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**Recent Changes
in the Phumdis
of Keibul Lamjao
National Park,
Manipur and
Management
Implications**

Abstract

Loktak Lake and the Keibul Lamjao National Park (KLNP) in the state of Manipur, North-east India support unique wetland vegetation, i.e., floating meadows, locally known as 'Phumdi'. These are made up of a heterogeneous mass of soil, vegetation and organic matter. They occur in varying thickness ranging from a few centimeters to about 2.5 m with one-fifth of it floating above and four-fifth submerged under the water. Phumdis play a crucial role in the survival of the endangered Eld's deer or Sangai (*Rucervus eldii eldii*) as they provide necessary space, shelter and forage for the species. Despite their tremendous significance very little is known about the dynamics, structure and composition of these meadows. We conducted floristic studies on the phumdis of KLNP area during 2005-2010. A total of 185 plant species belonging to 50 families and 121 genera were recorded. Poaceae was the dominant family followed by Cyperaceae and Asteraceae. The dominant species of the meadows were *Zizania latifolia*, *Hedychium coronarium*, *Impatiens* sp., *Cyperus difformis*, *Cyperus rotundus* and *Polygonum* spp. The species common to both the meadows and terrestrial habitat were *Phragmites karka*, *Capillipedium assimile*, *Leersia hexandra*, *Oenanthe javanica* and *Cyanotis barbata*. Perusal of past records reveals that noticeable changes have taken place in the structure and composition of phumdis in KLNP. This may be due to the changes in the hydrology of the lake and de facto extraction of plant species by the local communities. In order to maintain the natural growth and dynamics of the phumdi it is suggested to allow the phumdi to settle on the ground between February to May and prevent burning, trampling and uprooting of vegetation from the phumdis.

Keywords: Floating meadows; species composition; Nativity; Habitat specificity; Keibul Lamjao National Park

Introduction

Various forms of wet or floating meadows have been reported globally which form important component of wetland vegetation distributed from the sub-arctic to the tropics (Hammond et al., 2008). Swarzenski et al. (1991) used the term 'floating marsh' to refer to wetlands in which the "floating mats of vegetation are thick enough to support a person's weight". Natural floating meadows are relatively rare and typically form when masses of terrestrial peat are torn off by the storms or when the buoyant peat uplifts from the floor of basins following inundation (Van Duzer, 2004). The plant species play significant role in determining the structure and composition of the natural floating meadows (Azza et al., 2000). The roots of floating plants determine the thickness of the mats by binding the organic material together (Sasser et al., 1991). The floating meadows appear to be less frequent in Asia, but buoyant thick floating mats occur in Thailand (Peck, 2000), floating loose and unconsolidated peat mat in Japan (Haraguchi, 1991), or floating platform comprising heaps of decomposing water hyacinth in Bangladesh, locally called 'dhap' (Islam and Atkins, 2007).

In India, the characteristic floating meadows are confined to the Loktak Lake, a large but shrinking freshwater body in the upper basin of the Manipur River. This area forms a distinctive part of the Indo - Burma biodiversity hotspot. Loktak is one of the largest freshwater lakes in India, though, much of which has been reclaimed for agriculture in recent decades. The floating meadows, locally known as phumdi(s) play a significant role in determining the nature of the wetland ecosystem as well as in the local livelihoods. Phumdis are a heterogeneous mass of soil, vegetation and organic matter in various stages of decomposition that occur in different thickness ranging from a few centimeters to about 2.5 m. With the reed *Phragmites karka* as the most dominant species, the other important species in the phumdi are *Eichhornia crassipes*, *Oryza sativa*, *Zizania latifolia*, *Cynodon dactylon*, *Sagittaria* sp., *Saccharum bengalense*, *Leersia hexandra* and *Carex* spp. (Sanjit et al., 2005).

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With no definite shoreline, the expanse of water and depth of the Loktak Lake varies seasonally. The Keibul Lamjao National Park (KLNP), located in the southern part of the Loktak Lake is a sole habitat of the endangered Eld's deer or the Manipur Brow antlered deer, locally known as Sangai (*Rucervus eldii eldii*). The Park supports the largest expanse of floating meadows covering 22.3 km² (Hussain et al., 2006). The increasing demand for goods and services provided by the Loktak lake ecosystem and the resultant pressures on the wetland have led to its degradation, threatening the survival of the endangered Sangai and livelihoods of the local communities' dependent on it.

The vegetation composition of the phumdi is believed to be changing over the years (Shyamjai, 2002). The habitat in the Park is declining primarily due to the change in water regime from the construction of the Ithai barrage. Prior to commissioning of the Loktak Multipurpose Project in the year 1983, water in the Lake exhibited broad seasonal changes. The phumdis, which used to settle during lean season and get replenished with soil and nourishment, are now continuously flooded resulting in their thinning, making them increasingly defunct in supporting the weight of the deer. During the dry period when the phumdis used to settle down, the nutrients and minerals were drawn by the phumdi vegetation from the bottom of the Lake. This natural cycle of floating and sinking of phumdi used to be maintained in KLNP. Maintenance of high water level in the Lake throughout the year for Loktak Multipurpose Project has broken this annual cycle and phumdi remains flooded throughout the year and periodic supply of nutrients and minerals during dry season is no more available to phumdi vegetation. Therefore, the growth of vegetation on phumdi and their thickness is believed to be gradually decreasing (Tuboi and Hussain, 2014). It is feared that eventually the phumdi may not be able to support the weight of the animal that is considered to be one of the limiting factors for the Sangai population.

The wetland vegetation exhibits diversity, ranging from microscopic to multi-cellular forms, and mainly constitutes of herbaceous species with an occasional shrubby species (Adhikari and Babu, 2008). The vegetation of the phumdi not only plays a crucial role in governing the wetland processes of the Loktak Lake but also influences hydrological regimes, harbors rich biodiversity, supports productive fisheries and provides several economically important plant species to the local communities. Keeping in mind, the important role played by the vegetation of the floating meadows for the ecosystem as a whole, particularly for the Sangai and the hog deer, the present study was conducted during 2006-10 to gain an insight into the vegetation composition and distribution of the economically important plants of the Park. As the Park has large expanse of floating meadows interspersed with open water and hillocks, comprehensive understanding of the vegetation composition of the Park will be helpful in effectively managing the Park.

This paper summarizes the plant species composition of the floating meadows of KLNP, identifies the changes taking place in the vegetation structure and suggests measures for minimizing such changes that may prove detrimental to both the ecosystem and its dependent species.

Study area

The study was conducted in the Keibul Lamjao National Park (KLNP), Manipur, India located in the Barak-Chindwin-Irrawaddy Basin (**Figure 7.1 & Plate 7.2a,b**). The KLNP is situated in the South-eastern fringes of the Loktak Lake. The Park lies between latitudes 24° 26' to 24° 31' N and longitudes 93° 49' to 93° 52' E. The ambient temperature around KLNP ranges from 1.7oC (January) to 36.4oC (May). During winter, low temperature, heavy dew and early morning frost characterize the climatic condition. There is heavy rain during June to September, and less or little rainfall from December to February. The annual rainfall is 1460 mm. Humidity is highest in August, with daily humidity measuring as much as 81% and least in March at 49%. In 1953, the Sangai which was believed to be extinct was rediscovered by E.P. Gee (Gee, 1960). Due to the persistent efforts of E.P. Gee, the Sangai was declared a protected animal and its habitat, Keibul Lamjao covering an area of about 52 km² was declared a sanctuary in 1954. In 1959, the total area was reduced to about 27 km². With a view to ensuring protection for the species, the Keibul Lamjao was declared protected in 1965, a reserved forest in 1974 and finally a National Park in 1977 (Singh, 1992). The Park received National and International attention when Loktak Lake was declared as a site of International Importance (Ramsar site No. 463, Designation Date: 23 March 1990) (Hussain et al., 2006). Presently the Park occupies an area of 40.05 km² out of which 26.41 km² is covered by a thick and almost contiguous mat of floating meadows (Tuboi, 2013).

The floating meadows of the Park vary in thickness, based on which the Park can be divided into the Western thick phumdi zone, Eastern thin phumdi zone and Northern open water and very thin phumdi zone. The construction of Ithai Barrage (1983) has affected the natural process of phumdi formation (Sanjit et al., 2005) which led to the rapid changes in the lake ecosystem. More than 185 species of grasses and sedges have been recorded from the meadows, of which *Zizania latifolia*, *Phragmites karka*, *Saccharum bengalense*, *Hemarthria compressa*, *Leersia hexandra*, *Carex* spp., *Oryza rufipogon* and *Capillipedium* spp. constitute the major primary food items of the Eld's deer (Tuboi et al., 2012).

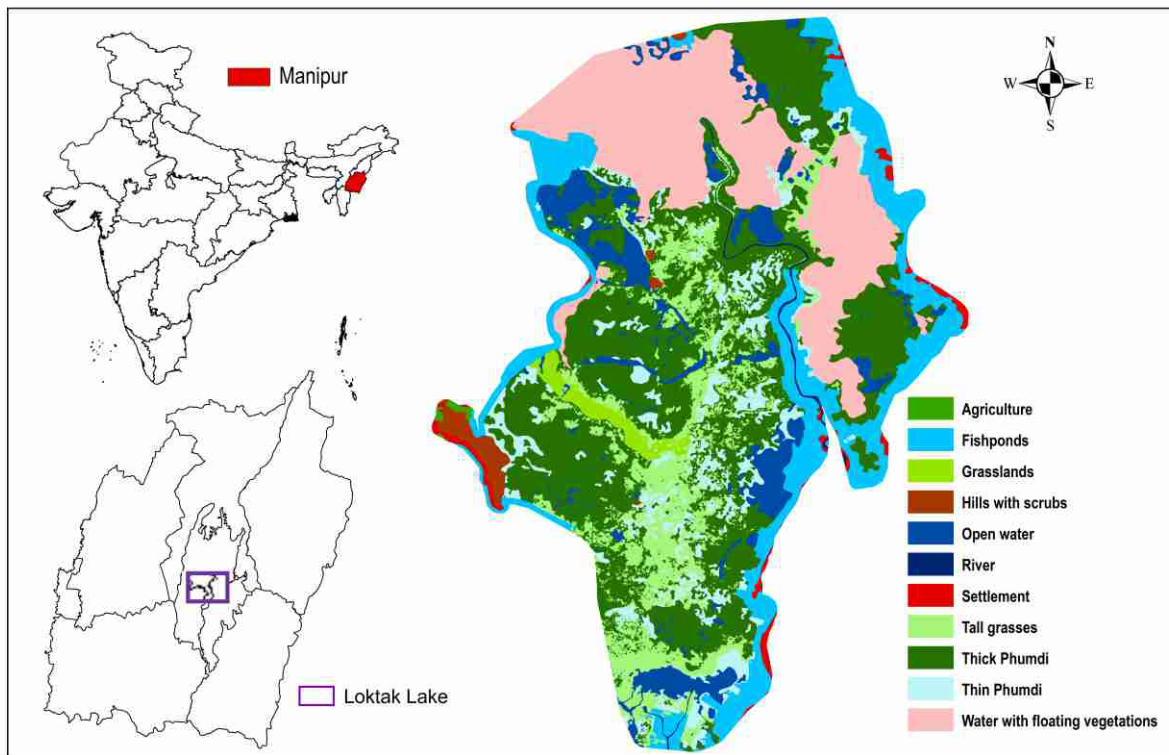


Figure 7.1. Location map of Keibul Lamjao National Park, Manipur and the land use-land cover types.

Methods

An extensive floristic survey was carried for the entire year in the Park so as to cover all the annual, as well as perennial plant species. However, during winter (November-January), due to high water level, sampling was restricted to mostly thick meadows. The KLNP and the adjacent areas of the Park were divided into 51 grids of 1000 x 1000 m. Depending on the open water and thickness of meadows 2 to 3 line transects of 500 m each were laid randomly on each of these grids. Quadrates of 0.5 x 0.5 m were laid randomly on these transect to study the dominant plant species and association among them. In each plot, the number of plant species present and their number were recorded. Plant samples were collected from the different mosaic of habitats viz., floating vegetation, hard ground and submerged areas. The collected specimen were numbered and pressed for the preparation of herbarium (Jain and Rao, 1977). The habitat types from which the sample was collected and the numbers of species present in each microhabitats were also recorded. Identification of plants in the field was done with the help of 'A Manual of Aquatic Plants' (Fassett, 1997) and 'The grasses of Burma, Ceylon, India and Pakistan' (Bor, 1960). Unidentified plants specimen were brought to Wildlife Institute of India (WII), Dehradun for further examination and cross verification.

To examine the changes in the plant species composition transects of 500 m were laid from the edge of the grassland towards the interior of the Park. In each transect quadrates of 50 cm x 50 cm were randomly laid at every 100 m distance. Counts of different tillers of grasses and average heights were recorded. During the study, information on resources extracted by local people and the parts extracted were also recorded so as to quantify the rate of extraction. We compared the extent dominant species and their present occurrence in the park based on past records and published information (Singh, 1992; Shyamjai, 2002; Shamungou, 2002; Sanjit et al., 2005).

Results

Plant species composition

A total of 185 plant species belonging to 50 families and 121 genera were recorded in the Keibul Lamjao National Park (Appendix I). These include 13 species of climbers, 33 grass species, 30 species of sedges, five ferns species, 97 species of herbs and seven shrub species. Out of 185 species, only 90 were recorded in the floating meadows and open water, 19 in terrestrial habitats and 76 species in both terrestrial and floating habitats. The species of the floating meadows consisted of 11 grasses, 27 sedges, 49 herbs and three ferns belonging to 32 families. The terrestrial species consisted of

six species of grasses, four climbers, nine herbs and one species of shrub belonging to 11 families (Figure 7.2). The species of both the floating and terrestrial habitat comprise of 16 species of grasses, nine climbers, three sedges, two ferns, 40 herbs and five shrubs belonging to 30 families. Poaceae was the dominant family with 33 species followed by Cyperaceae with 30 species and Asteraceae with 14 species. Twenty-three families were found to have a single species (Figure 7.3).

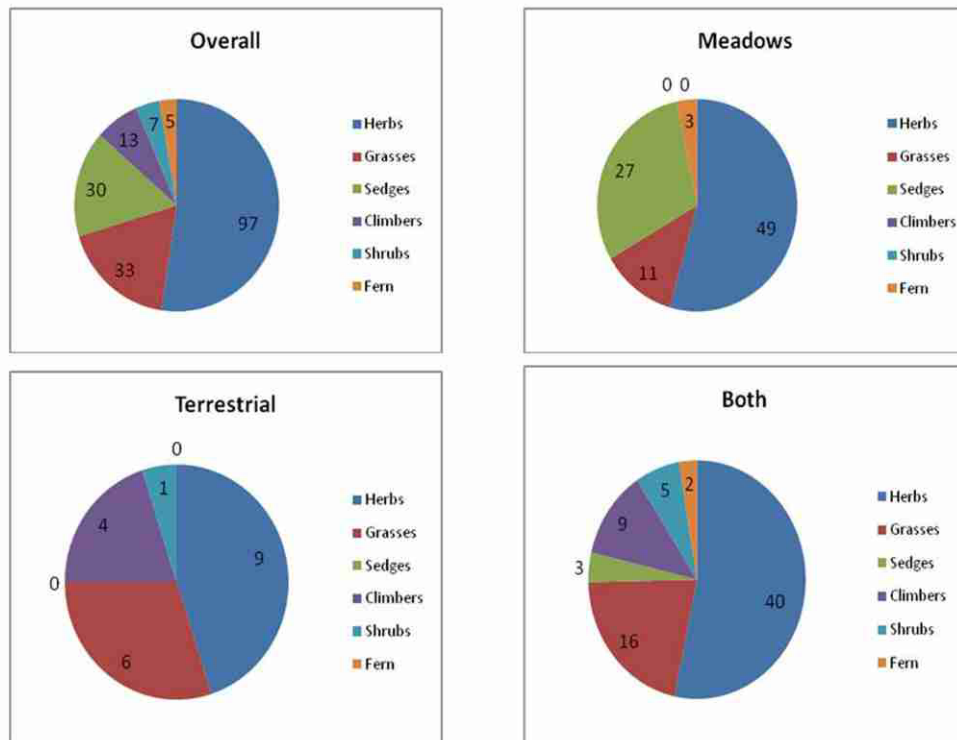


Figure 7.2: No. of species in different habitat types of the Keibul Lamjao National Park, Manipur.

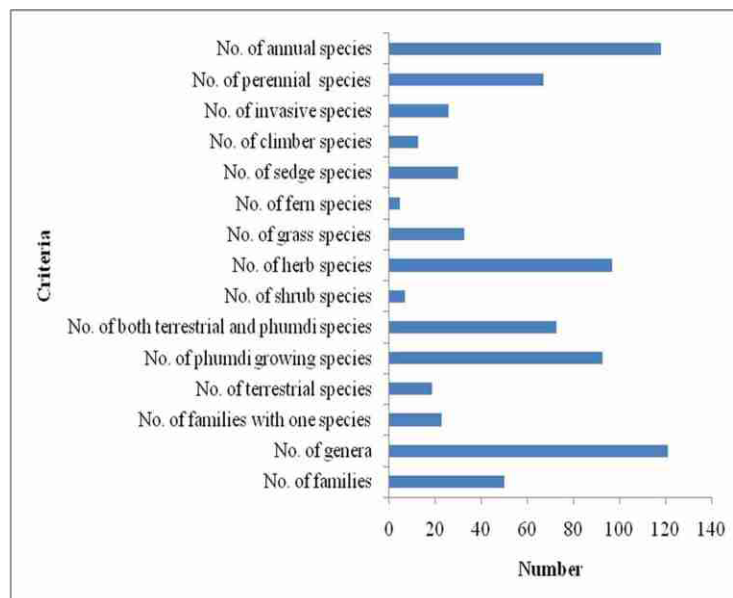


Figure 7.3: Details of the dominant families and habitat types of the plant species of Keibul Lamjao National Park, Manipur.

Habitat specificity

Since the Park has a mosaic of microhabitats (floating meadows, open water and terrestrial), the type of plants found in each habitat was also recorded. The percentage distributions of the species in the different habitats were: 48.6% in the floating meadows, 41.1% in both the floating meadows and terrestrial habitat and 10.3% only in terrestrial habitat. The dominant species found in the floating meadows were *Zizania latifolia*, *Hedychium coronarium*, *Impatiens* sp., *Cyperus difformis*, *Cyperus rotundus* and *Polygonum* sp. and the dominant species in the terrestrial habitat were *Dactyloctenium aegyptium*, *Ipomoea nil* and *Cynodon dactylon*. The species common to both the floating meadows and terrestrial habitats were *Phragmites karka*, *Capillipedium assimile*, *Leersia hexandra*, *Oenanthe javanica* and *Cyanotis barbata*. The common species floating or submerged in the open water were *Azolla pinnata*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Salvinia cucullata*, *Salvinia molesta*, *Utricularia* spp., *Nymphoides cristata* and *Pistia stratiotes*.

Occurrence of herbs was found to be the highest in both the floating meadows and terrestrial habitats (54.4% and 47.4% respectively) followed by sedges in the floating meadows (30%) and the grasses in the terrestrial habitat (26.3%). Herbs showed the highest percentage of distribution of the species common to both floating meadows and terrestrial habitats (52.6%) followed by grasses and climbers (21.1% and 11.8%, respectively). In the overall distribution of the plant species of the Park, herbs showed the highest percentage (52.4%) followed by grasses and sedges (17.8% and 16.2% respectively).

Extraction of plant species by local communities

Resource extraction occurred not only in the peripheral areas but throughout the Park. Besides depending on the Park for commercial sale of vegetables and fishes, it was also found that people depended on the Park for fuel wood for subsistence and fish feed. A total of 26 economically important plant species used by the local people for various purposes has been identified in the Park (Table 1). The most important plant species extracted for subsistence use and commercial purposes were *H. coronarium*, *Oenanthe javanica*, *Nymphaea* sp. and *Euryale ferox*. *Phragmites karka*, *Z. latifolia*, *L. hexandra*, *Scirpus* spp., *S. spontaneum*, *A. donax*, *Imperata cylindrica* and *Coix lacryma-jobi* were extracted by the local people for fencing, fuel wood and thatching the roof of huts (Plate 7.1). The important fodder species identified in the Park were *Z. latifolia*, *C. demersum*, *H. verticillata*, *Limnophila* sp. and *L. hexandra*. *Ageratum conyzoides*, *Alpinia allughas*, *H. coronarium*, and *Fureina umbellata* are used for medicinal purposes. *Cyperus* sp. and *Scirpus lacustris* were extracted for making handicrafts especially mats (Table 7.1).

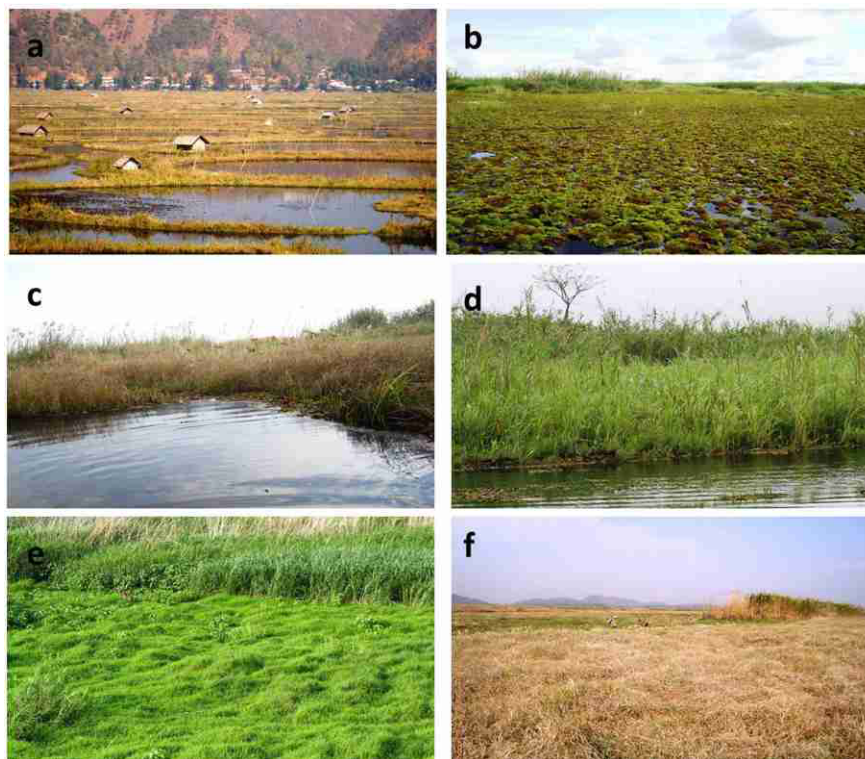
Table 7.1. A list of the economically important plant species of Keibul Lamjao National Park, Manipur.

Uses	Plant species	Parts used
Vegetables	<i>Alternanthera philoxeroides</i> , <i>Alternanthera sessilis</i> , <i>Centella asiatica</i> , <i>Oenanthe javanica</i> ,	Leaf, stem
	<i>Alpinia allughas</i> , <i>Hedychium coronarium</i>	Stem, young shoot
	<i>Euryale ferox</i> , <i>Nymphaea</i> sp.	Seeds
Thatching material	<i>Imperata cylindrica</i> , <i>Zizania latifolia</i>	Leaf, stem
Fuel	<i>Arundo donax</i> , <i>Coix lacryma-jobi</i> , <i>Phragmites karka</i> , <i>Saccharum spontaneum</i>	Stem
Handicrafts	<i>Cyperus</i> spp., <i>Scirpus lacustris</i>	Stem
Medicinal purposes	<i>Centella asiatica</i> , <i>Ageratum conyzoides</i> , <i>Alpinia allughas</i> , <i>Hedychium coronarium</i>	Leaf, young shoots
	<i>Ludwigia adscendens</i> , <i>Oxalis corniculata</i> , <i>Vetiveria zizanioides</i> , <i>Fureina umbellata</i>	Leaf, young shoots
Fodder	<i>Alternanthera philoxeroides</i> , <i>Alternanthera</i> <i>sessilis</i> , <i>Leersia hexandra</i> , <i>Polygonum</i> sp., <i>Zizania latifolia</i> ,	Leaf, Stem
	<i>Ceratophyllum demersum</i> , <i>Hydrilla verticillata</i> , <i>Limnophila</i> sp	Whole plant

Changes in Phumdi Vegetation

Due to the recent changes in the Loktak Lake and its catchments area, both natural and manual proliferation of Phumdis is taking place. Recent studies have also shown that the Phumdi area in the lake has increased. However, it is of little use to Sangai as recently formed Phumdis are thin. In 1989, the Phumdi area was 116.4 km² while in 2002 it increased to 134.6km² with maximum increase recorded in the central zone of the lake (Singh and Khundrakpam, 2009). It has been reported that the

Plate 7.1 Views of Phumdis in different seasons of Keibul Lamjao National Park, Manipur (a) Athaphum fishing (b) *Salvinia molesta* in open water after monsoon in September (c) view of phumdi in winter (d) view of phumdi in summer (e) view of hard ground in summer (f) view of hard ground in winter.



proliferation rate within six months is about 0.8 –2 m area in the lake and 0.1 m in the KLNP (Shyamjai, 2002). The data available from earlier studies of 1980s and 1990s (Shamungou, 2002) suggest that vegetation composition of the Phumdi in the Park is changing. During the present study, 185 plant species were recorded as compared to 223 reported by Singh (1991). Besides 145 aquatic, semi-aquatic and terrestrial plant species were reported by Shyamjai (2002) and 117 reported by Angom and Gupta (1999). Earlier studies conducted in 1986 by Singh (1992) reported that *L. hexandra* dominated the Phumdi with about 25% of occurrence followed by *Z. latifolia* (18.3%), *P karka* (14.4%) and *C. assimile* (11.1%). In a similar survey in 1996, he reported that percentage occurrence of *Z. latifolia* and *P karka* had reduced to 14.6% and 10% respectively while it had increased to 32.5% in the case of *L. hexandra* and 14.2% in *Capillipedium* sp. (Shamungou, 2002). During the present study the percentage occurrence of *Z. latifolia* was 8.06%, *P karka* was 6.41%, *L. hexandra* was 11.39 and *Capillipedium* sp. was 10.06 % (Table 7.2) indicating extent of change in these species.

Table 7.2. Percentage of occurrence of plant species during 1986, 1996 and 2010 in Keibul Lamjao National Park,

Botanical name	Local name	1986	1996	2010
<i>Zizania latifolia</i>	Ishing kambong	18.3	14.6	8.06
<i>Phragmites karka</i>	Tou	14.4	10	6.41
<i>Saccharum bengalense</i>	Khoimom	4.7	4.2	3.69
<i>Narenga porphyrocoma</i>	Singut	1.9	2.5	NO
<i>Leersia hexandra</i>	Hoop	24.7	32.5	11.39
<i>Carex</i> sp.	Hundang	3.9	3.1	0.29
<i>Oryza perennis</i>	Wainu chara	7.7	1.8	0.13
<i>Coix lachrymal-jobi</i>	Yawa chaning	4.2	1.6	0.14
<i>Capillipedium</i> sp.	Wana manbi	11.1	14.2	10.06
Others		8.6	15.5	16.93

Source: Singh (2002).

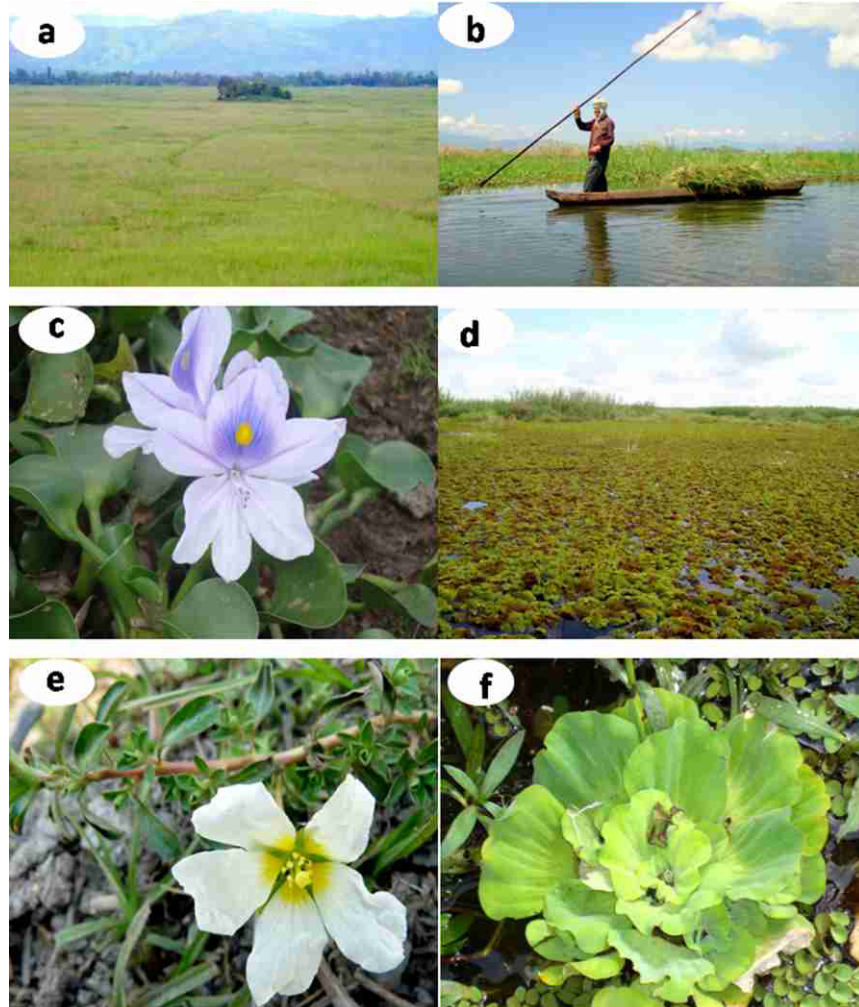


Plate 7.2. Some invasive plant species of the floating meadows of Keibul Lamjao National Park, Manipur (a) a view of the Park (b) extraction by local people (*Zizania latifolia*) (c) *Eichhornia crassipes* (d) *Salvinia molesta* (e) *Ludwigia adscendens* (f) *Pistia stratiotes*.

During the present study, a total of twenty-six species of alien invasive plants were recorded from the study area, viz., *Ageratum conyzoides*, *Alternanthera philoxeroides*, *Blumea* sp., *Chamaesyce hirta*, *Crassocephalum crepidioides*, *Crotalaria* sp., *Cyperus difformis*, *Echinochloa crus-galli*, *Eclipta prostrata*, *Eichhornia crassipes*, *Impatiens balsamina*, *Imperata cylindrica*, *Ipomea* sp., *Ludwigia* sp., *Ludwigia adscendens*, *Mikania micrantha*, *Monochoria vaginalis*, *Oxalis corniculata*, *Pistia stratiotes*, *Salvinia molesta*, *Sida acuta*, *Solanum nigrum*, *Sonchus* sp., *Stachytarpheta jamaicensis*, *Urena lobata* and *Xanthium strumarium*. Out of these, three species viz. *Salvinia molesta*, *Eichhornia crassipes* and *Pistia stratiotes* are free floating hydrophytes (Plate 7.2).

As part of the management practices annual burning and fire line cutting of the Phumdi is done during February-March. The local people also sometimes burn the phumdis so that fresh young shoots can come up for extraction. Studies have shown that burning affects vegetation composition (Gill et al., 2002; Dornbush, 2004; Khatri and Barua, 2011). This could be one of the factors contributing to the change in vegetation composition observed in the Park.

Discussion

The understanding of plant species composition in a habitat is crucial for understanding the succession and change in vegetation structure over time due to natural and anthropogenic impacts. The ecological structure of the plant species is the result of a rich array of factors relating to both the physical and the biological environment. The plant community structure represents a community's ability to capture and utilize resources (i.e., sunlight, water, and nutrients) from different positions in the canopy and soil profile. Often grazing and human interferences alter the plant community

structure and composition of grasslands (e.g. Kala et al., 2002). These changes in the composition and structure influence forage production, habitat values and, ultimately, the sustainability of the habitat to support itself (Kamau, 2004).

The vegetation, particularly in the floating meadows, plays a crucial role in governing the processes and function of the Loktak Lake. Apart from the moisture loving, submerged aquatic plants, the presence of terrestrial plants can also be attributed to the floating mats of vegetation (Sharma et al., 2002). These floating mats of vegetation influence hydrological regimes, harbor rich biodiversity, support productive fisheries and provide several economically important plant species to the local communities (Trisal and Manihar, 2002). The floating meadows also provide biological sinks for nutrients and are critical to the maintenance of the water quality of the lake. Shamungou (1999) reported the proportion of fodder grasses as 58% and shelter grasses as 42%. However, our field observations during the study revealed that the occurrence of food plants had further decreased over the years, and the ratio of shelter to food species now stood at 27: 37. This trend suggests that the availability of food plants has also reduced along with loss in shelter plants species of Sangai and hog deer such as *P. karka*, *Z. latifolia* and *S. spontaneum*. There has been a high degree of change in the plant composition in the grassland that is not beneficial for the Sangai. This decline in food plants could also be due to the fact that non-palatable grasses have started replacing the palatable ones. Successions in grassland take place in nature, but the anthropogenic disturbances have altered the species composition in the grasslands. The growth in burnt grassland areas of the Park were usually dominated by *Pteris* sp. Unpalatable species such as *Pteris* sp., *Persicaria perfoliata* and *Eupatorium* sp., together, occurred in more than 20% of the quadrats in the present study that was not the case earlier.

The most important plant species associated with the wild ungulates in the Park are *Z. latifolia*, *L. hexandra*, *Capillipedium* spp., *Scirpus* spp., *S. spontaneum*, *H. coronarium*, *P. karka*, *A. donax*, *O. javanica*, *C. lachryma-jobi*, *Setaria* spp. and *H. compressa*, which are also harvested by the local people. The tall grass species especially *P. karka*, *A. donax* and *S. spontaneum* act as a shelter for the Sangai and are extracted on a daily basis for household use. The favorite food plants of the Sangai such as *Z. latifolia*, *L. hexandra*, *Capillipedium* spp., *P. karka*, *A. donax* and *S. spontaneum* are also harvested in large quantities.

Although, *Z. latifolia* and *L. hexandra* were harvested in large quantities they did not contribute directly to the income of the family unlike *H. coronarium* and *O. javanica* which are extracted in huge amounts every day throughout the growing season mainly for commercial purposes. During the growing season, these two species provide an important source of livelihood for the local people. The people are mainly dependent on *Z. latifolia*, *C. demersum*, *H. verticillata*, *Limnophila* spp. and *L. hexandra* which are used as fodder for the fish farms in and around the Park. Fish farming being the main source of livelihood for the people living around the Park, the extraction of fish fodder is done all year round. *P. karka*, *A. donax* and *S. spontaneum* used for fencing and as fuel, are also extracted in large quantities by the households all year round. It can be stated that poverty (Osman et al., 2000; Roderick and Hirsch, 2000; Sills et al., 2003; Belcher and Kusters, 2004; Tickin, 2004; Quang and Anh, 2006), lack of alternate livelihoods (Richman, 2004) and excessive dependence on biomass resources of the park are the major management issues around KLNP. According to the survey conducted during early part (Trisal and Manihar, 2004) of the last decade, it was estimated that 33% of the lakeshore households harvest aquatic vegetation for use as fuel; 18% for use as vegetables; 2% for use as fodder and 1% for manufacturing handicrafts.

The role of anthropogenic activities might have resulted in the change in the composition of plant species and degrading the grassland habitat of the KLNP. Apart from resource extraction, Athaphum fishing in which huge chunks of Phumdis are cut off to create a fish pond inside the lake itself affects the floating grassland of the Lake and the Park. Fire could be another factor that might have contributed to the change. Fire is not only significant in maintaining an open sward, but also has the potential to control the invasion and spread of exotic species in native grasslands (Stuwe and Parsons, 1977; Stuwe, 1986).

During the present study, it was found that unpalatable plants such as *Pteris* sp. have invaded in areas that were burned; this needs to be substantiated by further research. Khatri and Barua (2011) also reported that frequent burning in the *Phragmites karka* dominated grasslands of Kaziranga National Park leads to replacements by *Saccharum*, *Themeda* and *Imperata* species. Though few studies have verified the claims that fire is beneficial, the burning season has remained the least understood component of the disturbed regime (Gill et al., 2002). Burning may also exert selective pressure, altering the composition of the native community over the years in Prairie grasslands (Dornbush, 2004). Another probable reason for the change in the composition may be the changes in the hydrological regime of the lake due to the construction of the Ithai barrage and excess nutrient loading. Kosygin (2002) had reported that the annual inflow of nitrate nitrogen was 372.6 ton, out of which 76.8 ton enters the Loktak Lake. The nitrogen concentration of the lake water was estimated at 2.3 g m⁻³. Thus high load of nutrients in the lake water may also have led to the proliferation of floating meadows in open waters of the lake. This might also be one of the causes for the change in the overall grassland composition as nitrogen addition experiments in grasslands indicate that one of the consequences was a reduction in plant diversity (Aguar, 2005) dominance of a few species and suppression of many other species (Silvertown, 1980).

Management Recommendations

Our study shows that changes are taking place in the floating meadows of the Park. These changes are affecting the habitat of the Sangai in terms of change in plant species composition and deteriorating habitat due to proliferation and thinning of the Phumdis. The invasive plant species recorded in the Park are aggressive colonizers especially around disturbed areas, common in stagnant or slow-flowing waters. The invasion potentially leads to a decrease in species richness, as native species are replaced. Over the years, the thickness of the Phumdis of the Park is reducing and becoming thinner that might explain the colonization of the invasive species. The majority of the people residing around the Park are also dependent on the bio-resources from the park for their livelihoods, and the local economy is based on it. Over-harvesting and unscientific management may have led to the change in the grassland composition that is not favorable for the conservation of Sangai. Based on the findings of the present study, following recommendations for proper maintenance of the grassland composition are made:

1. The construction of the Ithai barrage has played a significant role in the present status of the Lake's ecosystem, as the barrage blocks both the outlet channels, Ungamel and Khordak. Since the Park remains flooded during the monsoon to early winter making some of the areas inaccessible to the ungulates, therefore maintaining the water level through a consultative process is imperative for the survival of Sangai.
2. The Phumdis that 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. Hence, allowing a significant portion of the phumdis to settle during the lean season (February – April) by reducing the water level of the Lake is recommended.
3. Natural growth and thickening of the Phumdis is critical for the survival of Sangai. It is also seen that the newly formed Phumdis are unable to support the weight of the Sangai. Since the proliferation is mainly due to the excessive nutrients from pollutants that enter the Park from the Loktak Lake and remain trapped inside the Park due to the Ithai barrage, the opening of the barrage during monsoon, when the influx of pollutants is highest, is recommended.
4. Since the Phumdis are formed from dead and decaying vegetation matter, resource extraction inside the Park should be checked as the removal of plants reduces the amount of rootmass needed for the formation of the Phumdi. Also, the soil particles in the phumdi are held together by the roots of the plants (e.g., that of *Hedychium coronarium*), extraction of which reduces the thickness of Phumdis. Hence, controlled/regulated harvesting and moderate cutting/harvesting of the plants resources is recommended to provide optimum food plants and shelter plants for the Sangai
5. Grazing of cattle in the Park, especially in the periphery, should be regulated so as to reduce the pressure on the Park and reduce competition and spread of diseases to the wild ungulates.
6. Food, in abundance in the thick meadows, is crucial for the existence of Sangai in the Park. Therefore, it is important to maintain the integrity of the phumdi thickness for the long term conservation of the Sangai.
7. Burning of the grassland as a part of management practice, as well as by the local communities, leads to the loss of dead and decaying plant material that is essential for the formation of Phumdi. Hence, in order to maintain the thickness of the Phumdi, the grassland should be cut and left as such so that the base material for the formation of Phumdi is not lost.
8. Monitoring of invasive species is required which can be done through qualitative approaches such as species inventory (seasonally) and quantitative approaches using phytosociological methods for early detection of problematic species and the rapid assessment of the status and movement of invaders and their potential ecosystem impacts.

Acknowledgements

This study was conducted under the project “Conservation Ecology of Sangai and its Wetland Habitat” sponsored by the Wildlife Institute of India, Dehra Dun. We are grateful to the Department of Forests, Government of Manipur for granting us logistic support to work in Manipur. We thank the Director and the Dean at the Wildlife Institute of India for encouraging and extending all the Institutional facilities to us during the conduct of the study.

APPENDIX 1

List of plant species from the Keibul Lamjao National Park, Manipur, India. Note: Habit: Herb (H), Climber (C), Shrub (S), Sedge (Sd), Grass (G), Floating or Phumdi (P), Terrestrial (T), Phumdi / Terrestrial (P/T)

Scientific Name	Family	Habit	Habitat
<i>Apluda mutica</i> L.	Poaceae	G	P/T
<i>Arundo donax</i> L.	Poaceae	G	P/T
<i>Capillipedium assimile</i> (Steud.) A.Camus	Poaceae	G	P/T
<i>Coix aquatica</i> Roxb.	Poaceae	G	P
<i>Coix lacryma-jobi</i> L.	Poaceae	G	P
<i>Cymbopogon</i> sp.	Poaceae	G	P/T
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	G	T
<i>Cyrtococcum</i> sp.	Poaceae	G	P/T
<i>Dactyloctenium aegyptium</i> (L.) Willd.	Poaceae	G	T
<i>Echinochloa colona</i> (L.) Link	Poaceae	G	P/T
<i>Echinochloa crus-galli</i> (L.) P. Beauv. var. <i>brevisetata</i> (Döll) Podp.	Poaceae	G	P/T
<i>Echinochloa crus-galli</i> var. <i>crus-galli</i> (L.) P. Beauv.	Poaceae	G	P
<i>Eragrostis gangetica</i> (Roxb.) Steud.	Poaceae	G	P/T
<i>Eragrostis</i> sp.	Poaceae	G	P
<i>Erianthus ravennae</i> P. Beauv.	Poaceae	G	P/T
<i>Hemarthria compressa</i> (L.f.) R.Br.	Poaceae	G	P
<i>Hygroryza aristata</i> (Retz.) Nees ex Wight and Arn. (<i>Hygroryza aristata</i> Nees)	Poaceae	G	P/T
<i>Imperata cylindrica</i> (L.) Raeusch.	Poaceae	G	P/T
<i>Isachne globosa</i> (Thunb.) Kuntze	Poaceae	G	P
<i>Leersia hexandra</i> Sw.	Poaceae	G	P/T
<i>Oryza rufipogon</i> Griff.	Poaceae	G	P
<i>Oryza sativa</i> L. Poaceae	G	P/T	
<i>Panicum paludosum</i> Roxb.	Poaceae	G	P/T
<i>Panicum</i> sp.	Poaceae	G	P
<i>Paspalum scorbiculatum</i> Steud.	Poaceae	G	P
<i>Phragmites karka</i> (Retz.) Trin. ex Steud.	Poaceae	G	P/T
<i>Saccharum bengalense</i> Retz.	Poaceae	G	T
<i>Saccharum munja</i> Roxb.	Poaceae	G	P/T
<i>Setaria glauca</i> P. Beauv.	Poaceae	G	P/T
<i>Setaria pallidifusca</i> (Schumach.) Stapf and C.E.Hubb.	Poaceae	G	P/T
<i>Setaria verticillata</i> (L.) P.Beauv.	Poaceae	G	T
<i>Vetiveria zizanioides</i> (L.) Nash	Poaceae	G	T
<i>Zizania latifolia</i> (Griseb.) Turcz. ex Stapf	Poaceae	G	P
<i>Bulbostylis barbata</i> (Rottb.) C.B.Clarke	Cyperaceae	Sd	P
<i>Carex cruciata</i> Wahlenb.	Cyperaceae	Sd	P
<i>Carex</i> sp.	Cyperaceae	Sd	P
<i>Cyperus alopecuroides</i> Thunb.	Cyperaceae	Sd	P
<i>Cyperus alulatus</i> J.Kern	Cyperaceae	Sd	P
<i>Cyperus brevifolius</i> Hassk.	Cyperaceae	Sd	P
<i>Cyperus compressus</i> L.	Cyperaceae	Sd	P
<i>Cyperus cyperoides</i> (L.) Kuntze	Cyperaceae	Sd	P/T
<i>Cyperus difformis</i> L.	Cyperaceae	Sd	P

Scientific Name	Family	Habit	Habitat
<i>Cyperus globosus</i> Baldw. ex Torr.	Cyperaceae	Sd	P
<i>Cyperus iria</i> L.	Cyperaceae	Sd	P
<i>Cyperus niveus</i> Retz.	Cyperaceae	Sd	P
<i>Cyperus nutans</i> Vahl	Cyperaceae	Sd	P
<i>Cyperus pygmaeus</i> Rottb.	Cyperaceae	Sd	P/T
<i>Cyperus rotundus</i> L.	Cyperaceae	Sd	P
<i>Cyperus triceps</i> F.N.Williams (<i>Kyllinga triceps</i> Rottb.)	Cyperaceae	Sd	P/T
<i>Eleocharis acutangula</i> Schult.	Cyperaceae	Sd	P
<i>Eleocharis atropurpurea</i> (Retz.) J. Pres.	Cyperaceae	Sd	P
<i>Eleocharis dulcis</i> (Burm.f.) Trin. ex Hensch.	Cyperaceae	Sd	P
<i>Eleocharis palustris</i> FMuell.	Cyperaceae	Sd	P
<i>Fimbristylis bisumbellata</i> Bubani	Cyperaceae	Sd	P
<i>Fimbristylis dichotoma</i> (L.) Vahl	Cyperaceae	Sd	P
<i>Fimbristylis miliacea</i> (L.) Vahl	Cyperaceae	Sd	P
<i>Fimbristylis schoenoides</i> Vahl	Cyperaceae	Sd	P
<i>Fimbristylis tetragona</i> R.Br.	Cyperaceae	Sd	P
<i>Fuirena umbellata</i> Rottb.	Cyperaceae	Sd	P
<i>Scirpus juncooides</i> Roxb.	Cyperaceae	Sd	P
<i>Scirpus lacustris</i> L.	Cyperaceae	Sd	P
<i>Scirpus mucronatus</i> Roxb.	Cyperaceae	Sd	P
<i>Scleria oblata</i> S.T. Blake ex J.Kern	Cyperaceae	Sd	P
<i>Ageratum conyzoides</i> (L.) L.	Asteraceae	H	P/T
<i>Artemisia nilagirica</i> (C.B.Clarke) Pamp.	Asteraceae	H	T
<i>Blumea</i> sp.	Asteraceae	H	P/T
<i>Centipeda minima</i> (L.) A. Br. and Asch.	Asteraceae	H	P/T
<i>Crassocephalum crepidioides</i> (Benth.) S.Moore	Asteraceae	H	P/T
<i>Enydra fluctuans</i> Lour.	Asteraceae	H	P
<i>Eupatorium odoratum</i> L.	Asteraceae	H	P/T
<i>Grangea maderaspatana</i> (L.) Desf.	Asteraceae	H	P/T
<i>Gynura</i> sp.	Asteraceae	H	P
<i>Mikania micrantha</i> Kunth	Asteraceae	C	P/T
<i>Siegesbeckia orientalis</i> (L.)	Asteraceae	H	P/T
<i>Sonchus</i> spp.	Asteraceae	H	P/T
<i>Spilanthes acmella</i> (L.) L.	Asteraceae	H	P/T
<i>Xanthium strumarium</i> L.	Asteraceae	H	P/T
<i>Persicaria</i> sp.	Polygonaceae	H	P
<i>Polygala arvensis</i> Willd.	Polygalaceae	H	P/T
<i>Polygonum barbatum</i> L.	Polygonaceae	H	P
<i>Polygonum chinense</i> L.	Polygonaceae	H	P/T
<i>Polygonum flaccidum</i> Roxb.	Polygonaceae	H	P
<i>Polygonum lapathifolium</i> L.	Polygonaceae	H	P
<i>Polygonum</i> sp.	Polygonaceae	H	P
<i>Polygonum</i> sp.	Polygonaceae	H	P
<i>Borreria pusilla</i> DC.	Rubiaceae	H	P/T
<i>Galium mollugo</i> L.	Rubiaceae	H	P
<i>Galium</i> sp.	Rubiaceae	H	P/T
<i>Galium</i> sp.	Rubiaceae	H	P/T

Recent changes in the Phumdis of Keibul Lamjao National Park, Manipur and management implications

Scientific Name	Family	Habit	Habitat
<i>Oldenlandia corymbosa</i> L.	Rubiaceae	H	P/T
<i>Paederia foetida</i> L.	Rubiaceae	C	P/T
<i>Spermacoce hispida</i> L.	Rubiaceae	H	P/T
<i>Wendlandia wallichii</i> Wight and Arn.	Rubiaceae	S	P/T
<i>Commelina appendiculata</i> C.B. Clarke	Commelinaceae	H	P/T
<i>Commelina benghalensis</i> L.	Commelinaceae	H	P/T
<i>Commelina longifolia</i> Lam.	Commelinaceae	H	P/T
<i>Cyanotis barbata</i> D. Don	Commelinaceae	H	P/T
<i>Floscopa scandens</i> Lour.	Commelinaceae	H	P/T
<i>Murdannia nudiflora</i> (L.) Brenan	Commelinaceae	H	T
<i>Argyreia nervosa</i> (Burm.f.) Bojer	Convolvulaceae	H	P/T
<i>Ipomoea aquatica</i> Forssk.	Convolvulaceae	H	P
<i>Ipomoea fistulosa</i> Mart. ex Choisy	Convolvulaceae	S	P/T
<i>Ipomoea hederifolia</i> L.	Convolvulaceae	H	T
<i>Ipomoea nil</i> (L.) Roth	Convolvulaceae	H	T
<i>Ipomoea pentaphylla</i> Jacq.	Convolvulaceae	H	P/T
<i>Aeschynomene indica</i> L.	Fabaceae	H	P
<i>Atylosia scarabaeoides</i> Benth.	Fabaceae	C	P/T
<i>Crotalaria</i> sp.	Fabaceae	H	P
<i>Desmodium gyrans</i> DC.	Fabaceae	H	T
<i>Desmodium heterocarpon</i> (L.) DC.	Fabaceae	H	T
<i>Rhynchosia minima</i> (L.) DC.	Fabaceae	C	P/T
<i>Ludwigia prostrata</i> Roxb.	Onagraceae	H	P
<i>Ludwigia adscendens</i> (L.) H. Hara	Onagraceae	H	P
<i>Ludwigia clavellina</i> M. Gómez (<i>Jussiaea repens</i> L.)	Onagraceae	H	P
<i>Ludwigia octovalvis</i> (Jacq.) P.H. Raven (<i>Oenothera octovalvis</i> Jacq.)	Onagraceae	H	P/T
<i>Ludwigia</i> sp.	Onagraceae	H	P
<i>Lindernia cordifolia</i> Merr.	Scrophulariaceae	H	P/T
<i>Lysimachia javanica</i> Blume	Scrophulariaceae	H	P
<i>Limnophila heterophylla</i> (Roxb.) Benth.	Scrophulariaceae	H	P
<i>Lindenbergia</i> sp.	Scrophulariaceae	H	P
<i>Limnophila rugosa</i> (Roth) Merr.	Scrophulariaceae	H	P
<i>Actinostemma tenerum</i> Griff.	Cucurbitaceae	C	P/T
<i>Benincasa hispida</i> (Thunb.) Cogn.	Cucurbitaceae	C	P/T
<i>Zehneria wallichii</i> (C.B. Clarke) C. Jeffrey	Cucurbitaceae	C	T
<i>Zehneria scabra</i> (L.f.) Sond	Cucurbitaceae	C	T
<i>Euryale ferox</i> Salisb.	Nymphaeaceae	H	P
<i>Nymphoides cristata</i> (Roxb.) Kuntze	Nymphaeaceae	H	P
<i>Nymphaea nouchali</i> Burm.f.	Nymphaeaceae	H	P
<i>Nymphaea</i> sp.	Nymphaeaceae	H	P
<i>Hydrocotyle sibthorpioides</i> Lam.	Apiaceae	H	P
<i>Centella asiatica</i> (L.) Urb.	Apiaceae	H	P/T
<i>Oenanthe javanica</i> (Blume) DC.	Apiaceae	H	T
<i>Phyllanthus urinaria</i> L.	Euphorbiaceae	H	T
<i>Glochidion multiloculare</i> (Rottler ex Willd.) Voigt	Euphorbiaceae	S	P/T
<i>Euphorbia hirta</i> L.	Euphorbiaceae	H	P/T
<i>Urena lobata</i> L.	Malvaceae	H	P/T

Scientific Name	Family	Habit	Habitat
<i>Sida rhombifolia</i> L.	Malvaceae	H	T
<i>Sida acuta</i> Burm.f.	Malvaceae	H	P/T
<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	Amaranthaceae	H	P
<i>Alternanthera sessilis</i> (L.) R.Br. ex DC.	Amaranthaceae	H	P/T
<i>Pistia stratiotes</i> L.	Araceae	H	P
<i>Colocasia antiquorum</i> Schott	Araceae	H	P/T
<i>Impatiens balsamina</i> L.	Balsaminaceae	H	P
<i>Impatiens</i> sp.	Balsaminaceae	H	P
<i>Eriocaulon</i> sp.	Eriocaulaceae	H	P
<i>Eriocaulon truncatum</i> Buch.-Ham. ex Mart.	Eriocaulaceae	H	P
<i>Lemna perpusilla</i> Torr.	Lemnaceae	H	P
<i>Spirodela polyrhiza</i> (L.) Schleid.	Lemnaceae	H	P
<i>Cissampelos pareira</i> L.	Menispermaceae	C	T
<i>Cyclea</i> sp.	Menispermaceae	C	T
<i>Salvinia cucullata</i> Roxb.; Wall.	Salviniaceae	F	P
<i>Salvinia molesta</i> D. Mitch.	Salviniaceae	F	P
<i>Solanum torvum</i> Sw.	Solanaceae	S	T
<i>Solanum nigrum</i> L.	Solanaceae	H	P/T
<i>Triumfetta pilosa</i> Roth	Tiliaceae	H	P
<i>Triumfetta rhomboidea</i> Jacq.	Tiliaceae	H	P/T
<i>Utricularia</i> sp.	Utriculariaceae	H	P
<i>Utricularia</i> sp.	Utriculariaceae	H	P
<i>Stachytarpheta jamaicensis</i> Vahl	Verbenaceae	H	P/T
<i>Clerodendrum indicum</i> (L.) Kuntze	Verbenaceae	S	P/T
<i>Hedychium coronarium</i> J. König	Zingiberaceae	H	P
<i>Alpinia allughas</i> Roscoe	Zingiberaceae	H	P
<i>Sagittaria sagittifolia</i> L.	Alismataceae	H	P
<i>Azolla pinnata</i> R. Br.	Azollaceae	F	P
<i>Cassia occidentalis</i> L.	Caesalpiniaceae	H	T
<i>Drymaria cordata</i> (L.) Willd. ex Schult.	Caryophyllaceae	H	P/T
<i>Ceratophyllum demersum</i> L.	Ceratophyllaceae	H	P
<i>Hydrilla verticillata</i> C. Presl	Hydrocharitaceae	H	P
<i>Hydrolea zeylanica</i> (L.) Vahl	Hydrophyllaceae	H	P
<i>Mosla dianthera</i> (Buch.-Ham. ex Roxb.) Maxim.	Lamiaceae	H	P/T
<i>Lygodium flexuosum</i> (L.) Sw.	Lygodiaceae	C	P/T
<i>Rotala rotundifolia</i> (Buch.-Ham. ex Roxb.) Koehne	Lythraceae	H	P
<i>Osbeckia stellata</i> Buch.-Ham. ex D. Don	Melastomataceae	S	P/T
<i>Monochoria vaginalis</i> C. Presl	Monochoriaceae	H	P
<i>Habenaria</i> sp.	Orchidaceae	H	P
<i>Oxalis corniculata</i> L.	Oxalidaceae	H	P/T
<i>Passiflora foetida</i> L.	Passifloraceae	C	P/T
<i>Eichhornia crassipes</i> Solms	Pontederiaceae	H	P
<i>Potamogeton nodosus</i> Poir.	Potamogetonaceae	H	P
<i>Pteris</i> sp.	Pteridaceae	F	P/T
<i>Rubus</i> sp.	Rosaceae	S	P/T
<i>Selaginella amblyphylla</i> Alston	Selaginellaceae	F	P/T
<i>Sparganium erectum</i> L.	Typhaceae	H	P
<i>Vallisneria spiralis</i> L.	Vallisneriaceae	H	P
<i>Ampelocissus latifolia</i> (Roxb.) Planch.	Vitaceae	C	P/T

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