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Research Article

Loktak Lake of the state Manipur: A review to educate the intellectuals and awareness on its biowealth

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ABSTRACT

The floating "Loktak Lake" is the largest fresh water lake of Northeastern region of India situated at the valley of Manipur with an average elevation of 790 m MSL. The lake appears oval in shape with irregular boundary or no definite shoreline specifically because of the floating vegetation known as Phumdi. Phumdi creates a unique ecosystem with nutritive substrate for vegetation floating on the surface of the lake. The major vegetation of Phumdi comprises *Zizania latifolia, Learsia hexandra, Phragmites karka, Saccharum* spp., *Carex* spp., etc. which are also a food plant of the endangered Sangai deer. The study highlights the pollution scenario of the lake, large drainage brought down by rivers, records of aquatic fauna including water birds (migratory and local) fishes, reptiles, amphibians, crustaceans, protozoans, etc. The change in vegetative profile since the primitive age to the recent years of the lake is shown here. The present study attempts to congregate all the possible information of the lake in the past years by the research communities, governmental and non-governmental organization about its physiochemical, hydrological, biodiversity assessment, ethnobotany and therapeutic plants, etc. through literature survey. The study also enlisted the ethnobotanical information of medicinal plants documented so far from the lake. The study helps to analyze the gap of research activities that could taken up for conservation, restoration and preserving the indigenous knowledge of the indigenous communities around the lake. Although, there are enumeration of plants of Loktak lake, pictorial documentation of the flora could help in easy identification of the species as discrepancies in local name could confuse the identity of plant species. The ethnobotany on the therapeutic uses of flora of the lake are enlisted that are recorded so far. Different conservation strategies of the lake ecosystem with community involvement can be thought and work out. Other such gaps and recommendations are described here.

Keywords: Phumdi, ecosystem, medicinal plants, floral diversity, aquatic fauna, pollution, conservation

INTRODUCTION

Loktak Lake of the state Manipur is one of the most unique wetlands with rich diversity of flora, fauna, avifauna, lower vertebrate, invertebrates, and other smaller organisms. It is considered the largest freshwater lake of Northeast India. The lake is unique from other lakes of India because of its floating vegetation upon which the rich biodiversity thrives inclusive of the threatened deer known as "Sangai". The state is the region extended from the lower Eastern Himalayan Range with hilly regions surrounding the valley that is mostly wetlands, marshy areas, lakes, smaller hillocks, plateau, etc. Most part of the valley is plain without much variation in the elevation or has a gentle slope. Loktak Lake (Figure 1) is the major lake situated south of the capital Imphal city at an elevation of 768.5m above MSL (Sharma and Sharma 2009; Das et al. 2015). The lake appears an oval shape with irregular outline, elongated with the direction from north to south and with no definite shoreline and depth because of the floating vegetation "Phumdi" and variation in water levels according to season change respectively (Singh and Moirangleima 2009). The lake is broadly divided into three parts i.e., northern zone, central zone and southern zone. The southern part of the lake comprises of 14 small varying hillocks and some appearing like small islands example Sendra, Thanga and Ithing. It also has small beels 63 smaller lakes that

could observed significant change in water levels during the eighties. These change with the construction of the Ithai Barrage leading to flood these areas permanently (Singh and Moirangleima 2009). Initially the area of the lake was reported to be about 495 Km^2 which in 1966 that gradually decreases to 390 Km^2 during 1979 and further reduced to 246.72 Km^2 in 1988 which showed a fast-shrinking rate. On the other hand, earlier GIS data have shown that the open water area used to be about 84.6 Km^2 in 1989 and was then reduced to about 43.9 Km^2 in 2002. An area of about 1040 Km^2 covers direct catchment area which are under human settlement, agricultural areas and a small portion of forest. The indirect catchment areas are mainly the catchment areas of main rivers like Thoubal, Iril, Imphal, Khuga, Sekmai, etc (Sharma and Sharma 2011; Sharma et al., 2002).

Climatic conditions

The average rainfall of the Central valley including Loktak Lake is about 146.71cm and a relative humidity between 43% - 92% and an average temperature ranging between 5°C - 32°C (Sharma and Sharma 2005). However, the mean temperature of the lake water range between 14.2 °C -28.5 °C. Earlier during 1966, the lake was reported to be expanded in an area of about 495Km^2 and an average depth of 5m. In early 1980's, a profound change in the water level of the lake could be observed during different seasons and the small wetlands and waterbodies could be seen as one during rainy season and could differentiate in dry or winter season. The construction of the Ithai barrage has led to the permanent flooding of the lake and very less change in the water level. Reports have shown that the annual rainfall of the Imphal Valley including Loktak Lake is 1392 mm with an average of 150 rainy days. The temperature of water may vary from 11°C to 25°C depending upon the season and a relative humidity ranging between 51% to 81%. Although the pH of the lake may vary in different parts of the lake, the average pH of the lake may be slightly towards acidic i.e., 6.0 - 7.5. However, the pH range of the Keibul Lamjao National Park (KNLP) is found to very highly acidic with surface pH ranging from 4.5-8.5 and 4.1-8.3 at the bottom of this National Park (LDA and WISA 2002).

Figure 1: View of Loktak lake with mass growth of *Phragmites karka*

Phumdi

The floating mat of vegetation on the surface of the lake is locally known as "Phumdi". They are composed of thick floating mat of vegetation along with soil, organic matter with different layers of decomposition. It is often initiated with the undecomposed organic matter with water hyacinth, Salvinia spp., Cyperus spp., etc. accumulated together. Once started to form, it gradually increases in size and further proliferates until they become thick mature vegetative mat that floats on the surface of the lake. The maximum mature Phumdi has shown about 7 to 8 feet thickness although there could be varying thickness as it depends on the conditions during the formative stage. One-fifth of Phumdi floats and four-fifth of the Phumdi under water provides enough buoyancy to support thatch houses and substrate for the growth of other terrestrial plants. The Phumdi keeps proliferating although the rate of proliferation varies. There is a practice of fishing using Phumdi. Such artificial Phumdi are known as athaphum which are large mostly circular in shape. After the use of athaphum for fishing, they are mostly left abandoned which enhance the proliferation rate to mature Phumdi. Phumdi constitutes about 36% carbon, 2.08% nitrogen, 29% organic matter and 38% of other residues. The core of the mat composed of black detritus and spongy material (Singh and Khundrakpam 2011). Phumdi covers about 70% of the total lake and Keibul Lamjao National Park (KLNP) lies in the southern part of the lake and is the

only floating National Park that is mostly covered by Phumdi with an area of 40 Km^2 out of which 26 Km^2 is covered by Phumdi and the rest consist of small hillocks, island and some open waters. This floating National Park creates a unique ecosystem and forms the base for the growth of rich floral diversity and the habitat of faunal diversity especially the endangered species *Cervus eldii eldii,* a brow-antlered deer locally known as Sangai deer. It is also the state animal. The species is restricted to this unique ecosystem of Keibul Lamjao (Devarani and Basu 2009). The major food plants of this species from the Phumdi of KLNP comprises *Zizania latifolia, Pragmites karka, Saccharum munja, Carex cruciata, Learsia hexandra, Alpinia nigra, Hedychium coronarium*. Other reports of fodder plants of Sangai include *Oenanthe javanica, Leersia hexandra, Persicaria perfoliata, Imperata cylindrica, Oryza rufipogon,* etc. however, they have economic value and so local people collect such plants from the habitat of Sangai and marketed that could lead to habitat destruction (Tuboi 2018; Singh and Khare 2018) The highly preferred food plant among them is *Zizania latifolia* (Meitei et al. 2021). Proliferation of Phumdi has been an issue of the lake. Reports have shown that Phumdi proliferate in a high rate (0.8-2 m) in the main lake and at a slower rate at the KLNP (0.1 m) per 6 months. The high proliferation in the main lake is due to the high nutrient inflow carried down by drainage, rivers, channels, etc. The proliferation rate is speed up with the construction of Ithai Barrage Dam, human habitation, pollutions, increase in the practice of Athaphum fishing. The Ithai Barrage Dam for the purpose of hydroelectric project to generate 105 MW of power by 3 units and to provide 24000 hectares of irrigation facilities (Singh and Khundrakpam 2011).

Hydrology

The main water inflow of the lake is through rivers including Nambul, Ningthoukhong, Nambol, Khujairok, Thongjaorok, Moirang, Sekmai, Potsangbam, Naga, etc. and through precipitation. The highest contribution is seen through streams with about 52% channels contributing 23% and through precipitation contributing 25% (Singh and Moirangleima 2009). Most of the west flowing streams and rivers namely Nambul, Nambol, Awang Khujairok, Thongjaorok, Ningthoukhong, Oinam, Potsangbam, etc. discharge into the lake along with silts, organic and chemical pollutants (Kundagar and Associates 2020). Studies have shown varied Dissolved Oxygen (DO) from different areas and the lowest have been recorded as 2.2 mg/l in September from Keibul and 9.2 mg/l in April from Hibidak. The Biochemical Oxygen Demand (BOD) fluctuates from 3.9 mg/l to 8.5 mg/l (LDA and WISA 2002). In a study in 2002, the nutrient system of the lake revealed to possess a balanced system in comparison with IS:2296(1982). Inorganic phosphate range between (0.09-0.18) mg/l and organic phosphate range between (0.82-1.81) mg/ml. The earlier documentation on the bacterial Standard Plant Count (SPC) of the KNLP was reported to be high ranging between 74000-970000 which is considered to be very high and the MPN of coliform bacteria per 100ml revealed 105-311 and faecal coliform range between 92-180 (LDA and WISA 2002; LDA and WISA 2003). Researchers have worked on the physiochemical nature of the lake by selection of different sites of the lake. In 2012-2013, the sites of Loktak Lake namely Phoubakchao, Laphupat tera, Nongmaikhong, Karang and Ithing were studied and found that the Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) had cross the standard limit given by World Health Organization (WHO). The Free Carbon dioxide (Free CO_2) had shown to be very high during the monsoon season and the Total Dissolved Solids (TDS) of these studied sites revealed to contain mostly inorganic salts and small concentration of organic matter like carbonates, bicarbonates, sulphates, chlorides, nitrates, sodium, potassium, calcium and magnesium (Laishram and Dey 2014; Roy and Majumder. 2019). A study carried out during 2010 – 2013 at KLNP especially at the sites including Keibul, Sargam, Nongmaikhong, Kumbi, Khordak and Komlakhong revealed that the (SPC) for bacteria was 73,500 -96,500; the MPN of coliform bacteria was recorded to be 100-320 per 100 ml; fecal coliform bacteria between the range of 95-200 per 100ml and pH range to be between 3.0-8.0. Studies shown Free CO_2 of the surface of KLNP (2-60 mg/l) was variable than that of the bottom (6-70 mg/l) (Devi et al. 2015). The high pollution has been reported from the northern and southern zones of the lake. The high anthropogenic activities, inflow of huge polluted water, high intensity use of fertilizers for the purpose of agriculture and fishing in the northern zone and the accumulation of the pollutants and poor drainage in the southern zone have been observed (Kundangar and Associates 2020).

Faunal diversity

Loktak Lake represent an important and unique wetland ecosystem with a diverse faunal, avifaunal, and lower organism biodiversity. One of the most important reasons is it provides the habitat for the endangered mammal species i.e., *Cervus eldii eldii* or Sangai. This species can only thrive on the floating vegetation i.e., Phumdi. This species was once considered extinct that slowly found again in its habitat. The 1975 census of Sangai was only 14 individuals gradually increased to 104 in 1991 and further increased to 260 in 2016 (Singh and Khare 2018; Chandra et al. 2021). Many studies have recorded the diversity of fauna and avifauna especially waterfowls, reptiles, amphibians, fishes, mollusks, insects, crustaceans, nematodes, rotifers, protozoans, etc. About 32 species of mammals have been recorded including Sangai deer, Sambhar deer, Barking deer, etc (Sharma et al. 2016; Sharma and Sharma 2018; Chandra et al. 2021). The Loktak Development authority (LDA) in association with Environmental Social Reformation and Sangai Protection Forum (ESRSPF) organized a bird census at the lake between November 2000 to December 2001. About 59 species of birds including 14 waterfowls were recorded in the project. Later a project with respect to conservation of globally threatened migratory bird species of the lake was carried out, about 18 months survey revealed a total of 121 bird species

including 69 waterfowls. During the 2013 census, about 32,000 migratory birds were reportedly sighted. In 2021, research activities revealed about 116 species of birds out of which 21 species of waterfowls were migratory birds from the different parts of the northern hemisphere. Some of the waterfowls sighted include Lesser whistling teal, Black headed gull, White ibis, Gadwall, Pintail, White-eyed pochard, Ruddy shelduck, Tufted duck, Great crested grebe, Wigeon, Eastern sarus crane, Grus Antigone sharpie, Spot-billed Pelican, Greated spotted eagle, etc. Near threatened species like Oriental darter, Black-necked stork and Ferruginous duck were reportedly spotted. (LDA and WISA 1999, LDA and WISA 2002; Devi 2012; Chandra et al. 2021). Chandra and coworkers reported the diversity of 30 species of reptiles, 28 species of amphibians, 15 species of crustaceans, 196 species of insects, 51 species of protozoans, 15 species,15 species of rotifers (Chandra et al. 2021). Earlier report of 2015 revealed the diversity of 176 invertebrates including 150 arthropods, 10 species of molluscs and 249 vertebrates including 6 amphibian species, 106 avifaunal species, 32 species of mammals. About 51 species of Cladocera, a food for many fish species marked the highest number from the freshwater lakes of India have been recorded from the lake. Again, about 186 species of zooplankton have been recorded. Out of the 186 fish species have been identified as food (Sharma 2010; Kangabam et al. 2015). Freshwater fish is a major food of every household of Manipur especially for the people residing in the valley part. The floodplains, wetlands, lakes, ponds and rivers are the major sources of fishes. Loktak Lake is one of the major sources from which fresh water fishes are obtained. Early survey works revealed 53 species of fishes out of which 20 species were found to be rare and 6 species to be vulnerable. Some of the recorded species include *Cyprinus carpio, Labeo rohita, Channa punctatus, Channa striatus, Chana gariepinus, Channa batrachus, Clarias gariepinus*, etc. Later reports showed that about 67 species of fishes were recorded. The habitat of many of the indigenous fish species have been disturbed due to many factors like pollution, over exploitation and other anthropogenic activities. The lake is also a habitat for *Osteobrama belangeri,* an indigenous fish species that was once considered extinct from the wild. Phumdi pose a suitable breeding site for many migratory fishes from the Irrawaddy-Chindwin River in Myanmar. (Kangabam et al. 2015; Chandra et al. 2021).

Floral diversity

The lake has a rich floral biodiversity mainly rich in wetland macrophytes although there is presence of sporadic distribution of tree species, marshy shrubs, herbs, etc. Nautiyal and Chauhan in 2009 documented the vegetation during the last 1650-600 years B.P. through pollen and chemical-based sediment profiling. The study revealed the dominance of grasses aquatic taxa, algal species and herbaceous plants of Amaranthaceae and Tubuliflorae at the vicinity of the lake. It also revealed that the lake would have bordered by marshy plants, sedges and from the family Polygonaceae. Further the evidence of agricultural crops like *Artemesia, Rumex*, Amaranthaceae, Brassicaceae, Caryophyllaceae, etc. was found which inferred the human interference. Sporadic distribution of trees of genus *Holoptelea, Symplocos, Acacia, Grewia, Aspidopterys* and family like Fabaceae were found. There were some evidences of the presence of *Alnus, Corylus* and *Pinus* which indicates the transportation of pollens from high altitude subtropical and temperate regions (Nautiyal and Chauhan 2009). Sharma and his coworkers compiled the sporadic data on the dicotyledonous plants from Loktak lake and several surveys showed 238 species of dicotyledonous plants of 156 genera and 53 families. The study revealed the edibility of the plant parts of 57 plant species. Some of the edible species include *Alternanthera sessilis, Amaranthus spinosus, Benincasa hispida, Centella asiatica, Chenopodium album, Oenanthe javanica, Pseudognaphalium luteo-album, Spondias pinnata, Ipomoea aquatica, Rhus hookeri, Hibiscus cannabinus, Neptunia prostrata, Euryale ferox, Nymphaea pubescens, Polygonum perfoliatum*, etc (Sharma et al. 2002). Sharma in 2014 mentioned 137 monocotyledons belonging to 77 genera from 9 different wetlands including Loktak Lake of Manipur (Sharma 2014). Early survey under the Sustainable Development and Development and Water Resources Management of Loktak Lake (SDWRML) project enumerated about 162 species of plants and 33 economically important plants from Phumdis of the lake and the survey of the Phumdis from KLNP showed 135 plant species which comprises mainly aquatic and semi-aquatic plants. Of these, some dominant flora of the Phumdi comprises *Brachiaria mutica, Cyperus sp., Echinochloa stagnina, Phragmites karka, Saccharum munja, Salvinia spp., Zizania latifolia*, etc. The survey also enumerated 22 economically important plant species that was used by the local inhabitants for food, fodder and for therapeutic uses. Devi and her coworkers documented about 89 species of ethnobotanical plants. Other than the Phumdi, a total of 145 plant species of aquatic and semi-aquatic plants have been recorded during the survey (Singh et al. 2000; LDA and WISA 2002; Singh 2002; Devi et al. 2022). About 233 species of macrophytes have been documented from the Lake (Kangabam et al. 2015). A survey carried out for macrophytes from the Phumdi of KLNP in 2010-2012, revealed 85 dominant species from areas including Kumbi, Khordak, Keibul, Toya, Nongmaithem and Sargam. Some of the dominant macrophytes from these areas include *Ageratum conyzoides, Hedychium coronarium, Leersia hexandra, Oenanthe javanica, Phragmites karka, Polygonum sagittatum, Saccharum munja, Zizania latifolia,* etc (Devi and Singh 2016). Slowly researchers grabbed the attention for documenting a different aspect of the plants found in the lake. Selective food plants or vegetables having therapeutic values have been documented from the lake. Such plants including *Alpinia nigra, Hedychium coronarium, Trapa natans, Polygonum barbatum, Ipomoea aquatica, Neptunia oleracea, Euryale ferox, Nelumbo nucifera* and *Nymphaea alba* (Devi et al. 2017). In 2019, Laishram and his coworkers documented the ritualistic and cultural values of 22 plant species. During the year 2018-2019, Devi and her coworkers conducted a survey and gathered the information of traditional usage of 30 aquatic plants. Out of these plants, some common edible aquatic

plants have been listed like *Alocasia cuculata, Cyperus haspan, Enhydra fluctuans, Eryngium foetidum, Euryale ferox, Hedichium coronarium, Houttuynia cordata, Ipomoea aquatica, Nelumbo nucifera, Neptunia oleraceae, Oenanthe javanica, Polygonum barbatum, Sagittaria sagittifolia, Trapa natans* and *Zizania latifolia*. Apart from this, income generating and providing livelihood from the bioresources of the lake has been documented. This identified 16 species of vegetables, 8 species of fodder plants, 6 species of fuelwoods, 3 species of grasses used for making thatch, 2 species for making handicraft materials and 12 species of medicinal plants. Others reports of income generation plants have been recorded from Nambol market of about 30 species out of which 27 species are common sold by the vendors. Another report shows the utilization of 23 species as food plants and some common genus *Zizania, Polygonum, Nelumbo, Nymphaea*, etc.,18 species of fodder plants including *Zizania, Alternanthera, Brachiaria, Echinocloa, Capilipedium*, etc., 2 fuel plants like *Phragmites* and *Saccharum*, 8 species of building materials like *Arundo*, *Phragmites, Zizania, Saccharum,* etc. 11 culturally important plants like *Echinocloa, Nymphaea, Nelumbo*, etc. and 17 medicinal plants like *Fuirena, Polygonum, Impatiens*, etc. (Bhatt and Vania 2016; Laishram et al. 2019; Devi et al. 2021; Laishram 2021; Devi et al. 2022b). In consideration of phytosociological or ecological aspects of the wetland flora of the lake, a study revealed 24 wetland plant species belonging to 23 genera and 17 families. The study further compared the iron accumulation in four plants and found the highest in *Pistia stratiotes* followed by *Lemna minor, Eichhornia crassipes* and *Salvinia cucullata* (Rai and Singh 2020).

Lake dependency

The local people inhabiting around the catchment areas of the lake largely depend on the bioresources of the lake. The major communities residing around the catchment areas are dominant of Meitei community however there are other communities like Meitei-Pangal (Muslim) in some areas followed by Christians (tribal) communities that lie around the lake with various professions including plant collector, aquaculture, farmer, forage collector, pisciculture and other professions. Earlier studies have revealed that about 12 villages and 52 settlements are located around the lake with a population of about 2,20,017 people or in other words 9% of the state population according to the 2011 Census report (Singh and Moirangleima 2012; Kangabam et al. 2015; Bhatt and Vania 2016; Devi 2017). Research works from KLNP areas like Keibul, Nongmaikhong, Kumbi, Khordak, Komlakhong, Sargam, etc. revealed that maximum profession belongs to the plant collector group followed by forest guard, agriculture, aquaculture, farmer, pisciculture, etc (Devi et al. 2015). Fishing is one of the main occupations for the people residing near the lake. It is also because fish has a high economic value not only near the lake but also for the main valley of the state. This is because most people of the valley are constant consumers of fish. The diversity of many fish species, some species of mollusks, prawns, fresh water shells are also marketed well in different parts of the valley. Loktak plays a major role for the source of freshwater fishes, prawns, etc. Athaphum practice of fishing is an old practice where the Phumdis are cut and joined to desired shaped especially as large circles with a diameter of about 152.4 m. The fishermen attached nets surrounding the circumference of the Athaphum which are weigh down till it touches the lake floor. This restricts the movement of fishes and make it easier for fishing (Devi et al. 2022a). The culture of fish farming through Athaphum practice intensified between 2000-2005 as the construction of Ithai Barrage flooded the lake permanently. Many livelihoods had shifted towards fishing farming in the above-mentioned way in open water lake and it increased to a certain level. The remote sensing data revealed that the number of athaphum tremendously increased from 217 in 92 hectares in 1989 to 2286 in 967 hectares in 1999 and 2642 in 1118 hectares in 2002 that the government had to forcefully remove them from the lake (Singh and Khundrakpam 2011). Again, the lake periphery are mostly wetlands, marshy and swampy areas which was later converted to agricultural lands and fish farms. Collection of vegetables, snails, prawn, oysters, eels, thatching material, handicraft material, fodder, fuelwood, medicinal plants, etc. have been observed from the lake for personal use as well as a means of livelihood (Laishram and Dey 2014).

Medicinal plants

So far, 64 species of medicinal plants have been clearly listed out of which 54 species are documented with medicinal uses. Some species of plants have been shown to have diverse therapeutic use using different plant parts of the same plant or mixing with other medicinal plants in a proper amount and ways. Such plants include *Acorus calamus, Amaranthus spinosus, Enhydra fluctuans, Equisetum debile, Eryngium foetidum, Euryale ferox, Hedychium coronarium, Houttuynia cordata, Ipomoea aquatica, Jussiaea repens, Leucas aspera, Nelumbo nucifera, Neptunia oleracea, Oenanthe javanica, Plantago erosa, Polygonum barbatum, Polygonum posumbu, Sagittaria sagittifolia* and *Trapa natans*. The list of medicinal plants so far been reported with its therapeutic values are listed in Table 1.

Table 1: Medicinal Plants reported from Loktak Lake

Botanical Name	Family	Uses	Source
Acorus calamus	Acoraceae	Rhizome used in cough, stomach ulcer, fever, biliousness and also applied externally to bleeding piles; The small rhizome cut to small piece and worn by children as neck necklace, the smell relieves cough, chest congestion and fever; Rhizome chewed can get relieve from asthma; steam heated combination of the rhizome, leaves of *Cannabis sativa* and *Datura stramonium* applied as foment relieve from muscular pain	Jain et al. (2007); Devi et al. (2021)
Ageratum conyzoides	Asteraceae	Leaf paste used in cuts and wounds; Leaf use to prepare hair lotion; shoot mix with salt used in dysentery	Jain et al. (2007)
Alocasia cucullata	Araceae	Fresh petiole juice applied to cuts and injuries; Grated corm use as an ingredient of traditional salad called Singju	Devi et al. (2021)
Alpinia nigra	Zingiberaceae	Consuming the tender culms helps to treat gout and colic problems	Laishram (2021)
Alternanthera philoxeroides	Amaranthaceae	Shoot mix with salt and taken to cure dysentery	Jain et al. (2007)
Amaranthus spinosus	Amaranthaceae	Root paste applied to bruises and also treat leprosy; the combination of the plant mix with *Mimosa pudica* as a steam heated packet applied as foment to reduce rheumatic pains, boiled plant is consumed to treat constipation; plant extract mixed with sugar is use to treat leucorrhoea, jaundice and hemorrhoids; Pounded plant shoot mix with egg is used to treat skin burns and mix with lime is use to treat skin sores	Devi et al. (2021)
Amomum aromaticum	Zingiberaceae	Seed consumed to control high blood pressure	Jain et al. (2007); Devi et al. (2022b)
Arundo donax	Poaceae	Tender shoot mixed with honey used to cure intestinal worms, typhoid and pneumonia in children	Jain et al. (2007)
Cardamine hirsuta	Brassicaceae	Whole plant cooked and taken to reduce urinary problems	Jain et al. (2007)
Centella asiatica	Apiaceae	Whole plant mix with *Oxalis corniculata* and *Ocimum sanctum* taken to fight dysentery; Whole plant mix with sugarcane molasses taken to treat urinary calculus	Jain et al. (2007); Devi et al. (2022b)
Chenopodium album	Amaranthaceae	Not given	Devi et al. (2022a)
Colocasia cucullata	Araceae	Petiole juice applied to cuts and wounds	Jain et al. (2007)
Colocasia esculenta	Araceae	Petiole juice applied to cuts and wounds; leaf boiled with milk and taken to enhance pregnancy; It is also use as an antidote for snakebite and scorpion sting	Jain et al. (2007); Devi et al. (2017)
Commelina benghalensis	Commelinaceae	Leaf paste applied on cuts and wounds; hot fermented plant wrapped on banana leaf sniff to treat tonsilitis; leaf used to treat muscular sprains	Jain et al. (2007)
Crassocephalum crepidioides	Asteraceae	Not given	Laishram (2021)
Cynodon dactylon	Poaceae	Decoction of the stolon taken with honey used to treat strangury; hot stolon chewed to reduce dysmenorrhoea	Jain et al. (2007)
Cyperus haspan	Cyperaceae	Rhizome paste mix with honey used to treat fever and bronchitis; Boiled tuber is consumed in diabetes	Jain et al. (2007); Devi et al. (2021)
Drymaria cordata	Caryophyllaceae	Hot plant extract applied as poultice in muscular sprains; plant extract along with honey to treat cough and dysentery	Jain et al. (2007)
Eclipta alba	Asteraceae	Plant extract mix with charcoal applied to treat toothache; Leaf extract mix with honey taken to treat cough and fever	Jain et al. (2007)
Eclipta prostrata	Asteraceae	Not given	Laishram (2021)
Enhydra fluctuans	Asteraceae	Cooked with less water to treat calculus and other urinary problems; also taken as antidote to food poisoning; plant mixed with mustard oil to treat scabies and skin diseases; boiled plant is consumed to	Jain et al. (2007)

		treat diabetes; plant decoction taken to treat diarrhoea, dysentery; fresh plant taken as antidote in food poisoning	
Equisetum debile	Equisetaceae	Boiled plant applied to dropsy and hysteria; Boiled plant is consumed to treat haematuria; the boiled plant mix of the plant with bark of *Terminalia arjuna* and *Caesalpinia pulcherrima* is externally applied to treat backache, rheumatic pain and sciatica; The plant boiled with root of papaya id taken in diabetes	Devi et al. (2021)
Eryngium foetidum	Apiaceae	The plant is consumed or paste is applied externally in rheumatic pains; the plant mix with *Allium sativum, A. ascalonicum* or *A cepa* and root of *Plantago erosa* is applied in muscular sprains and body pain; Boiled plant mix with sugar is taken to treat kidney stones; the leaves of the plant with inflorescence of *Elsholtzia blanda* boiled with salt is used to gargle in tonsilitis; leaves of the plant mix with bulbs of *Allium sativum* and fermented fish is consumed to control high blood pressure; the plant mix with rhizome of *Zingiber officinale,* bulb of *Allium sativum* and seeds of Brassica juncea and fermented fish crushed together and massage to treat paralysis; the plant is mixed with other vegetable and consume in epilepsy and paralysis	Devi et al. (2021)
Euryale ferox	Nymphaeaceae	Rhizome is used for the treatment of dropsy, jaundice and gonorrhoea; the rhizome boiled with a small piece of alum is used for the treatment of scabies; petiole juice is applied in burns and boils; raw petiole is consumed in abdominal inflammation; fruit is consumed in diabetes; seed flour is consumed and helps in digestion. It also treats leucorrhoea and postpartum weakness	Devi et al. (2021)
Fagopyrum esculentum	Polygonaceae	Cooked tender shoots taken in diabetes; seed paste with honey in empty stomach to treat stomach ulcer	Jain et al. (2007)
Hedychium coronarium	Zingiberaceae	Rhizome cooked and eaten as an appetizer and also used to treat cough and fever; consuming the tender culms help to treat stomach, liver problems; it is also used as a tonic and helps reduce inflammation and as an antidote in snakebite	Jain et al. (2007); Devi et al. (2022a); Devi et al. (2022b)
Hedyotis auriculata	Rubiaceae	Leaf juice taken to treat jaundice; hot leaves applied in muscular sprains	Jain et al. (2007) Devi et al. (2021)
Houttuynia cordata	Saururaceae	The crushed leaf extract is consumed to treat diarrhoea and dysentery; crushed rhizome can be consumed in stomach ulcers and applied on skin diseases; consumption of boiled rhizome reduces muscular pain; Consuming fresh leaves helps to treat measles, gonorrhoea and eye problems; crushed leaves can be applied to boils, sore skins, snakebites and other skin disorders; leaves decoction is used for the treatment of cough, fever, enteritis and even cancer; consuming the plant raw help to strengthen immune system	Devi et al. (2021)
Hydrocotyle sibthorpioides	Araliaceae	Decoction of leaf extract used to treat cough, fever and jaundice	Jain et al. (2007); Devi et al. (2021)
Ipomoea aquatica	Convolvulaceae	Decoction of shoots and leaves used as droplets to treat otorrhoea and retinitis; The plant is consumed raw to treat cardiovascular diseases and paralysis; consuming the plant helps in blood circulation, debility and also used as a purgative; plant juice mix with salt applied to treat ringworm; plant paste applied as poultice in swelling joints and insect bites; plant paste applied to acne and pimples	Jain et al. (2007)
Iris bakeri	Iridaceae	Rhizome paste applied as coolant and also use to treat hysteria	Jain et al. (2007)
Jussiaea repens	Onagraceae	Leaf paste applied on boils and burns; cooked shoots eaten to treat strangury; boiled plant is consumed to treat diabetes and menstrual disorder; Plant paste	Jain et al. (2007); Devi et al. (2022b)

		applied externally to reduce inflammation, body pain and skin infections like ringworms; the plant paste also acts as coolant and applied to boils and burns; the plant juice can be taken orally to reduce urinary problems	Devi et al. (2021)
Jussiaea suffruticosa	Onagraceae	Leaf paste mix with common salt applied to aching gum and also eaten to treat strangury	Jain et al. (2007)
Knoxia roxburghii	Rubiaceae	Not given	Laishram (2021)
Leucas aspera	Lamiaceae	Consumption of the plant helps to treat piles, menstrual disorders, diarrhoea, dysentery; the boiled plant extract is taken to get relief from bronchitis, asthma and body pain; The crushed plant extract is externally applied for the treatment of scabies, headache; consuming leaves, flowers and young stems help purify; The plant juice is applied to poisonous insect bite, painful swellings and skin eruptions; consuming raw flower reduces cold and cough	Devi et al. (2021)
Leucas lavandulifolia	Lamiaceae	Not given	Laishram (2021)
Ludwigia adscendens	Onagraceae	Not given	Laishram (2021)
Marsilea minuta	Marsileaceae	Plant decoction taken to treat strangury; root paste applied externally to eczema	Jain et al. (2007) Devi et al. (2021)
Mukia maderaspatana	Cucurbitaceae	Not given	Laishram (2021)
Nasturtium indicum		Decoction taken to treat strangury; cooked and consume to treat diabetes and dysentery; shoot decoction is taken in empty stomach to treat strangury	Jain et al. (2007) Devi et al. (2021)
Nelumbo nucifera	Nelumbonaceae	Tender leaf consumed as salad to treat strangury; leaf petiole consumed raw to treat stomach ulcer; flower used in vertigo; rhizome consumed to treat diabetes; raw seed kernel good for eyes; tender shoot boiled with *Phyllanthus fraternus* is used for the treatment of diabetes; decoction of the flower is taken for blood purification: root, flower and seeds are also used for the treatment of diarrhoea, cholera, liver problems, cardiac complaints, piles, leprosy and bleeding; crushed root is applied to ringworms and other skin infections; pounded leaves applied on forehead reduces headache; consuming raw petiole helps to reduce stomach problems and urinate well	Jain et al. (2007); Devi et al. (2022a) Devi et al. (2021)
Neptunia oleracea	Mimosaceae	Boiled plant with little salt is used to treat stomach ulcers and other stomach problems like parasitic infection; the crushed plant extract is applied as ear drop in otitis and glandular swellings at the neck; the decoction of the stem along with *Centella asiatica* and inflorescence of *Elsholtzia blanda* is given orally to treat worm infection in children; the leaf paste mix with *Mimosa pudica* is applied to boils and skin diseases; the pounded plant paste is used for the treatment of syphilis ulcers or necrosis of the nose	Laishram (2021); Devi et al. (2022b); Devi et al. (2021) Devi et al. (2017)
Nymphaea stellata	Nymphaeaceae	Fresh petiole paste mix with cumin seed powder, salt, butter and honey to treat dysmenorrhoea	Jain et al. (2007); Devi et al. (2021)
Nymphoides indica	Menyanthaceae	Leaf paste applied to cuts and wounds; rhizome paste along with honey use to treat diuresis	Jain et al. (2007); Devi et al. (2021); Laishram (2021)
Oenanthe javanica	Apiaceae	Consumed fresh as salads in dyspepsia; shoot decoction taken in diuresis; the filtrate used to treat otorrhoea; Plant extract is taken to control high blood pressure and diabetes; leaves consume as appetizers; fresh leaf juice taken for the treatment of liver diseases	Jain et al. (2007); Devi et al. (2021)

		and abdominal pain; Consuming it helps acts as a tonic for ulcer and other stomach problems	
Pistia stratiotes	Araceae	Plant paste applied to boils and burns	Jain et al. (2007)
Plantago erosa	Plantaginaceae	Whole plant boiled and taken orally reduces urinary problems, kidney stones and gall bladder stones, inflammation and constipation; plant extract also taken to treat chronic fever; plant paste mix with bulbs of *Allium sativum, A. ascalonicum* and *Eryngium foetidum* is used for massaging in rheumatic pains and muscular pains; leave extract mix with honey and taken orally reduces body temperature in fever; seeds are consumed in genito-urinary tract complains, diarrhoea, dysentery, etc.	Devi et al. (2022b); Devi et al. (2021)
Polygonum barbatum	Polygonaceae	Fresh tender shoot cooked and consumed to treat stomach disorder and constipation; seed powder soaked in water and taken to treat strangury; leaf paste used to treat skin infection and cutaneous infection; the leaf and shoot decoction is taken to treat ulcers; boiled leaves extract taken to treat stomach problems like diarrhoea, dysentery, colic problems	Jain et al. (2007); Devi et al. (2021); Devi et al. (2017)
Polygonum hydropiper	Polygonaceae	Crushed shoot applied on forehead to reduce fever; seed powder soaked in lukewarm water and taken to treat strangury	Jain et al. (2007)
Polygonum minus	Polygonaceae	Plant shoot decoction is taken to treat strangury	Jain et al. (2007)
Polygonum molle	Polygonaceae	Fresh shoot applied on wounds and eczema	Jain et al. (2007)
Polygonum orientale	Polygonaceae	Plant decoction taken to treat strangury; seed powder soaked in water and taken to treat cystitis	Jain et al. (2007)
Polygonum perfoliatum	Polygonaceae	Hot leaf wrapped with banana leaf and applied to wounds, injuries and muscular sprain; the seed paste is used as antidote in snakebite	Jain et al. (2007); Devi et al. (2021)
Polygonum posumbu	Polygonaceae	Leaves cooked with *Puntius phutunio* for the treatment of diarrhoea and stomach complaints; crushed plant extract applied to treat skin allergies; The mix juice of this plant with *Eryngium foetidum* and *Leucas aspera* is applied externally to treat weak mscle and paralysis; consuming raw shoot controls high blood pressure; leave juice mix with warm water is use for the treatment of gastric problems; Consuming the culms helps in digestion	Devi et al. (2021); devi et al. (2017);
Pteridium aquilinum	Dennstaedtiaceae	Not given	Laishram (2021)
Ranunculus sceleratus	Ranunculaceae	Slightly burnt leaves and applied to treat gout; Boiled plant paste applied to treat blisters and eczema	Jain et al. (2007)
Rotala rotundifolia	Lythraceae	Plant decoction used to treat strangury; plant paste applied to treat eczema	Jain et al. (2007)
Rumex maritimus	Polygonaceae	Leaf paste applied to burns and injuries; Stem heated and squeezed juice and applied in ear to treat ottorrhoea	Jain et al. (2007)
Sagittaria sagittifolia	Alismataceae	Fresh root paste mix with honey to treat cough; boiled rootstock paste applied externally for the treatment of skin diseases like scabies and itches; leave powder reduces itchiness; leave powder mix with honey reduces sore throat and inflammation of the breast; boiled vegetative part of the plant is consumed to reduce hypertension	Jain et al. (2007); Devi et al. (2021)
Stellaria media	Caryophyllaceae	Not given	Devi et al. (2022b)
Stephania glabra	Menispermaceae	Not given	Laishram (2021)
Tinospora sinensis	Menispermaceae	Not given	Laishram (2021)
Trapa natans	Trapaceae	Plant is consumed and helps to improve blood circulation and to treat leucorrhoea; fruits are astringent and are used as a coolant; fruit is considered a tonic and appetizer and helps to reduce	Devi et al. (2022b); Devi et al. (2021);

		constipation, relieves thirst, urinary problems and weakness	Devi et al. (2017)
Zizania latifolia		The plant paste is applied to burns and injuries; consuming culms, rhizome and grains are considered to be good in anaemia, heart, kidney and liver problems	Devi et al. (2021)

GAPS AND RECOMMENDATION

Loktak Lake is a lake with unique ecosystem because of its floating vegetation that supports a large diversity of plants and a habitat for different faunal species especially Cervus *eldii eldii*. Keibul Lamjao National Park (KLNP) is also the only floating National Park in the world. Earlier research activities have listed the diversity of a section of angiosperms like dicotyledons of the lake. Other scientists and researchers have documented the diversity of plants of Loktak lake from selected areas of the lake sometimes with the ethnobotanical values. There are also documentations on the faunal species especially fish species and lower organisms like Cladocera or rotifers, etc. Many have bought to light regarding the issues related to Phumdi proliferation and how it affected the ecosystem and lake dwellers.

Suggestions regarding the management of the lake have also been highlighted. Nevertheless, some of the gaps of research are listed below:

1. More research activities could be conducted on the biodiversity of flora, fauna, avifauna, other aquatic organisms from time to time to provide the better idea of the biodiversity of the lake. This could also help to work on other aspects of research for example to understand the health of the ecosystem.
2. Although, there are enumeration of plants of Loktak lake, pictorial documentation of the flora could help in easy identification of the species as discrepancies in local name could confuse the identity of plant species.
3. The relationship of the existing flora, aquatic fauna, other terrestrial animals, and lower organisms could be found out to bring a wholistic idea and help in making strategies for conservation.
4. Different conservation strategies of the lake ecosystem with community involvement can be thought and work out.
5. There are patches of work documented on the ethnobotanical uses of the flora of Loktak lake. More research activities could be carried out to explore the ethnobotanical values especially food and medicinal values by dividing the lake into different sections and work collaboratively to cover the lake at a time.
6. Scientific validation of the therapeutic and food values could be done for more authentication of the uses of the respective plants of the lake.
7. The increasing health problems of the world and antimicrobial resistance that has become a major issue in the present time could find some solution. The phytochemical compounds of the potentials medicinal plants could be identified for future drug development.
8. The less known plants having nutraceutical values could be documented and create an awareness to people in others parts of the world so that people could be benefitted and serve the issue of hunger and malnutrition that is also a major problem of the world.
9. Toxicity test could be done for the claimed food and medicinal plants and calibrate the quantity of use especially for medicinal plants.
10. Considering the livelihood of the people around the lake, plants of the lake having high species richness and with food and medicinal values could be considered for value addition of the plant product through sustainable way of collection.

REFERENCES

1. Bhatt JR and Vania F. (2016). The Economics of Ecosystem and Biodiversity – India Initiative: Facsheets. GIZ India.
2. Chandra K, Bharti D, Kumar S, Raghunathan C, Gupta D, Alfred JRB and Chowdhury BR. (2021). Faunal Diversity in Ramsar Wetlands of India. Jointly Published by the Director, Zoological Survey of India and Wetland Division, Ministry of Environment, Forest and Climate Change, Government of India. 1-292.
3. Das A, Idapuganti RG, Makdoh B, Sarkar D, Layek J, Mandal S and Lal R. (2015). Managing Soils of the Lower Hamalayas. Encyclopedia of soil science. 1-6.
4. Devi KN. (2017). A Wetland and a lifeline: the importance of Loktak Lake for Manipur, India. Journal of Innovation and Inclusive Development. 2(1):30-35.
5. Devi MH and Singh PK. (2016). Diversity of habitats of Macrophytes in Keibul Lamjao National Park (KLNP), a floating mat (Phumdi) environment of Loktak Lake, Manipur, India. IRA-International Journal of Applied Sciences. 3(2):157-179.
6. Devi MH, Singh PK and Choudhury MD. (2015). Water quality and socio-economic studies of Phumdi environment of Keibul Lamjao National Park, Loktak Make, Manipur, India. Frontiers in Environmental Microbiology. 1(1): 1-8.
7. Devi OA, Saikia MB and Ningthoujam SS. (2021). Traditional usage of underutilized aquatic plants flound in the Imphal valley of Manipur. Research square. 1-35.

8. Devi OS. (2012). Conservation of Globally Threatened Migratory Bird Species of Loktak Lake, A Ramsar site in Manipur, India. Project submitted to Oriental Bird Club, UK. Conservation Grant No. P916.
9. Devi RS, Satapathy KB and Kumar S. (2022a). Ethnobotanical Plants of Phumdi, Loktak Lake, Manipur, India. Asian Pacific Journal of Health Sciences. 9(4):77-80.
10. Devi SN, Singh KSJRF and Chanu PO. (2017). Traditional vegetables with medicinal value from Loktak Lake shore and threats to the community around. International Journal of Current Research. 9(5): 50974-50978.
11. Devi TS, Devi MH, Singh SS, Thokchom R and Singh PK. (2022b). Studies on the income-generating wild edible wetland plants traditionally consumed by the people of Bishnupur district, Manipur. 11(11): 915-920.
12. Jain A, Roshnibala S, Kanjilal PB, Singh RS and Singh HB. (2007). Aquatic/ semi-aquatic plants used in herbal remedies in the wetlands of Manipur, Northeastern India. Indian Journal of Traditional Knowledge. 6(2): 346-351.
13. Kangabam RD, Boominathan SD and Govindaraju M. (2015). Ecology, disturbance and restoration of Loktak Lake in Indo-Burma Biodiversity Hotspot – An overview. NeBIO. 6(2): 9-15.
14. Kundagar MRD and Associates. (2020). Management Action Plan of Loktak Lake, An Overview. FM2 Consultants
15. Laishram J and Dey M. (2014). Water quality status of Loktak Lake, Manipur, Northeast India and need for conservation measures: A study on five selected villages. International Journal of Scientific and Research Publications. 4(6): 1-6.
16. Laishram J, Dey M and Thokchom R. (2019). Bioresources in rituals and cultural life of the people of five villages in and around the Loktak Lake, Manipur and their conservation. The Pharma Innovation Journal. 8(6):1234-1237.
17. Laishram J. (2021). A study on the bioresources of the Loktak Lake, Manipur (India) for livelihood by the people living in five villages located in and around the lake. Current World Environment. 16(3): 928-941.
18. LDA (Loktak Development Authority) and WISA (Wetlands International-South Asia). (1999). Loktak Newsletter. Vol. 1. LDA and WISA, New Delhi.
19. LDA (Loktak Development Authority) and WISA (Wetlands International-South Asia). (2002). Loktak Newsletter. Vol. 2. LDA and WISA, New Delhi.
20. LDA (Loktak Development Authority) and WISA (Wetlands International-South Asia). (2003). Loktak Newsletter. Vol. 3. LDA and WISA, New Delhi.
21. Meitei AL, Sen S and Meetei TR. (2021). Studies on feeding behavior of Sangai deer (Rucervus eldii eldii) in Keibul Lamjao National Park, Manipur (India). Journal of Entomology and Zoology Studies. 9(2):1163-1167.
22. Nautiyal CM and Chauhan MS. (2009). Late Holocene vegetation and climate change in Loktak Lake region, Manipur, based on pollen and chemical evidence. The Palaeobotanist 58: 21-28.
23. Rai PK and Singh MM. (2020). Wetland Plants' Chemical Ecology for Iron of a Ramsar site in an Indo-Burma Hotspot: In-situ bioaccumulation and phytoremediation Implications. Nature Environment and Pollution Technology. 19(4):1607-1615.
24. Roy R and Majumder M. (2019). Assessment of water quality trends in Loktak Lake, Manipur, India. Environmental Earth Sciences. 78(383):1-12.
25. Sharma BK and Sharma S. (2009). Faunal diversity of Cladocera (Crustacea: Branchiopoda) of Loktak Lake (A Ramsar site), Manipur (N.E. India). Journal of the Bombay Natural History Society. 106(2): 156-161.
26. Sharma BK and Sharma S. (2011). Zooplankton diversity of Loktak Lake, Manipur, India. Journal of Threatened Taxa. 3(5):1745-1755.
27. Sharma BK and Sharma S. (2018). Loktak Lake, Manipur, revisited: A Ramsar site as the rotifer (Rotifer: Eurotatoria) biodiversity hot-spot of the Indian sub-region. Bonn zoological Bulletin. 67(1): 5-13.
28. Sharma BK, Haokip TP and Sharma S. (2016). Loktak Lake, Manipur, northeast India: a Ramsar site with rich rotifer (Rotifera: Eurotatoria) diversity and its meta-analysis. International Journal of Aquatic Biology. 4(2):69-79.
29. Sharma BK. (2010). Diversity of Cladocera (Crustacea: Branchiopoda) in floodplain lakes of Manipur, Northeastern India. Records of Zoological survey of India. 110(4):19-29.
30. Sharma HM, Devi AR and Sharma BM. (2002). Plant Diversity of the Loktak Lake (Manipur) II: Dicotyledons. Ecology and Coservation of Lakes, Reservoirs and Rivers. 544-555. ISBN: 81-85771-47-2.
31. Sharma HM. (2014). Wetland Flora of Manipur: I Monocotyledonous Plants. Proceedings of Two Day National Seminar on "Recent Advances in Science", 7-8 March. D.M. College of Science, Imphal.
32. Singh AL and Khundrakpam ML. (2011). Phumdi proliferation: a case study of Loktak Lake, Manipur. Water and Environment Journal. 25: 99-105.
33. Singh AL and Moirangleima K. (2009). Shrinking water area in the wetlands of the central valley of Manipur. The open renewable energy Journal. 2(1-5).
34. Singh AL and Moirangleima K. (2012). Dying wetlands: A threat to livelihoods of Loktak Lake Dwellers. Greener Journal of Physical Sciences. 2(4): 107-116.

35. Singh M and Khare N. (2018). Distribution, status and conservation of Sangai deer (*Rucervus eldii eldii*) in Manipur, India. Journal of Entomology and Zoology Studies. 6(5):732-737.
36. Singh NP, Chauhan AS and Mondal MS. (2000). Flora of Manipur Vol. I. Botanical Survey of India, Culcutta.
37. Singh PK. (2002). Some ethnobotanically important plants available on the phumdis of Loktak Lake. In Management of Phumdis in Loktak Lake. Edited by Trisal CL and Manihar T, Loktak Development Authority, Manipur. 37-42.
38. Tuboi C, Irengbam M and Hussain SA. (2018). Seasonal variations in the water quality of a tropical wetland dominated by floating meadows and its implication for conservation of Ramsar wetlands. Physics and Chemistry of the Earth A/B/C. 103:107-114.