7.1. INTRODUCTION

Habitat loss is the primary environmental cause of biodiversity decline at local, regional and global scales (Bibby, 1995; Ehrlich, 1995; Fahrig, 2001; Dirzo & Raven 2003; Balmford et al., 2005; Schipper et al., 2008). Loss and fragmentation of habitat results in reduced population size that increases the probability of extinction by demographic and/or environmental stochasticity (Burkey, 1995). Among land species, habitat loss is prevalent across the tropics, which coincides with areas of high deforestation in the America, Africa, and Asia (Schipper, et al., 2008). The recent increase in habitat loss is due to growth of the human population leading to expansion of human activities into formerly natural areas (Sisk et al., 1994). At the same time, there has been a growing concern for conservation of species and ecosystems (Gore, 1992). Given the pressures on habitat, for conservation efforts to be successful, the most important question that must be answered is how much habitat must be conserved to ensure persistence of populations? (Fahrig, 2001). Such question is often addressed at the patch scale, i.e. what is the minimum (or ‘critical’) patch size necessary to maintain a viable population (e.g. Beier, 1993; Wenny et al., 1993; Howells & Edwards-Jones, 1997; Marshall & Edwards-Jones, 1998; Fahrig, 2001)? Modeling studies suggest that the critical patch size depends on a combination of quality of patch (habitat), reproductive rate of the organism, rate of emigration from the adjacent patches, population genetics of the organism, and stochastic factors such as disturbances (Soulé & Simberloff, 1986, Lande, 1987, Schneider & Yodzis, 1994, Wissel & Zaschke, 1994, Bevers & Flather, 1999, Fahrig, 2001).

In India, the floating meadows of the Loktak Lake and Keibul Lamjao National Park, Manipur is the only remaining habitat of the Eld’s deer *Rucervus eldii* locally known as Sangai. It is considered as one of the most endangered deer species in India. Once widely distributed throughout the State of Manipur, it is now restricted to the southeastern fringe of Loktak Lake. The purpose of the present study was to improve upon the existing ecological knowledge base of the severely fragmented, small and
isolated population of Eld’s deer in the Park, so as to develop appropriate measures for the conservation of this species and related cervids.

Among deer, the population characteristics and dynamics vary in relation to physical and biological characteristics of individual habitats (Mackie, 1981). The main elements of the interaction between a herbivore and the plants that it eats can be summarized as: (a) The rate of increase of edible plant biomass per unit area as a function of its standing density and environmental attributes such as the temperature of the air and the amount of moisture in the soil (plant growth response). (b) Rate of intake of food per herbivore as a function of the standing density of the edible vegetation (functional response). (c) The rate of increase of herbivore population as a function of the standing density of the edible vegetation, and (4) The rate of increase of the herbivore population as causal function of its own density (intrinsic response) (Caughley & Gunn, 1993).

Keeping in view the above discussion, the following synthesis has been made based on the findings of the study for effective conservation of Sangai and associated cervids in the Keibul Lamjao National Park.

7.2. Water quality and nutrient status

‘Loktak’ is a very common word for the people of Manipur denoting the importance of the Lake for the people of Manipur. This name is used in multiple ways in various aspects of the society – education, culture, folklore and economy of the state. Exploitation of the Lake for various interests has resulted in a rapid deterioration of the Lake ecosystem. Since an ecosystem function is governed by the biotic and abiotic elements of the systems, it becomes critical to study these elements of the ecosystem (Prasad et al., 2007). Hence, the present study was undertaken to assess the water quality and nutrient status of the soil sediment of the Loktak Lake and Keibul Lamjao National Park and discuss the impact of this overexploitation on the Lake ecosystem. The results of the study are indicative of the excess nutrient load on the Lake. The water quality of the Lake is deteriorating due to excess nutrient and pollutant from the rivers viz. Nambul, Nambol, Moirang, Potsangbam and Naranseina that drain into the Lake. The sites where the Nambul and Nambol rivers drain into the Lake were found to be highly polluted, in terms of water quality and nutrient load. Besides, the surface
runoffs from the catchment brings large amount of nutrient due to forest degradation and jhuming resulting in hypereutrophic conditions of the Lake. The construction of the Ithai barrage has also played a significant role in the present status of the Lake ecosystem, as the barrage blocks both the outlet channels, Ungamel and Khordak. As a result of this blockage nutrients entering the Lake and the Park do not flow out. The excess nutrient retention by the meadows is resulting in their proliferation and resultant decrease in their thickness, which is detrimental for the survival of Sangai. The anthropogenic activities, such as livestock rearing, aquaculture, deforestation and jhumming in the catchment area increase the influx of sediments and nutrients enhancing the siltation of the Lake.

A need for holistic approach is felt to save the lake from the present trend of rapid deterioration. The outflow of nutrients through its outlets channels needs to be restored especially during monsoon. Restoration of flushing mechanism of the ILake will reduce the nutrient load in the Lake as well as the Park. Athaphum fishing, where the meadows are cut off from its continuous mass to create fish farms in the open water bodies are not only destroying the integrity of the meadows but are also deteriorating the water quality from the household waste disposed from the floating huts constructed for these purpose of farming. An awareness campaign amongst local people involved in resource extraction and meadows fishing should be organized to educate them to minimize extraction and to reduce the number of athaphum and minimize its impact on the Lake.

Activities in the catchment area enhancing siltation need to be checked. Establishment of a treatment plant on the most polluted rivers entering the Lake and watershed management along the catchment area will go a long way in maintaining the integrity of the Lake.

7.3. Vegetation composition and plant community structure
The plant community plays a significant role in the understanding a particular habitat. Vegetation, particularly of the floating meadows plays a key role in governing the wetland processes and function of the Loktak Lake. The vegetation of the floating meadows include emergent, submerged and floating type life forms. They influence hydrological regimes, harbor rich biodiversity, support productive fisheries and
provide several economically important plant species to the communities. In the present study, as many as 185 plant species belonging to 121 genera and 50 families have been recorded. The most dominant families, Poaceae and Cyperaceae indicate the grassland nature of the Park. The dominant grass species like *Phragmites karka, Saccharum spontaneum, Zizania latifolia, Leersia hexandra, Capillipedium* spp, and herb species like *Alternanthera philoxeroides, Oenanthe javanica* and *Hedychium coronarium* also contribute maximum to the forage diet of the wild ungulates (Sangai and Hog deer) in the Park. The dominance of *Hemarthria compressa, Oryza rufipogon, Setaria* spp and *Leersia hexandra* in the dry hard ground of the Park indicates the distinct habitat type exhibited by the hard ground compared to the floating meadows. These grass species also contribute maximum to the diet of the wild ungulates emphasizing the importance of these dry patch of hard ground in the Park.

The dominant grass species which contribute maximum to the forage diet of the ungulates in the Park are also being extracted by the local people. The plant species of the Park provide food, fodder, fuel, medicinal, handicraft and thatching material for hut construction. People living in the periphery of the Park collect these economically important plants daily for their own use as a means of livelihood. *Hedychium coronarium* and *Oenanthe javanica* are extracted in huge quantities everyday throughout the growing season mainly for commercial purposes. *Phragmites karka, Arundo donax* and *Saccharum spontaneum* are extracted in large quantities for fuel and fencing. Extraction of these economically important plants is done almost all year round which is degrading the habitat and is a threat for the survival of Sangai. In view of these, restriction on extraction of biomass from the Park needs to be imposed in strict sense. Simultaneously, development of sustainable livelihood options for the local people will greatly reduce the anthropogenic pressure on the Park. A balance needs to be maintained whereby the anthropogenic pressure and hydrological regime do not disturb the habitat of the wildlife and the Park integrity is maintained.

Since the Park remains flooded during monsoon to early winter making some of the areas inaccessible to the ungulates, maintaining the water level of the Lake and Park is imperative for the survival of Sangai.
The habitat of Sangai in the Park is deteriorating primarily due to the change in water regime negatively affecting the thickness of the floating meadows. The floating meadows which used to settle during lean season and get replenished with soil and nourishment, are now continuously floating resulting in their thinning, making them increasingly defunct in supporting the weight of the Sangai. In this study, an attempt was made to examine the changes in floating meadows thickness and the resultant impact on the habitat. The study revealed that the thickness of the floating meadows is decreasing at rate of 9% per annum in the Park. The floating meadows thickness in the northern and southern zone is decreasing at the rate of 6% and 12% per annum respectively. The meadows in the northern zone are dynamic due to close proximity to open water and tend to float around depending on the direction of the wind whereas the meadows in the southern zone of the Park are fixed. The higher rate of decline in meadows thickness in the southern zone could be due to the reason that meadows proliferation is taking place from the inside towards the northern zone as the northern zone is close to open water and there is no open space for the meadows to proliferate in the southern zone.

The frequent or prolonged presence of water at or near the soil (hydrology) is the dominant factor determining the process of soil development and composition of plant and animal communities living in the soil and on its surface in wetlands. Thus alteration of wetland hydrology can change the soil chemistry and the plant and animal community (Mitsch & Gosselink, 1993). In the case of the Park, the change in hydrology resulting in its effect on meadows thickness is man-made i.e. the construction of the Ithai barrage in 1983 for the generation of power. The changes in the hydrology have greatly reduced the carrying capacity of the Lake ecosystem, enhanced siltation, changed the whole nature of the Lake and adversely affected the livelihoods of the local people dependent on this Lake (Singh & Khundrakpam, 2009). Apart from affecting the thickness, change in hydrology has also resulted in the proliferation of the meadows so much so that it has become a problem in some areas of the Loktak Lake. These newly formed meadows are thin due to proliferation and cannot support the weight of Sangai. For the successful conservation of Sangai, the meadows thickness needs be to be maintained at least at 1 m or >1 m thickness (Singh, 2002). Out of the 40 km² of the Park, floating meadows occupy only 26 km².
and the rest 14 km² is open water. Transects laid out during 2005-2010 covering the entire Park to map the habitat use of Sangai during the present study revealed that although floating meadows cover 26 km², signs of habitat use were observed only in 22.3 km² of the Park (Angom, 2012). Based on these transects, the habitat most suitable for Sangai in terms of meadows thickness was found to be only 8.64 km². So, even though the area under meadows is increasing due to proliferation, the same might not be beneficial for Sangai. The change in meadows thickness due to the change in hydrology and meadows proliferation is of great concern for the survival of Sangai. To maintain the integrity of the floating meadows it is important to allow major portion of the floating meadows to settle during lean seasons by reducing water level of the Lake and minimize burning, walking, trampling, resource extraction and grazing in the meadows.

7.5. Aboveground biomass productivity (AGB) and forage availability

Standing biomass measured in its maximum is usually equalized with production (Richardson, 1978). Plants that dominate a site, in terms of biomass, are a reflection of the plants that are controlling the nutrient, water, and solar resources on the site. Therefore, biomass is often measured to assess the ecological status of a site. In the present study, a total of 41 plant species (six enclosures which were used as control) belonging to 18 families were recorded from the 16 enclosures, of which 27 species were recorded on thick, 33 species on thin meadows and only 6 species were recorded in the hard ground indicating the high species diversity of the meadows. Productivity of the grass species was higher compared to the herbs indicating the dominance of grasses in the Park. The grass species *Zizania latifolia*, *Phragmites karka* and *Arundo donax* which contribute maximum to the annual productivity are also important food plants for Sangai and Hog deer.

Vegetation of wetland meadows varies depending on the environmental (soil, water) conditions and management regime. In monsoonal wetlands of Northern India, the productivity of wetlands changed seasonally in response to changing water level and temperature (van der Valk et al., 1993). In the present study, productivity was highest in the month of August and least in February but there was no significant difference in the productivity across the seasons probably because of the present hydrological regime whereby the meadows remain afloat throughout the year. Since the Park
remains inundated all throughout the year, there is no shortage of nutrients and moisture. Also due to the Ithai Barrage, very less amount of nutrient entering the Park flows out, as there is no outlet and the water in the Park remains stagnant. The easy availability of nutrients and moisture and lack of abundant tall grasses has resulted in weak competition in the Park.

To study the impact of management practices in the Park, the 16 enclosures were given different management treatments (control, cut and burnt). Highest productivity was observed in the enclosure subjected to the burnt treatment followed by cutting treatment and the least productivity was observed in the control enclosures. Though burning enhanced AGB production, it fails to provide base materials for maintaining the thickness of the meadows. Thus cutting of grasses and leaving it as such is recommended. Besides, burning is mostly done to increase the nutrients in the soil which is not required in the present study since the Park is already facing excess nutrient load in the water and soil sediments.

The utilization of the AGB by the wild ungulates was also studied since apart from the abundance and availability it is important to know the usage of the food plants and preferred food species of the ungulates for successful management (Ellis et al., 1976). The present study has revealed that although food is in abundance, only 26.32% was utilized by the wild ungulates. The productivity in the thick meadows was more with 61.8% contribution from the perennials compared to the thin meadows where annual plant species contributed 76.2% to productivity. The perennial grass of the thick meadows provides food and act as shelter grass for the ungulates. In other words, food is in abundance in the thick meadows and is thus a suitable habitat for Sangai and Hog deer. But the scenario of the meadow thickness predicted shows that in ten years time, even the present days’ most suitable habitat will become unsafe to support the weight of Sangai. Therefore, it is important to maintain the integrity of the meadows thickness for long term conservation of Sangai. As evident from sustained breeding of Sangai in many zoos, Sangai will survive and breed in wild where habitats are swampy having adequate food supply.
7.6. Recommendations for improved conservation of the Loktak Lake and the Park

The present study identifies eutrophication, deterioration of water quality, heavy soil sediment nutrient load, change in hydrologic regime due to construction of Ithai barrage, pollution from Nambul and Nambol rivers and degradation of catchment area and inflow of silt every year during monsoon are the salient problems affecting the integrity of the Loktak Lake and the Keibul Lamjao National Park. Apart from these, encroachments into the Lake, shallowing due to siltation, excessive proliferation and thinning of meadows and increase in its horizontal dimensional growth is decreasing the open water area of the Lake, These problems need to be addressed immediately for the long term survival of Sangai and for maintaining the integrity of the Lake ecosystem.

The water quality is deteriorating due to excess nutrients and pollutants from the rivers viz. Nambul, Nambol, Moirang, Potsangbam and Naranseina that drains into the Lake and also from the catchments. The outflow of nutrients through its outlets channels needs to be restored especially during monsoon. Maintaining outflow of excess nutrient will reduce the nutrient load on the Park as well as on the Lake which can check the rate at which meadows are proliferating.

The construction of the Ithai barrage has played a significant role in the present status of the Lake ecosystem, as the barrage blocks both of the outlet channels, Ungamel and Khordak. Since the Park remains flooded during monsoon to early winter making some of the areas inaccessible to the ungulates, therefore maintaining the water level through consultative process is imperative for the survival of Sangai.

The changes in the hydrology and siltation of the Lake has reduced the carrying capacity of the Lake ecosystem, adversely affected the livelihoods of the local people who depend on the Lake. To maintain the integrity of the floating meadows it is important to allow major portion of the floating meadows to settle during lean seasons by reducing water level of the Lake and minimize burning, walking, trampling, resource extraction and grazing on the meadows.
Availability of the forage seems to not be a limiting factor for the Sangai. Forage is in abundance in the thick meadows and crucial for the existence of Sangai in the Park. Therefore, it is important to maintain the integrity of the meadows thickness for long term conservation of Sangai. Due to fire as a part of management practice and also by the local people, the base material for the formation of meadows is getting lost. Hence, cutting of the grasses and leaving it as such is recommended so as to maintain the thickness of the meadows.

The dominant grass species which contributes maximum to the forage diet of the wild ungulates in the Park are also being extracted by the local people. Extraction of these economically important plants is done almost all year round which is degrading the habitat and is a threat for the survival of Sangai. In view of these the restriction on extraction of biomass from the Park needs to be improved. Simultaneously, development of sustainable livelihood options for the local people will greatly reduce the anthropogenic pressure on the Park. A balance needs to be maintained whereby the anthropogenic pressure and hydrological regime do not disturb the habitat of the wildlife and the Park integrity is maintained.

Encroachment in the periphery by the local people especially for fish farming needs to be checked through a consultative process with local communities and by monitoring the land use change in the peripheral areas. An awareness campaign amongst local people involved in resource extraction and meadows fishing should be organized to educate them, to minimize extraction and to reduce the number of athaphum fishing and minimize its impact on the Lake.