et al, 2014).

Natural Threats for Mangroves

Barnacle Infestation

Barnacles adhere to the stems of young plants causing damage to them. The plant usually affected is Rhizophora mucronata as a result of its rough bark that provides a good base for the attachment of barnacles. This occurrence is quite pronounced in the Mandovi estuary (Goa Forest Department, 2004). Oysters also attach to the roots of the trees.

Insect Infestation and Diseases

Some species of insects or borers cause considerable damage to the trunks of mangroves. Insect infestation of the leaves of *Rhizophora mucronata* is a regular occurrence and if unchecked, can result in complete damage to young plants and older trees. Infestations of *Avicennia alba* is observed at a regular interval of about 5 years during which the insect larvae feed on the leaves of the plants, making them bare and causing serious damage to the plants (Goa Forest Department, 2004).

Factors Affecting *Khazan* Ecosystems

Several factors – ecological, socio-economic, and institutional - have an effect on the khazan ecosystems and cause changes in the use of the land and the cover in the coastal wetland regions of Goa. This has been reported by Sonak et al (2005), Sonak (2014a) and Sonak (2014b) (F- 10):

Ecological Factors

a. Salinisation of land: The sluice gates that are present in the embankments are made using wooden planks and are therefore susceptible to attack from wood-boring causes. Regular checking of the wood and replacement as required is necessary. Mud crabs *(Scylla serrata)* are the primary agents that cause breaching of the embankments by burrowing in them. Any delays in repairing the damage can result in enlargement of the breaches, and the estuarine water that gains access to the agricultural fields and well water, leads to their salinisation. Increased salinisation of khazan lands can also cause reversion to their original mangrove ecosystem.

b. Non-cultivation of land: In those cases where remuneration from agriculture is not sufficient, the land is allowed to lie fallow. Agricultural khazan land becomes overgrown with weeds if it is not cultivated, and the task of weeding is expensive due to the high wages of agricultural labour in Goa. When this occurs, degradation of the khazan land is the outcome. Fields that lie fallow become unproductive and have lower contents of organic biomass, which leads to reduced yields of fish.

c. Change in the rice varieties cultivated: Over time, the cultivation of salt-tolerant varieties has been successful, but the yield from traditional varieties is low compared with other varieties. This has caused a shift towards cultivation of high-yielding varieties. The disadvantage of high-yielding varieties is that they require inorganic fertilisers and pesticides, and the run-off from these fields can affect fish yields.

Socio-economic Factors

a. Effects of mining activities: The River Mandovi, in which Chorao is located, was used by barge traffic as a waterway for the transportation of ore from the loading point in mining areas to Mormugao harbour. Silt that originates from mining activities gets

deposited on the land as well as in the water reservoirs ('poiem'). The reservoirs, which earlier used to be de-silted on a regular basis, have become shallow due to the accumulated silt that has arisen from mining barges and run-off from active mining sites.

b. Infrastructure erection: Tourism and urbanisation are responsible for the conversion of khazan lands in many parts of Goa. Population pressure and catering to tourism in coastal areas hastens land conversion.

c. Effects of migration: Maintenance of khazan lands necessitates skilled manpower, which becomes scarce due to migration. Many other livelihood opportunities provide higher returns and for this reason, people have moved out of the agricultural sector. This has raised the demand and expense of labour for agriculture.

d. Erosion of traditional values: With the changes in traditional communities to modern societies and weakening of cultural and religious institutions, the correlation between society and the environment has altered. These previously important relationships are losing their significance, and profits to the individual are taking priority over the safeguarding of collective resources. Leases on fishing rights to an individual are permitted for a single year per time, and therefore improper fishing methods are used to exploit the resources. Dykes have been intentionally breached to allow the entry of larger volumes of water. A higher yield is accumulated by this action, but on the downside, the khazan lands become damaged.

e. Other demographic changes: Improved literacy rates and the associated higher income levels and social status have led people to shift from the primary to the tertiary sector. As a consequence, uncultivated agricultural land became degraded. Land-use change has been encouraged by the growth of the market economy and increased tourist demands for certain products like cultured prawns, speeding up the ecological degradation of the khazan lands due to environmental impacts of industrial agriculture.

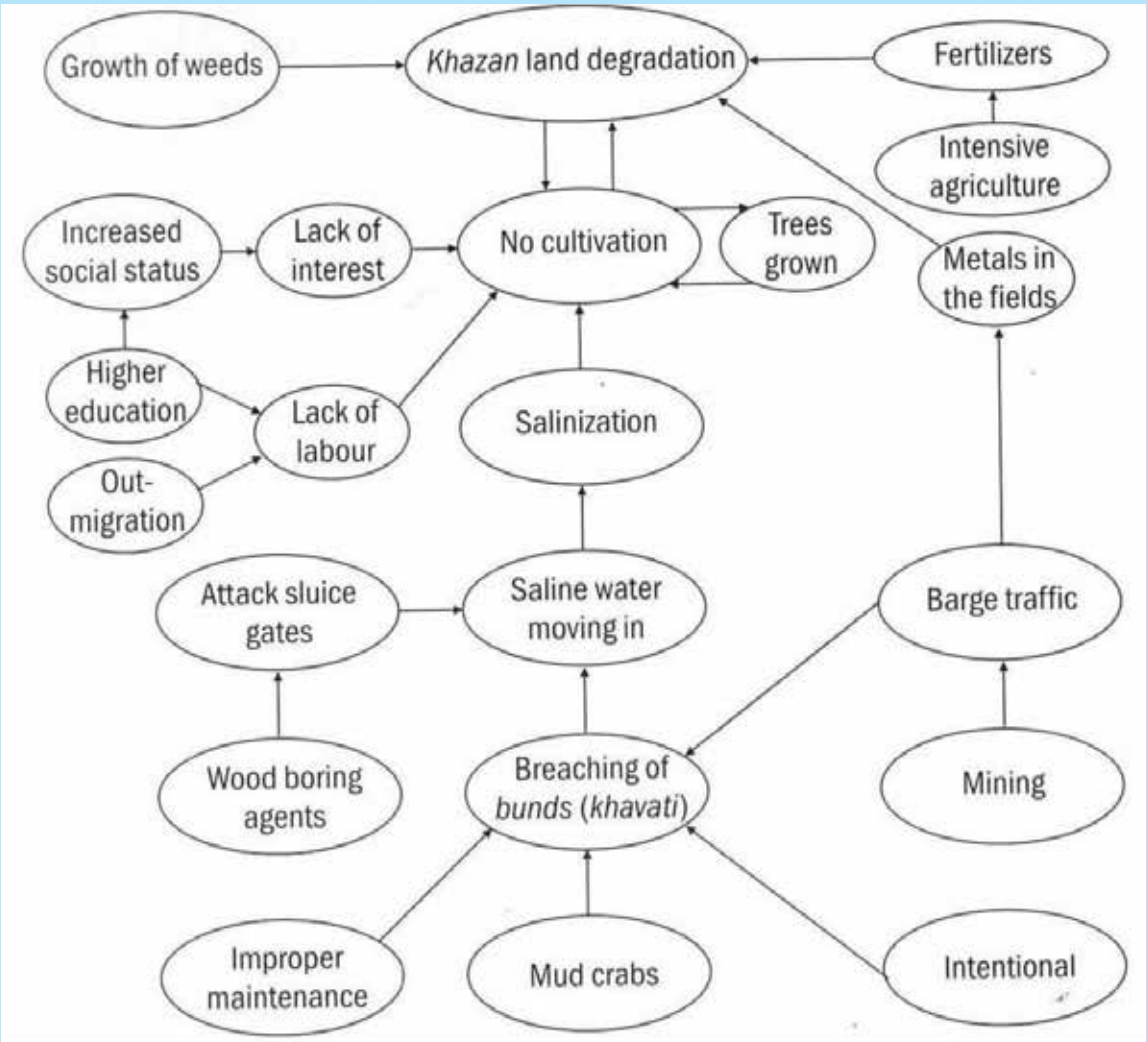
Institutional Factors

a. Changes in property rights: The control of the khazan lands during Portuguese colonial times in Goa lay with the 'gaunkaris' or 'communidade', who collectively owned the land. Following Goa's liberation, several agrarian reforms were introduced legislatively under the constitution of India. The Goa Agricultural Tenancy Act of 1964 initially provided security of tenure to agricultural tenants and allowed the formation of tenants' associations. The legislation was amended in 1976 so as to vest the agricultural land to the tiller of the land. Joint responsibility of Tenants' Rules 1975 was enacted and responsibility was conferred upon the tenants in the management of the khazan lands. This rendered the gaunkari system irrelevant to a large extent and the tenants became deemed purchasers of the land, which became individually owned but jointly managed. The notable changes in property rights that occurred paired with low market for agricultural produce brought negative incentives for cultivation.

b. Changes in financial returns to officials: In the gaunkari system, paid employees were assigned certain responsibilities. The members of the tenants' associations formed post liberation hold honorary positions and have to obtain alternate means of livelihood, and are unable to dedicate sufficient time to carry out the responsibilities towards the khazans. This result in the inability to allot adequate time for resource management, and reluctance to do so has been created due to lack of payment.

c. Changes in basic rules of traditional CPR institutions: The gaunkari system did not

Figure 10
Flow Diagram of Factors Responsible for *Khazan* Ecosystem Degradation



Source : Sonak 2005

allow non-residents of a village access to land or fish resources that were collectively owned by the village. With the change in the institutional set-up, non-residents were allowed fishing rights. This led to the loss of social cohesion, and unsustainable fishing practices that were introduced caused conflicts between local farmers and non-resident fishers. This resulted in the erosion of traditionally evolved common property resource management institutions. In present times, khazan lands that are officially leased to local farmers are further sublet to migrant fishers.

d. Reduced income: The income provided to the communidade for maintaining the khazan lands reduced due to lower sources of income and reduced strength of membership, and the funds received by the tenants' associations are now insufficient to maintain the khazans.

e. This had lead to dependency on state subsidies for repairs and maintenance. The process of obtaining subsidies through bureaucratic procedures causes delays and affects the repair of embankments, thereby enhancing the salinisation of the khazan lands.

Intervention by the state: The state government notified to offer 50% - 90% subsidies for maintaining the protective embankments and sluice gates. However,

estimates need to be sanctioned for the work to be carried out, and the funds received via state subsidies are insufficient for the proper repair of the dykes and sluice gates. Delays in government procedures intensifies the damage caused to the dykes, and this coupled with the high cost of labour in Goa, brings about salt water intrusion and salinisation of land and water.

f. Weak implementation of rules: The sluice gates are leased out to the highest bidder by the tenants' associations, and an agreement is signed between the two parties. Under the provisions of the agreement, the mamlatdar is empowered to take action on matters that have not specifically been provided for, including resolution of disputed pertaining to defaulting payments. As there is no fixed time frame imposed on the mamlatdar for action, the settlements get delayed for various reasons, thus delaying the payments due to the tenants' association, which is central to the maintenance of the embankments and sluice gates.

Gaps in Management of Mangroves And *Khazan*

Lacunae in Available Data

Forest/Mangrove ecosystem

- Baseline data is required
- Economic valuation of the ecosystems is needed
- Further research is required on biodiversity and the interactions between the main species/groups of organisms inhabiting Chorao and the Dr Salim Ali Bird Sanctuary
- Research is required into the potential of various organisms of Chorao as bioindicators of ecosystem health
- Research on the ecological impacts of unchecked harvesting of commercial species of organisms from Chorao is necessary
- The feasibility of the placement of large-mesh nets at entry points of creeks to restrict entry of plastic material into the backwaters has to be determined. Also, research should be conducted to determine negative impacts
- It has been proposed that guided tours be conducted into the creeks of the protected area. Some of the birds in the sanctuary have the global status of 'vulnerable' or 'near threatened', therefore, studies may need to be conducted to appraise the potential impacts of such activities.

Khazan ecosystem

- Investigations on the impacts of intensive fishing and the breaching of bunds of khazan lands on associated flora and fauna
- Research should be conducted into traditional ecological knowledge
- Research is required into sustainable management strategies for khazans
- Research into the salt-tolerant/halophilic ecology of the khazans of Chorao should be further conducted

Lacunae in Management Actions

Forest/Mangrove ecosystem

- Attention has been given to reforestation and regeneration of forests, but not to conservation of original forests
- Some focus of the awareness programmes should be given to stakeholders of Chorao
- Measures that will be taken to maintain minimum interference in the core zone of the sanctuary have not been elaborated on
- Rules and regulations for ecotourism and other activities should be strictly enforced

Khazan ecosystem

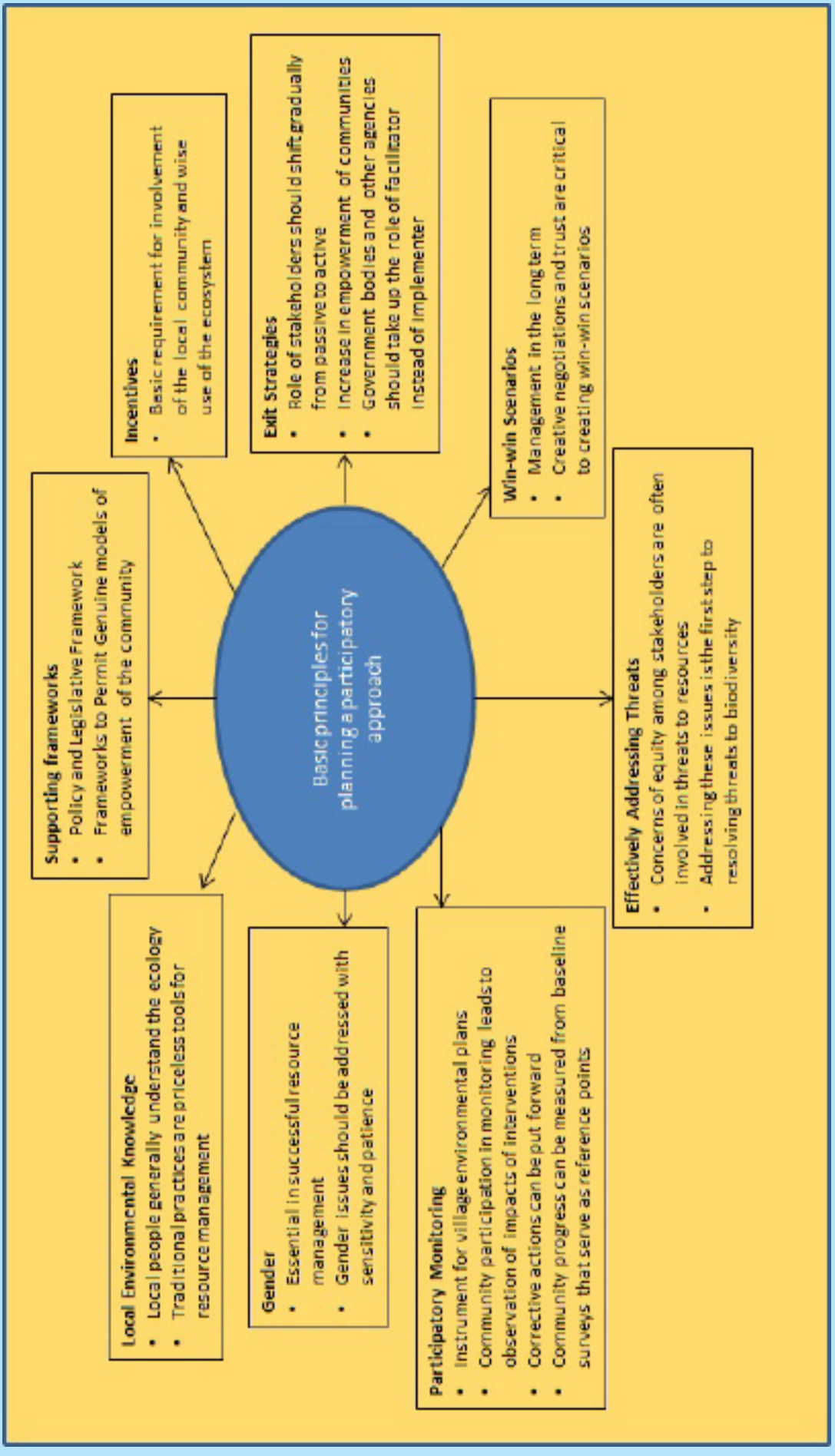
- Official posts in tenants' associations are honorary and employees are not paid. There is a lack of skilled labour in Goa, and the cost for hired labour is much higher than outside. This makes the tenants' associations dependent on state subsidies instead of attaining self-sufficiency
- Low business for sale of agricultural produce
- Incentives are required for individual owners to cultivate khazan lands
- It is necessary to involve indigenous institutions for successful resource management

Chapter 6

Participatory Management of Mangroves and *Khazans*

Community-based participatory approach differs from the conventional way most research institutions use for technology adaptation and verifications. A community does it because they have a greater interest in sustainable use of available resources available to them. With this approach, there is active participation of the community, which sensitises them to the value of information-based decision making. The participatory nature often intends to implement a holistic approach to the overall management of the system. Local community members who are dependent on these resources usually become active to protect and conserve their environment if they obtain direct benefits from their efforts. Additionally effective management can be accomplished through planning, implementation and monitoring of the sustainable use of coastal resources via cooperative action and judicious decision making. Protection and management of resources that are considered to be common property in a community is extremely difficult to achieve if the stakeholder community does not lend its support and cooperation. Trimble and Berkes (2013) have reported that centralised government action in resource management is not adequate to deal with the range of issues that come up. Decentralised management has become more common as a solution, with increased rights and responsibilities handed to resource users via delegation of management authority. The involvement of local and indigenous people can make significant contributions towards maintenance or restoration of the ecological integrity of an ecosystem, as well as to the well-being of the community, along with fair access to resources (Ramsar Convention Secretariat, 2010). Co-management of resources, as indicated by NOAA, involves both a top-down and bottom-up approach where local governments and community members share responsibility of local resources and actively participate in their management. Wiber et al (2004) also reported that co-management approaches provide benefits such as better flow of information from locals to managers, greater compliance with rules, and lower costs of transactions. The

Figure 11
Basic Principles or Planning Community-Based Participatory Resource Management



participation of all stakeholders in the framework of management is the basis of this collaborative process. Gawler (2002) has provided basic principles that could be applied for community based resource management plans as illustrated in the Figure 11 above.

Approach for Participatory Management

The involvement of the people of Chorao in participatory management will gain by its proper management, especially those who depend directly on the ecosystems for their livelihood. The strategies involved in participatory management can be broadly defined as:

I. The planning process
II. Establishment of Institutions
III. The community participation process

These have been elucidated below and their interdependency has been illustrated in Figure 12 (adapted from the EU Water Framework Directive, 2000; European Parliament and Council Recommendation concerning the implementation of Integrated Coastal Zone Management in Europe, 2002; Bruckmeier and Larsen, 2008; Nasuchon and Charles, 2010; Ramsar Convention Secretariat, 2010; Röckmann et al, 2012; and UNEP, 2014).

The planning process commences in three stages: the diagnosis of the ecosystem i.e., mangrove and khazan ecosystems, mapping of the stakeholders and policy framework, and the development of a database.

Diagnosis of Ecosystem

This involves the analysis of the physical, ecological, economical, social, and administrative subsystems of the ecosystem in order to obtain a holistic view of the areas. These analyses will provide the preliminary diagnosis and SWOT analysis of the ecosystem.

Physical subsystems - would include characteristics such as climate and topography with geomorphological units.

The ecological subsystem - accounts for the species of flora and fauna found within the ecosystem and indicates the role of the ecosystem in the biodiversity. Determining the components and issues that are crucial to the health/vulnerability of the ecosystem is essential, and the biological and non-biological components which are unique to each ecosystem must be identified. Damage occurring to these particular components will be expressed in the health of the ecosystem, making it vulnerable.

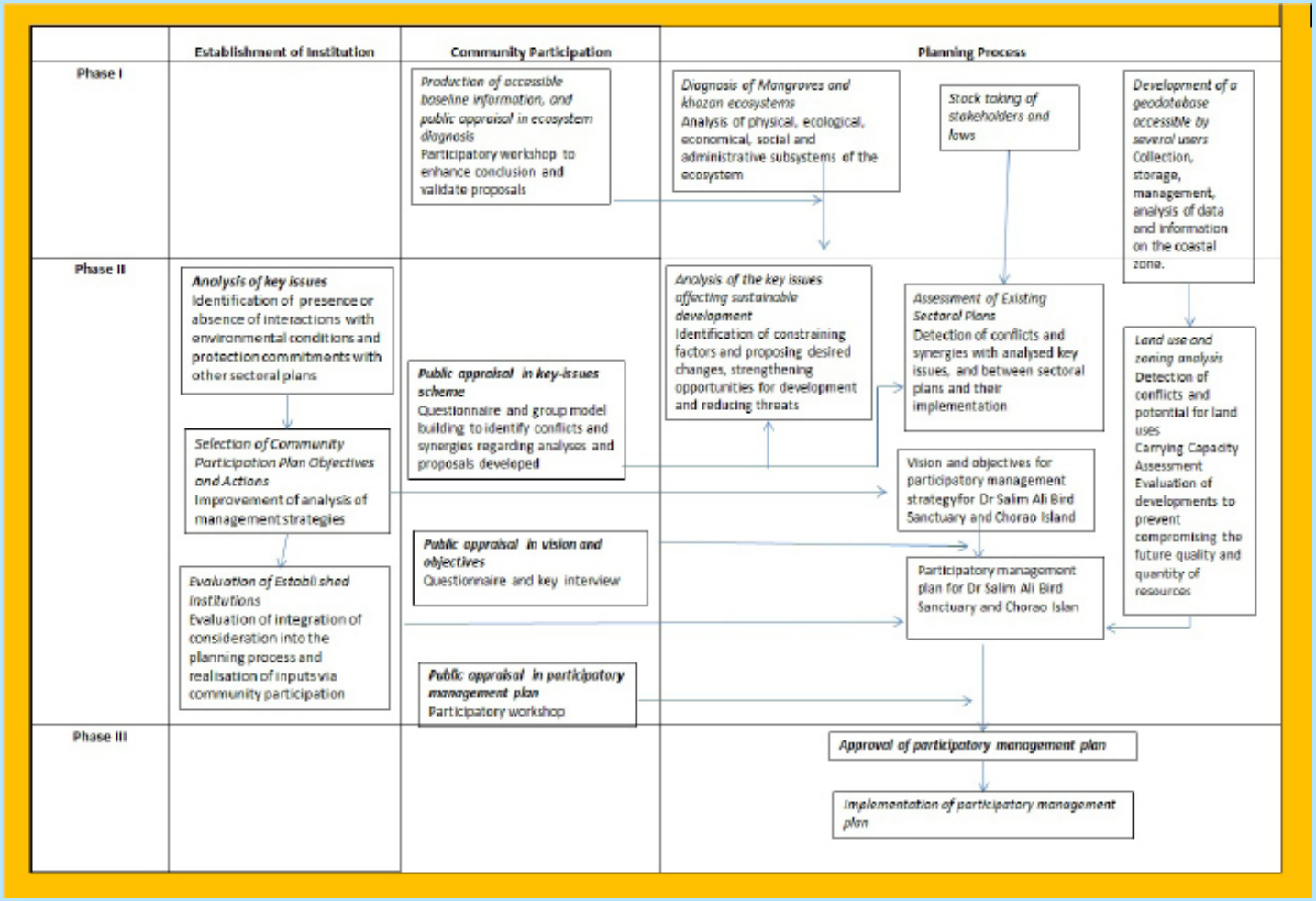
The social subsystem - indicates the human population density and social groups and demographics with special reference to education and employment, as well as population size, structure, class, occupation, attitude of people. Ecosystems have great impacts on the livelihoods of people, food security, and income generation. In traditional societies, such as those of Goa - and in the present situation, Chorao - it is highly important to take up gender issues with sensitivity and patience.

The economic subsystem - lists the activities that generate income. These may include traditional activities such as agriculture, livestock production, fishing, or other activities like tourism. Economic valuation of the Chorao ecosystems would make the worth of the ecosystems apparent to the stakeholders, and highlight the need for conservation.

Mapping of The Stakeholders and Policy Frameworks

This involves the preparation of a comprehensive list of the stakeholders and the legislation pertaining to the ecosystem. Stakeholders are the best judges of their own interest and therefore should be able to participate in decision-making. Their participation ensures that their local knowledge is integrated in the planning and management process. Based on the stake holder mapping for the management of the Chorao, various stakeholders of Chorao, such as the Farmers' Club, Biodiversity Management Committee, Panchayat, Water Department, River

Figure 12
Participatory Process Flow Diagram for Estuarine Ecosystem of Chorao Island



Navigation Department, Agriculture Committee, among others, should be made aware of the extent to which they depend on the resources of Chorao and the requirement to conserve it. Their active collaboration is essential. The daily lives of the people and rituals, both cultural and religious, make access to the resources a must. Both these factors make the involvement of the local community in participatory management a wise decision.

The management of protected areas that come under environmental agreements should be assessed, and effectiveness and weakness in the management plan should be addressed. Apart from national- and state-level legislation that has been passed, rules and regulations and other supporting frameworks that are especially pertinent to Chorao have to be put in place. Legal framework is needed to clarify the objectives, instruments and tools, planning procedures, implementation and monitoring action, conflict resolution and public participation process.

Development of a Database

This includes the development of a unique geodatabase that is user friendly and accessible. This takes into account the collection, storage, management and analysis of data and information on the mangrove and khazan ecosystems. Upon diagnosis of the mangrove and khazan ecosystems, baseline information should be produced that is accessible and the public should be involved in appraisal of the diagnosis of the ecosystem.

Establishment of Institutions and Community Participation

Based on the stakeholder mapping a Chorao Co-management Institution (CCI) should be established which will include members from the government, local institutions and local community, particularly influential persons of Chorao. The committee would initially identify and analyse the list of key issues based on the available data acquired in the planning process. These issues would come under the wider headings of urban development, opportunities for economic development, natural risks, environmental management, socio-cultural issues, and governance. The analysis involves identifying constraining factors and proposing any changes that are desired, which will also look into strengthening the opportunities for development and for the reduction of threats. This list of the issues develops the platform for community participation in the management process.

CCI will engage the local community of Chorao for the public appraisal during different stage of management plan. During this process, the role of the facilitators/coordinators should be understood by all stakeholders of Chorao. All sectors of the population should participate, especially the women and youth of the community. The community participation process for the management plan is briefed below. Following several appraisals the approved participatory management plan should be implemented.

I. Key issues identified following ecosystem diagnosis
II. Priority issues after the public appraisal
III. Vision and objectives
IV. Participatory management plan

} **Public appraisal through workshops, surveys and questionnaires**

Further activities that the CCI will play a role in are:

- Approaching Funding agencies and Incentives
- Training, Capacity building and Awareness Campaigns
- Sustainable Development of Chorao
- Monitoring
- Efficiency and timeline
- Engagement of local community

Other institutions/groups that needs to be established in order to strengthen the participatory management plan include:-

- Research advisory group
- Working groups
- Issue-driven groups
- Implementation of stewardship for management of resources

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Annexure 1
Macrofauna Species

Sr. No.	Species
Family – Polychaeta	
1	*Aphroditidae* sp.
2	*Phyllodoce* sp.
3	*Ancistrosyllis* sp.
4	*Cabira* sp.
5	*Nephtys* sp.
6	*Hesione* sp.
7	*Nereis* sp.
8	*Dendronereis* sp.
9	*Lycastis* sp.
10	*Lysilla* sp.
11	*Glycera alba*
12	*G. alba, Rathke*
13	*G. longipinnis, Rathke*
14	*Goniada* sp.
15	*Glycinde* sp.
16	*Glycinde oligodon*
17	*Mediomastus* sp.
18	*Heteromastus* sp.
19	*Parheteromastus* sp.
20	*Neomediomastus* sp.
21	*Capitellethus* sp.
22	*Axiothella* sp.
23	*Clymene* sp.
24	*Polydora* sp.
25	*Pseudopolydora* sp.
26	*Prionospio* sp.
27	*P. cirrifa, Wiren*
28	*Minuspio cirrifera*
29	*Paraprionospio pinnata*
30	*P. pinnata Ehlers*
31	*Staurocephalus* sp.
32	*Scolelepis squamata*
33	*Lumbrineris* sp.
34	*Diopatra* sp.
35	*D. neapolitana, Delle chiaje*
36	*Scoloplos* sp.
37	*Aricidae* sp.
38	*Levinsenia* sp.
39	*Cossura* sp.
40	*Cirratulidae*
41	*Chaetozone* sp.

Source : Reported by Gaonkar et al, 2013 (Mandovi estuary)

Annexure 1(*Contd...*)
Macrofauna

Sr. No.	Species
Family – Polychaeta	
42	*Poecilochaetus sp.*
43	*Opheliidae sp.*
44	*Terebellidae sp.*
45	*Terebella ehrenberg, Grube*
46	*Sternaspis scutata*
Family – Oligochaeta	
1	*Tubificidae sp.*
2	*Solenidae sp.*
Family – Mollusca	
1	*Modilous sp.*
2	*Meretrix casta*
3	*Veneridae sp.*
4	*Timoclea scabra*
5	*Dosinia sp.*
6	*Mactra sp.*
7	*Tellina sp.*
8	*Solenidae sp.*

Annexure 2
Macrofauna

Sr. No.	Species
Family – Polychaeta	
	G. alba, Rathke
Family – Mollusca	
1	*Dentalium octangulatum, Donovan*
2	*Crepidula walshi, Herrman*
3	*Natica tigrina* (Roding)
4	*Cerithideafluviatilis* (Poteez and Michoud)
5	*Turritella attenuate, Reeve*
6	*Thais ruguosa* (Lamarck)
7	*Telescopium telescopium* (Linne)
8	*Terebralia palustris* (Linne)
9	*Neretina depressa, Benson*
10	*Onchidium verruculatum, Cuvier*
11	*Paphia malabarica* (Chemnitz)
12	*P. textile,* (Gmelin)
13	*Sunetta solandri, Gray*
14	*Donax incarnates Linne*
15	*D. apperitus, Linne*
16	*Nucula semiramisensis, Reeve*
17	*Martesia striata* (Linne)
18	*Siliqua albida* (Monothyra)
19	*Pholas orientalis, Gmelin*
20	*Anomia acheus* (Linne)
21	*Mytilus viridis, Linne*
22	*Anadara granosa, Lam.*
23	*Fossularca symmetrica, Brug.*
24	*Placenta placenta* (Linne)
25	*Crassostrea bicolor, Hanley*
26	*C. madrasensis, Preston*
27	*C. cucullata, Born*
28	*Modilous sp.*
29	*Modiolus metcalfei* (Hanley)
30	*Meretrix casta*
31	*Gafrarium sp.*
32	*Dossinia modesta*, (Sowerby)
33	*D. trigona* (Reeve)
34	*Solen truncates* (Sowerby)

Source : Reported by Parulekar et al, 1980 (Mandovi estuary off Chorao)

Annexure 2 (*Cntd...*)
Macrofauna

Sr. No.	Species
Family – Polychaeta	
1	*Sthenalais boa* (Johnston)
2	*Marphysa sanguinea, Montague*
3	*M. mossambica, Peters*
4	*Sabellaria cementarium, Moore*
Family – Echiuroidea	
	Thalassema sp.
Family – Brachiopoda	
	Lingula sp.
Family –	**Neretina depressa, Benson**
1	*Balanus Amphitrite, Darwin*
2	*Sphaeroma annandalei, Stebbings*
3	*Limnoria sp.*
4	*Corophium sp.*
5	*Eurydice sp.*
6	*Alpheus malabaricus, Fabricius*
7	*Alpheus Sp.*
8	*Metapenaeus monoceros, Fabricius*
9	*Caridina sp*
10	*Dorippe astute* (Fabricius)
11	*Matuta victor* (Fabricius)
12	*M. lunaris* (Forskal)
13	*Calappa hepatica,* (Linnaeus)
14	*Charybdis cruciate,* (Hebst)
15	*Scylla serrate* (Forskal)
16	*Portunus pelagicus* (Linnaeus)
17	*P. sanguinolentus* (Hebst)
18	*Marcophthalmus sulcatus,* (Milne-Edwards)
19	*Sesarme oceanica, de Man*
20	*Diogenes custus,* (Fabricius)
21	*Clibararius padavensis, de Man*
22	*Pinnotheres sp.*
23	*Petrolisthes boscii,* (Audouln)
Family – Echinodermata	
1	*Astropecten indica, Smith*
2	*Temnopleura toreumaticus,* (Klein)
3	*Ophiactis savignyi, Muller & Troschel*
4	*Synapta sp.*

Annexure 3
List of Resident Bird Species that are Found in Chorao Island

Sr.No.	Species	Common name
1	*Phalacrocorax niger*	Little cormorant
2	*Anhinga melanogaster*	Darter
3	*Egretta garzetta*	Little egret
4	*Egretta gularis*	Western reef egret
5	*Ardea cinerea*	Grey heron
6	*Ardea purpurea*	Purple heron
7	*Casmerodius albus*	Large egret
8	*Bubulcus ibis*	Cattle egret
9	*Ardeola greyii*	Indian pond heron
10	*Butorides striatus*	Little green heron
11	*Nycticorax nycticorax*	Black-crowned night heron
12	*Pernis ptilorhyncus*	Oriental honey buzzard
13	*Milvus migrans*	Black kite
14	*Heliastur indicus*	Brahminy kite
15	*Haliaeetus leucogaster*	White-bellied sea eagle
16	*Ictinatus malayensis*	Black eagle
17	*Parvo cristatus*	Indian peafowl
18	*Amaurornis phoenicurus*	White-breasted water hen
19	*Vanellus indicus*	Red-wattled lapwing
20	*Columba livia*	Blue rock pigeon
21	*Streptopelia chinensis*	Spotted dove
22	*Treron pompadora*	Pompadour green pigeon
23	*Psittacula krameri*	Rose-ringed parakeet
24	*Eudynamys scolopacea*	Asian koel
25	*Centropus sinensis*	Greater coucal
26	*Tyto alba*	Barn owl
27	*Alcedo atthis*	Small blue kingfisher
28	*Halcyon capensis*	Stork-billed kingfisher
29	*Halcyon smyrnensis*	White-breasted kingfisher
30	*Halcyon pileata*	Black-capped kingfisher
31	*Ceryle rudis*	Lesser pied kingfisher
32	*leschenaulti*	Chestnut-headed bee-eater
33	*Megalaima viridis*	White-cheeked barbet
34	*Megalaima haemacephala*	Coppersmith barbet
35	*Alauda gulgula*	Eastern skylark
36	*Hirundo smithii*	Wire-tailed swallow
37	*Anthus rufulus*	Paddyfield pipit
38	*Aegithina tiphia*	Common lora
39	*Copsychus saularis*	Oriental magpie-robin

Source: GBCN & Forest department, Goa, 2014

Annexure 3 (*Contd...*)
List of Resident Bird Species that are Found in Chorao Island

Sr.No.	Species	Common name
40	*Prinia socialis*	Ashy prinia
41	*Orthotomus sutorius*	Common tailorbird
42	*Parus xanthogenys*	Black-lored yellow tit
43	*Dicaeum concolor*	Plain flowerpecker
44	*Nectarinia zeylonica*	Purple-rumped sunbird
45	*Nectarinia asiatica*	Purple sunbird
46	*Passer domesticus*	House sparrow
47	*Acridotheres fuscus*	Jungle myna
48	*Dicrurus macrocercus*	Black drongo
49	*Corvus spendens*	House crow

Annexure 4
List of Migratory Bird Species that are Found in Chorao Island

Sr.No.	Species	Common name
1	*Phalacrocorax carbo*	Great cormorant
2	*Egretta gularis*	Western reef egret
3	*Ardea cinerea*	Grey heron
4	*Mesophoyx intermedia*	Median egret
5	*Nycticorax nycticorax*	Black-crowned night heron
6	*Anastomus oscitans*	Asian openbill stork
7	*Ciconia episcopus*	White-necked stork
8	*Leptoptilos javanicus*	Lesser adjutant stork
9	*Plegadis falcinellus*	Glossy ibis
10	*Threskiornis melanocephalus*	Oriental white ibis
11	*Dendrocygna javanica*	Lesser whistling duck
12	*Tadorna ferruginea*	Brahminy shelduck
13	*Anas poecilorhyncha*	Spot-billed duck
14	*Anas acuta*	Northern pintail
15	*Anas querquedula*	Garganey
16	*Anas crecca*	Common teal
17	*Elanus caeruleus*	Black-shouldered kite
18	*Circus aeruginosus*	Eurasian marsh harrier
19	*Aquila clanga*	Greater spotted eagle
20	*Hieraaetus pennatus*	Booted eagle
21	*Pandion haliaetus*	Osprey
22	*Pluvialis fulva*	Pacific golden plover
23	*Pluvialis squatarola*	Grey plover
24	*Charadrius dubius*	Little ringed plover
25	*Charadrius alexandrinus*	Kentish plover
26	*Vanellus indicus*	Red-wattled lapwing
27	*Gallinago gallinago*	Common snipe
28	*Lymnocryptes minimus*	Jack snipe
29	*Numenius phaeopus*	Whimbrel
30	*Numenius arquata*	Eurasian curlew
31	*Tringa erythropus*	Spotted redhsnak
32	*Tringa tetanus*	Common redshank
33	*Tringa stagnatilis*	Marsh sandpiper
34	*Tringa nebularia*	Common greenshank
35	*Tringa ochropus*	Green sandpiper
36	*Tringa glareola*	Wood sandpiper
37	*Xenus cinereus*	Terek sandpiper
38	*Actitis hypoleucos*	Common sandpiper
39	*Calidris alba*	Sanderling

Source: GBCN & Forest department, Goa, 2014

Annexure 4 (*Contd...*)
List of Migratory Bird Species that are Found in Chorao Island

Sr.No.	Species	Common name
40	*Calidris minuta*	Little stint
41	*Calidris temminckii*	Temminck's stint
42	*Himantopus himantopus*	Black-winged stilt
43	*Larus ichthyaetus*	Pallas's gull
44	*Larus brunnicephalus*	Brown-headed gull
45	*Larus ridibundus*	Black-headed gull
46	*Gelochelidon nilotica*	Gull-billed tern
47	*Sterna aurantia*	River tern
48	*Chlidonias hybridus*	Whiskered tern
49	*Merops philippinus*	Blue-tailed bee-eater
50	*Coracias benghalensis*	Indian roller
51	*Hirundo rustica*	Common swallow
52	*Motacilla alba*	White wagtail
53	*Motacilla flava*	Yellow wagtail
54	*Lanius isabellinus*	Rufous-tailed shrike
55	*Saxicola torquata*	Common stonechat
56	*Acrocephalus agricola*	Paddyfield warbler
57	*Acrocephalus dumetorum*	Blyth's reed –warbler
58	*Acrocephalus stentoreus*	Indian great reed-warbler
59	*Sturnus pagodarum*	Brahminy starling
60	*Oriolus oriolus*	Eurasian golden oriole

Annexure 5
List of Vertebrate Species of Chorao Island and their Global Status

Sr. No.	Species	English name	Global status (IUCN Red List)	Global population trend (IUCN Red List)
Fish				
1	*Mugil cephalus*	Flathead mullet	Least Concern	Stable
2	*Chanos chanos*	Milkfish	Not assessed for entry on IUCN Red List	
3	*Lates calcarifer*	Sea bass	Not assessed for entry on IUCN Red List website	
4	*Periophthalmus*	Mudskipper	Least Concern (P. barbarous Atlantic mudskipper)	Unknown
5	*Mugil persica*		Not assessed for entry on IUCN Red List	
6	*Etroplus suratensis*	Green chromide	Least Concern	Decreasing
Reptiles				
1	*Crocodylus palustris*	Marsh crocodile	Vulnerable	Stable
2	*Varanus salvator*	Common Water Monitor	Least Concern	Unknown
3	*Calotes versicolor*	Garden lizard	Not assessed for entry on IUCN Red List	
4	*Varanus benghalensis*	Water monitor lizard	Not assessed for entry on IUCN Red List	
5	*Enhydrina schistose*	Bearded sea snake	Not assessed for entry on IUCN Red List	
6	*Acrochordus granulates*	Wart snake	Least Concern	Stable
7	*Cerberus rynchops*	Dog-faced water snake	Least Concern	Unknown
8	*Dendrelaphis tristis*	bronze backed tree snake	Not assessed for entry on IUCN Red List	
9	*Hierophis viridiflavus*	green whip snake/ Western Whip Snake	Least Concern	Stable
10	*Xenochrophis piscator*	Checkered keelback	Not assessed for entry on IUCN Red List	
11	*Ptyas mucosa*	Rat snake	Not assessed for entry on IUCN Red List	
12	*Daboia russelii*	Russel's viper	Eastern Russell's Viper Concern	Decreasing
Mammals				
1	*Mus booduga*	Little Indian field mouse	Least Concern	Stable
2	*Bandicoota indica*	Bandicoot	Not assessed for entry on IUCN Red List	
3	*Lutragale perspicillata*	Smooth Indian otter	Not assessed for entry on IUCN Red List website	
4	*Pteropus giganteus*	Indian Flying fox	Least Concern	Decreasing
5	*Canis aureus*	Golden Jackal	Least Concern	Increasing

Annexure 5 (*Contd...*)
List of Vertebrates Species of Chorao Island and their Global Status

Sr. No.	Species	English name	Global status (IUCN Red List)	Global population trend (IUCN Red List)
Birds				
1	*Phalacrocorax niger (R)*	Little cormorant	*Microcarbo niger* (Little Cormorant) Least Concern ver 3.1	Unknown
2	*Anhinga melanogaster* (R)	Oriental Darter	Near Threatened	Decreasing
3	*Egretta garzetta* (R)	Little egret	Least Concern	Increasing
4	*Ardea purpurea* (R)	Purple heron	Least Concern	Decreasing
5	*Casmerodius albus* (R)	Large egret	Ardea alba (Great White Egret)	Unknown
6	*Bubulcus ibis* (R)	Cattle egret	Least Concern	Increasing
7	*Ardeola greyii* (R)	Indian pond heron	Not assessed for entry on IUCN Red List	
8	*Butorides striatus* (R)	Little green heron	Not assessed for entry on IUCN Red List	
9	*Pernis ptilorhyncus* (R)	Oriental honey buz-zard	Least Concern	Stable
10	*Milvus migrans* (R)	Black kite	Least Concern	Unknown
11	*Heliastur indicus* (R)	Brahminy kite	Not assessed for entry on IUCN Red List	
12	*Haliaeetus leucogaster* (R)	White-bellied sea-eagle	Least Concern	Decreasing
13	*Ictinatus malayensis* (R)	Black eagle	Not assessed for entry on IUCN Red List	
14	*Parvo cristatus* (R)	Indian peafowl	Not assessed for entry on IUCN Red List	
15	*Amaurornis phoenicu-rus* (R)	White-breasted waterhen	Least Concern	Unknown
16	*Vanellus indicus* (R)	Red-wattled lapwing	Least Concern	Unknown
17	*Columba livia* (R)	Blue rock pi-geon/Rock dove	Least Concern	Decreasing
18	*Streptopelia chinensis* (R)	Spotted dove	Not assessed for entry on IUCN Red List	
19	*Treron pompadora* (R)	Pompadour green pigeon/Sri Lanka Green-pigeon	Least Concern	Decreasing
20	*Psittacula krameri* (R)	Rose-ringed para-keet	Least Concern	Increasing
21	*Eudynamys scolopacea* (R)	Asian koel/ Western Koel	Least Concern	Stable
22	*Centropus sinensis* (R)	Greater coucal	Least Concern	Stable
23	*Tyto alba (R)*	Common Barn-owl	Least Concern	Stable
24	*Alcedo atthis* (R)	Small blue king-fisher/ Com-mon Kingfisher	Least Concern	Unknown
25	*Halcyon capensis* (R)	Stork-billed king-fisher	Not assessed for entry on IUCN Red List	
26	*Halcyon smyrnensis* (R)	White-breasted kingfisher	Least Concern	Increasing
27	*Halcyon pileata* (R)	Black-capped king-fisher	Least Concern	Decreasing
28	*Ceryle rudis* (R)	Lesser pied king-fisher/ Pied Kingfisher	Least Concern	Unknown
29	*Merops leschenaultia* (R)	Chestnut-headed bee-eater	Not assessed for entry on IUCN Red List	

Annexure 5
List of Vertebrates Species of Chorao Island and their Global Status (*Contd...*)

Sr. No.	Species	English name	Global status (IUCN Red List)	Global population trend (IUCN Red List)
Birds				
32	*Alauda gulgula* (R)	Eastern skylark/ Oriental	Least Concern	Decreasing
33	*Hirundo smithii* (R)	Wire-tailed swallow	Least Concern	Increasing
34	Anthus rufulus (R)	Paddyfield pipit	Least Concern	Stable
35	Aegithina tiphia (R)	Common lora	Least Concern	Unknown
36	*Copsychus saularis* (R)	Oriental magpie-robin	Least Concern	Stable
37	*Prinia socialis* (R)	Ashy prinia	Least Concern	Stable
38	*Orthotomus sutorius* (R)	Common tailorbird	Least Concern	Stable
39	*Parus xanthogenys* (R)	Black-lored yellow tit/Black-lored Tit	Least Concern	Stable
40	*Dicaeum concolor* (R)	Plain flowerpecker	Least Concern	Stable
41	*Nectarinia zeylonica* (R)	Purple-rumped sunbird	Least Concern	Stable
42	*Nectarinia asiatica* (R)	Purple sunbird	Least Concern	Stable
43	*Passer domesticus* (R)	House sparrow	Least Concern	Decreasing
44	*Acridotheres fuscus* (R)	Jungle myna	Least Concern	Decreasing
45	*Dicrurus macrocercus* (R)	Black drongo	Least Concern	Unknown
46	*Corvus spendens*	House crow	Not assessed for entry on IUCN Red List	
47	*Egretta gularis*	Western reef egret	Least Concern	Stable
48	*Ardea cinerea*	Grey heron	Least Concern	Unknown
49	*Nycticorax nycticorax*	*Black-crowned night heron*	*Least Concern*	*Decreasing*
50	*Phalacrocorax carbo* (M)	*Great cormorant*	*Least Concern*	*Increasing*
51	*Mesophoyx intermedia* (M)	*Median egret*	*Not assessed for entry on IUCN Red List*	
52	*Anastomus oscitans* (M)	*Asian openbill stork/ Asian Openbill*	*Least Concern*	*Unknown*
53	*Ciconia episcopus* (M)	*White-necked stork/ Asian Woollyneck*	*Vulnerable*	*Decreasing*
54	*Leptoptilos javanicus* (M)	*Lesser adjutant stork/ Lesser Adjutant*	*Vulnerable*	*Decreasing*
55	*Plegadis falcinellus* (M)	*Glossy ibis*	*Least Concern*	*Decreasing*
56	*Threskiornis melanocephalus* (M)	*Oriental white ibis/ Black-headed Ibis*	*Least Concern*	*Decreasing*
57	*Dendrocygna javanica* (M)	*Lesser whistling duck*	*Least Concern*	*Decreasing*
58	*Tadorna ferruginea* (M)	*Brahminy shelduck/ Ruddy Shelduck*	*Least Concern*	*Unknown*
59	*Anas poecilorhyncha* (M)	*Indian Spot-billed duck*	*Least Concern*	*Decreasing*
60	*Anas acuta* (M)	*Northern pintail*	*Least Concern*	*Decreasing*
61	*Anas querquedula* (M)	*Garganey*	*Spatula querquedula (Garganey) Least Concern ver 3.1*	*Decreasing*
62	*Anas crecca* (M)	*Common teal*	*Least Concern*	*Unknown*
63	*Elanus caeruleus* (M)	*Black-shouldered kite/ Black-winged Kite*	*Least Concern*	*Stable*
64	*Circus aeruginosus* (M)	*Eurasian marsh harrier/ Western Marsh-harrier*	*Least Concern*	*Increasing*

Annexure 5
List of Vertebrates Species of Chorao Island and their Global Status (*Contd...*)

Sr. No.	Species	English name	Global status (IUCN Red List)	Global population trend (IUCN Red List)
Birds				
65	*Aquila clanga* (M)	*Greater spotted eagle*	*Clanga clanga (Greater Spotted Eagle) Vulnerable C2a(ii) ver 3.1*	*Decreasing*
66	*Hieraaetus pennatus* (M)	*Booted eagle*	*Least Concern*	*Decreasing*
67	*Pandion haliaetus* (M)	*Osprey*	*Least Concern*	*Increasing*
68	*Pluvialis fulva* (M)	*Pacific golden plover*	*Least Concern*	*Decreasing*
69	*Pluvialis squatarola* (M)	*Grey plover*	*Least Concern*	*Decreasing*
60	*Charadrius dubius* (M)	*Little ringed plover*	*Least Concern*	*Stable*
71	*Charadrius alexandrines* (M)	*Kentish plover*	*Not assessed for entry on IUCN Red List*	
72	*Gallinago gallinago* (M)	*Common snipe*	*Least Concern*	*Decreasing*
73	*Lymnocryptes minimus* (M)	*Jack snipe*	*Least Concern*	*Stable*
74	*Numenius phaeopus* (M)	*Whimbrel*	*Least Concern*	*Decreasing*
75	*Numenius arquata* (M)	*Eurasian curlew*	*Least Concern*	*Decreasing*
76	*Tringa erythropus* (M)	*Spotted redshank*	*Least Concern*	*Stable*
77	*Tringa tetanus* (M)	*Common redshank*	*Not assessed for entry on IUCN Red List*	
78	*Tringa stagnatilis* (M)	*Marsh sandpiper*	*Least Concern*	*Decreasing*
79	*Tringa nebularia* (M)	*Common greenshank*	*Least Concern*	*Stable*
80	*Tringa ochropus* (M)	*Green sandpiper*	*Least Concern*	*Stable*
81	*Tringa glareola* (M)	*Wood sandpiper*	*Least Concern*	*Stable*
82	*Xenus cinereus* (M)	*Terek sandpiper*	*Least Concern*	*Stable*
83	*Actitis hypoleucos* (M)	*Common sandpiper*	*Least Concern*	*Decreasing*
84	*Calidris alba* (M)	*Sanderling*	*Least Concern*	*Unknown*
85	*Calidris minuta* (M)	*Little stint*	*Least Concern*	*Decreasing*
86	*Calidris temminckii* (M)	*Temminck's stint*	*Least Concern*	*Unknown*
87	*Himantopus himantopus* (M)	*Black-winged stilt*	*Least Concern*	*Increasing*
88	*Larus ichthyaetus* (M)	*Pallas's gull*	*Least Concern*	*Decreasing*
89	*Larus brunnicephalus* (M)	*Brown-headed gull*	*Least Concern*	*Stable*
90	*Larus ridibundus* (M)	*Black-headed gull*	*Least Concern*	*Decreasing*
91	*Gelochelidon nilotica* (M)	*Common Gull-billed tern*	*Least Concern*	*Decreasing*
92	*Sterna aurantia* (M)	*River tern*	*Near Threatened*	*Decreasing*
93	*Chlidonias hybrida* (M)	*Whiskered tern*	*Least Concern*	*Stable*
94	*Merops philippinus* (M)	*Blue-tailed bee-eater*	*Least Concern*	*Stable*
95	*Coracias benghalensis* (M)	*Indian roller*	*Least Concern*	*Increasing*
96	*Hirundo rustica* (M)	*Common swallow/ Barn Swallow*	*Least Concern*	*Decreasing*

Annexure 5
List of Vertebrates Species of Chorao Island and their Global Status (*Contd...*)

Sr. No.	Species	English name	Global status (IUCN Red List)	Global population trend (IUCN Red List)
Birds				
97	*Motacilla alba* (M)	*White wagtail*	*Least Concern*	*Stable*
98	*Motacilla flava* (M)	*Yellow wagtail*	*Least Concern*	*Decreasing*
99	*Lanius isabellinus* (M)	*Rufous-tailed shrike*	*Least Concern*	*Stable*
100	*Saxicola torquata* (M)	*Common stonechat*	*Saxicola torquatus (Common Stonechat) Least Concern ver 3.1*	*Stable*
101	*Acrocephalus agricola* (M)	Paddyfield warbler	Least Concern	Decreasing
102	*Acrocephalus dumetorum* (M)	Blyth's reed –warbler	Least Concern	Increasing
103	*Acrocephalus stentoreus* (M)	Indian great reed- warbler/ Clamorous Reed-warbler	Least Concern	Stable
104	*Sturnus pagodarum* (M)	Brahminy starling	Least Concern	Unknown
105	*Oriolus oriolus* (M)	Eurasian golden oriole White-browed fantail	Least Concern	Stable
106	*Rhipidura aureola (Residence status unclear)*	flycatcher/ White-browed fantail	Least Concern	Stable
106	*Rhipidura aureola (Residence status unclear)*	flycatcher/ White-browed fantail	Least Concern	Stable

About the Study

The Ecological Status and Management of Dr. Salim Ali Bird Sanctuary and Estuarine Areas of Chorao Island: A Desk Review highlights the existing information on the ecological status of the sanctuary and estuarine areas of Chorao Island, Goa (India). It identifies the gaps in available data for a comprehensive ecological baseline assessment of the sanctuary. The report also highlights the existing management and conservation plans and identifies opportunities for the conservation of estuarine areas of Chorao Island. A mode of participatory management has been suggested for the island estuarine ecosystem that includes three different processes,viz. planning, establishment of institutions, and community participation. This review will be useful for policy makers, researchers, scientists, various governmental and nongovernmental organizations, and anyone interested in the conservation of the marine and coastal biodiversity of Chorao Island.

The CMPA Project

The project "Conservation and Sustainable Management of Coastal and Marine Protected Areas" (CMPA) is a project of the Indo-German technical cooperation. It is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and implemented by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of BMUB.

Established to support the achievement of the Aichi targets of the Convention on Biological Diversity, the project's overall goal is to contribute to conservation and sustainable use of biodiversity in selected areas along the coast of India. Taking into consideration the economic importance of the coastal zone for large segments of the population, the project's approach is people-centered, thus ensuring the support for conservation by those depending on coastal ecosystems.

CMPA Technical Report Series

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