



Feeding Habitats Selection of Waterbirds in Loktak Lake, Manipur, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Waterbirds utilized the wetland primarily as a foraging ground and the significant predator-prey relationship between birds and fish, plants and benthic invertebrates can observe. Water depth is also an important variable factor that affects the use of wetland habitats by waterbirds for their foraging. The relationship based on water depth directly determines the accessibility of foraging habitats for waterbirds because of the restrictions of their morphology and feeding resources. The present study deals on foraging habitats of waterbirds in three guilds of Loktak Lake, Manipur. A total of 20 species of waterbirds, including resident and migratory, were analyzed for their feeding and foraging habitats. The species of the first and second guild are mainly non-vegetarian that

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feeds on fish and aquatic vertebrates. In the third guild, the maximum population was observed in Lesser Whistling Duck *Dendrocygna javanica*. Many waterfowls mostly forage the third guild that feeds on floating macrophytic vegetation. The main objectives of the study was to documented and analyse the feeding behavior and foraging habitats of waterbirds in the Loktak Lake.

Keywords: Waterbirds; feeding; foraging; Loktak Lake; Manipur.

1. INTRODUCTION

Invertebrate production in the water column may ultimately depend upon water temperatures and the ability of the wetland to produce algae. Cold water temperatures may not be hospitable for small animals and plants that some wetland birds eat. However, water that is too warm also might not produce foods that some birds prefer. Based on their feeding ecology, waterbirds of Loktak wetland can be categorized into the following types namely – piscivores, insectivores, and plantivores + herbivores + benthivores. Since the last category including ducks also consume benthic invertebrates, only two major guilds have been considered i.e. piscivores and benthivores. The benthivores comprising primarily shorebirds and ducks contributed to the majority of the waterbird population. Waterbird populations and densities increased concomitantly with that the total availability of benthic invertebrates, nematodes, crustaceans, and mollusks. Waterbirds utilized the wetland primarily as a foraging ground as can be observed by the significant predator-prey relationship between birds and benthic invertebrates. Migratory birds are known to feed a high-protein diet on their wintering ground [1].

Further study is required in this regard also. Waterbird congregations often feed in mixed assemblages [2-4].

Many studies have indicated that water depth is an important variable affecting the use of wetland habitats by waterbirds [5]. The relationship based on water depth directly determines the accessibility of foraging habitats for waterbirds because of the restrictions of bird morphology, such as the length of the tarsometatarsal for wading birds [6,7] or necks for dabbling ducks [8]. Larger species with longer necks, bills, and legs can feed in deeper habitats than smaller taxa. Non-diving waterbirds, such as wading and dabbling birds, generally require shallow water to forage and their access to foraging habitat is limited by water depth. In contrast, the diving waterbirds require deep water, and their access to foraging habitat is limited by the minimum water.

In addition to limiting access to foraging habitats, water depth affects the net energy intake of waterbirds because foraging efficiency decreases with increasing water depth. According to Gawlik [9] indicated that for wading birds that forage on prey in the water column, the locomotion of the birds might be slowed in deep

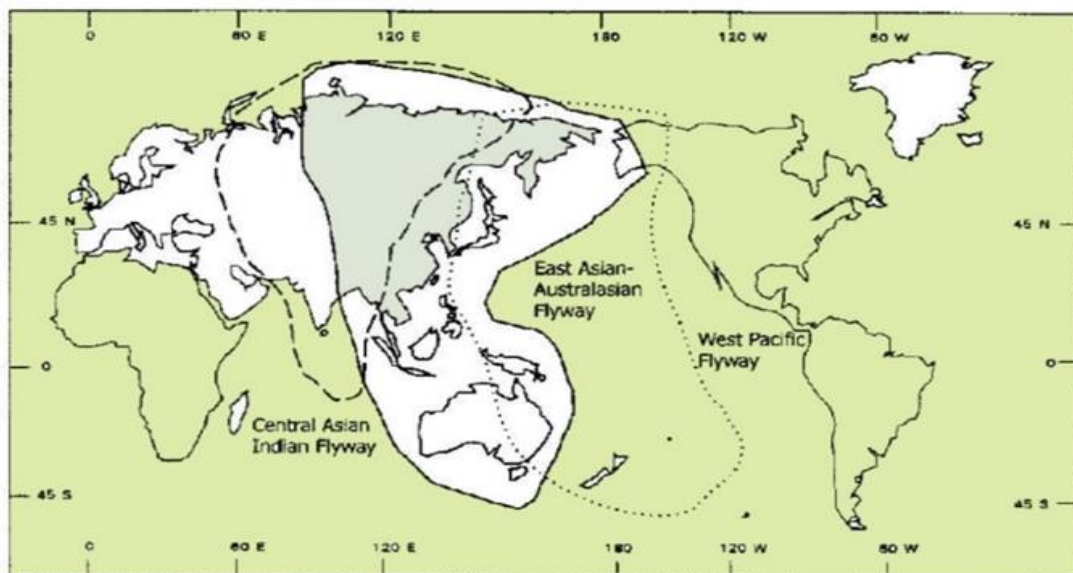


Fig. 1. Map showing Central Asian Flyways of migratory birds

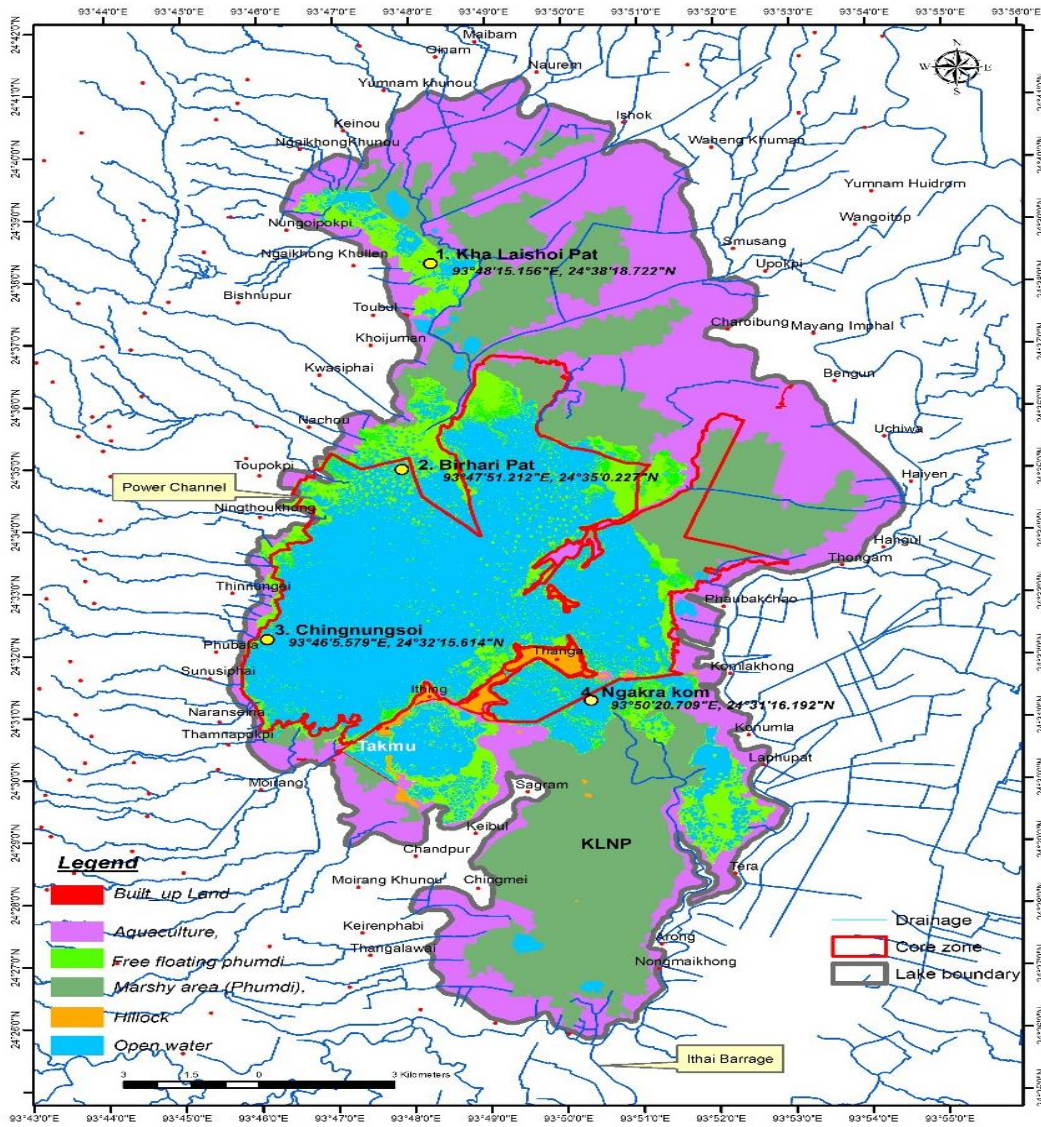


Fig. 2. Map showing four major congregation sites of the three guilds

water because of the increased water resistance with depth. Moreover, deeper water can also reduce foraging efficiency because prey can escape not only horizontally, as is the case in shallow water, but also vertically. In addition, prey in deep water may be more difficult to detect, especially if the water is turbid.

1.1 Study Area

Loktak Lake is the largest freshwater Ramsar site in North Eastern India. It is located between 93.462° – 93.551° E longitude and 24.254° – 24.426° N latitude in Bishnupur district, Manipur. It is home to thousands of resident and migratory birds having located at the juncture of two Asian

flyways of migratory birds (Map 1) and huge varieties of plant and fish species. According to Hume [10], he recorded as many as 50 species of waterfowl in Loktak alone and he had never seen such an enormous number of birds in any part of India. Given its rich flora and fauna, Loktak Lake has been declared a wetland of international importance by the Ramsar Convention in 1990. Loktak Ramsar provides food for waterbirds in its ecosystem in the form of plants, vertebrates, and invertebrates. Some feeders forage for food in the wetland soils, some find food in the water column, and some feed on vertebrates and invertebrates that live on submerged and emergent plants. Vegetarian birds eat fruits, tubers, and leaves of wetland

plants. The hydrological regime influences food production. For the present study, four study points were taken.

1.2 Northern Zone

1.2.1 Kha – Laishoipat

It is located at 24.381⁰ N; 93.481⁰ E coordinates with an elevation of 764.7 m asl covering the Yangoi area, Yawa Lamjao, Khoijuman in Bishnupur District. The surface area is approximately 5.1 sq. km with a water depth of around 1.5 m. The habitat features of this study area is a wetland with heterogenous floating aquatic vegetation biomass. This area is a major congregation site of wintering migratory and resident water birds like Common Teal, Lesser Whistling Teal, Gadwall, Little Grebe, Coot, Eurasian Wigeon, Garganey Duck etc.

1.3 Central Zone

1.3.1 Birahari Pat

It is located at 24.350⁰ N; 93.475⁰ E coordinates with an elevation of 762 m asl covering the area of Nachou, Potshangbam, Upokpi, Toupokpi and some parts of Ningthoukhong in Bishnupur District. The surface area is approximately 7.2 sq. km with a water depth of around 3.1 m. The habitat features of this area is an open water wetland with sparse floating aquatic vegetation biomass. The area is a major congregation site of wintering migratory and resident water birds like Common Teal, Lesser Whistling Teal, Gadwall, Little Grebe, Coot, etc.

1.3.2 Chingnungsoi, Moirang

Chingnungsoi is located in between 24.321⁰ N; 93.465⁰ E at an elevation of 760 msl covering the area of Thamnapokpi and is a fish farming area. The surface area is approximately 4.6 sq. km with a water depth of around 1.3 m. The habitat features of this area is a shallow water shoreline wetland area with swampy grassland vegetation. The area is the richest habitat for Lesser Whistling ducks and other associated species found in the area includes Common Indian Moorhen, Jacana, Purple Heron etc.

1.4 Southern Zone

1.4.1 Ngakrakom inside Keibul Lamjao National Park Area

This area is located at 24.311⁰ N; and 93.502⁰ E with an elevation of 778 msl at the southeastern corner of Loktak wetland complex. The surface

area is approximately 8.1 sq. km with a water depth of around 2.8 m. The habitat of this area is an open water area occupied by isolated mass of aquatic vegetation. The area is also one of the richest congregation sites of migratory and resident birds of Loktak. The species include Brahminy Shelduck, Open Bill Stork, Purple Heron, Cormorant, Pintail, Gadwall, and Little Grebes.

2. METHODOLOGY

The four study point were marked using GPS. The locations marked in the GPS were overlaid on the study area map. The study points were identified by approaching such flocks as close as possible without disturbing birds and the exact location was recorded.

Feeding and foraging observations were made during the wintering and breeding season of 2022 – 2023 at four major water bird congregation sites in Loktak from sunrise to sunset. The population size of the study area was estimated using point count method during summer (April and July) and winter season (November and January). To measure foraging behavior, the responses to food items by waterbirds was observed that measures prey detection and motivation to feed [11]. A sampling scan of all feeding and foraging water birds from all study sites was carried out using a 25-75 x 82 field scope and 10 x 50 binoculars. The species identity, foraging habitats, and feeding techniques of water birds encountered were recorded using the initial observation method, that is, only the 1st foraging observation of each individual was considered.

The types of foraging habitats identified for the present study are mentioned below –

1. Shallow Water (SW) – water depth range lies between 1- 2 meters.
2. Shallow Open Water (SOW) – water depth range lies between 2 – 4 meters,
3. Floating Phumdi and Macrophyte Habitat (FPM).
4. Swamp Grassland associated with shoreline (SGAS) – water depth range lies between 0.3 – 0.6 meter.
5. Halophytic Vegetation (HV).

The eleven foraging techniques identified for water birds are Diving, Grazing, Striking, Pecking, Probing, Head and neck dipping, Plunge diving, Sieving, Dabbling, Surface

plunging, and Upending. The approximate study area of the study has been calculated by using satellite imagery and GPS. The area covered by the present study (four study sites) is 26 sq. km.

3. RESULTS AND DISCUSSION

Out of the 62 waterbird species inclusive of migratory and resident birds (Loktak waterbird census-2023), 20 species have been included in the analysis due to 38 foraging visits and 88 scanning bouts conducted. The twenty species of waterbird include 11 resident waterbirds of which 6 species belong to the Ardeidae, 3 species of Anatidae family, 1 species of Podicipedidae

family, Little Grebe *Tachybatus ruficollis*, and the other one species of Phalacrocoracidae family, Great Cormorant *Phalacrocorax carbo*. The other 9 species were migratory with 7 species of the Anatidae family, 1 species of Ardeidae, Little Egret *Egretta garzetta* and 1 species of Anhingidae, Darter *Anhinga melanogaster*. The population of the waterbird species included in the analysis, their family and status have been given (Table 1).

Based on their feeding and foraging ecology of Loktak has been categorized into three foraging guilds (Table 1). The first guild consists of 3 species of shallow water frequenters exclusively foraged by diving.

Table 1. Population size of water bird species at Loktak

Sl. No.	Common Name	Scientific Name	Feeding Guild	Status	Population (Average±SD)	Dominance (Percentage)
1.	Little Grebe	<i>Tachybatus ruficollis</i>	P+I	R	95 ± 4.85	1.00
2.	Great Cormorant	<i>Phalacrocorax carbo</i>	P	R	160 ± 7.18	1.69
3.	Darter	<i>Anhinga melanogaster</i>	P	M	11 ± 2.83	0.12
4.	Little Egret	<i>Egretta garzetta</i>	P+I	R	18 ± 1.58	0.19
5.	Grey Heron	<i>Ardea cinerea</i>	P	M	2 ± 1.41	0.02
6.	Purple Heron	<i>Ardea purpurea</i>	P	R	147 ± 10.12	1.55
7.	Large Egret	<i>Casmerodius albus</i>	P+I	R	6 ± 1.87	0.06
8.	Median Egret	<i>Mesophayx intermedia</i>	P+I	R	76 ± 9.92	0.80
9.	Cattle Egret	<i>Bubulcus ibis</i>	P+I	R	4188 ± 41.76	44.18
10.	Indian Pond Heron	<i>Ardeola grayeii</i>	P+I	R	856 ± 74.98	9.03
11.	Large Whistling Duck	<i>Dendrocygna bicolor</i>	H+I	R	5 ± 2.92	0.05
12.	Lesser Whistling Duck	<i>Dendrocygna javanica</i>	H+I	R	142 ± 9.35	1.50
13.	Brahminy Shelduck	<i>Tadorna ferruginea</i>	H+I+P	M	80 ± 11.31	0.84
14.	Gadwall	<i>Anas strepera</i>	H+I	M	2470 ± 80.61	26.05
15.	Eurasian Wigeon	<i>Mareca penelope</i>	H+I	M	50 ± 5.66	0.53
16.	Spot Billed Duck	<i>Anas poecilorhyncha</i>	H+I+P	R	2 ± 1.58	0.02
17.	Northern Pintail	<i>Anas acuta</i>	H+I	M	7 ± 4.24	0.07
18.	Garganey	<i>Anas querquedula</i>	H+I+P	M	39 ± 5.66	0.41
19.	Ferruginous Pochard	<i>Aythya nyroca</i>	H+I+P	M	220 ± 15.56	2.32
20.	Common Teal	<i>Anas crecca</i>	H+I	M	906 ± 11.31	9.56

* P-Piscivorous; H-Herbivorous; I-Insectivorous

The species of the 1st guild are purely non-vegetarian waterbird species. Great Cormorant and Darter are purely piscivore, and Little Grebe feed on fish, frogs, tadpoles, crustaceans, mollusks, and aquatic insects. The main habitat preferred by this group is 60% - 70% shallow open water (SOW) followed by shallow water (SW); 10% - 15% and sometimes in floating phumdi and aquatic macrophyte habitats and rarely swim in grassland associated shoreline (SGAS), (Fig. 3). The two species of the guild, the Great Cormorant and Darter are diving specialists and exclusively depend on the fish as their food and sometimes seemingly much too large for the species slender bill and gullet. This guild used only a single feeding technique of diving, having a narrow habitat niche.

The 2nd guild consists of 7 stalking Ardeidae species (Fig. 4a and 4b). They exclusively capture their prey by striking and also are non-vegetarian waterbirds. They mainly feed on fishes, frogs, tadpoles, crustaceans, mollusks, aquatic insects, etc. Indian Pond Heron and Grey Heron prefer fish as their main food item. Grey Heron, Little Egret, and Indian Pond Heron have

the largest foraging niche among all the waterbirds and use a wide variety of foraging habitats. These species prefer swampy grasslands associated with shoreline (SGAS), 40% followed by shallow open water (SOW), nearly 20%, and other habitats are halophytic vegetation, floating phumdi, macrophytic habitats, etc. Indian Pond Heron *Ardeola grayii* depends on swampy grassland associated with shoreline up to 70%.

The 3rd guild consists of 10 species of ducks and most of them are shallow-water generalists (Fig. 5). The Brahminy Shelduck *Tadorna ferruginea* uses shallow water and wet shoreline grazing grounds of the lake. The main habitat of this group is shallow open water (SOW) preferring up to 80% - 90% and other includes shallow water and floating macrophyte habitat. The Lesser Whistling Duck mostly depend on shallow water associated macrophyte vegetation. Two species of the guild belonging to Anatidae family, Large Whistling Duck and Common Teal *Anas crecca* are purely vegetarian species exclusively depend on plant materials as their food.

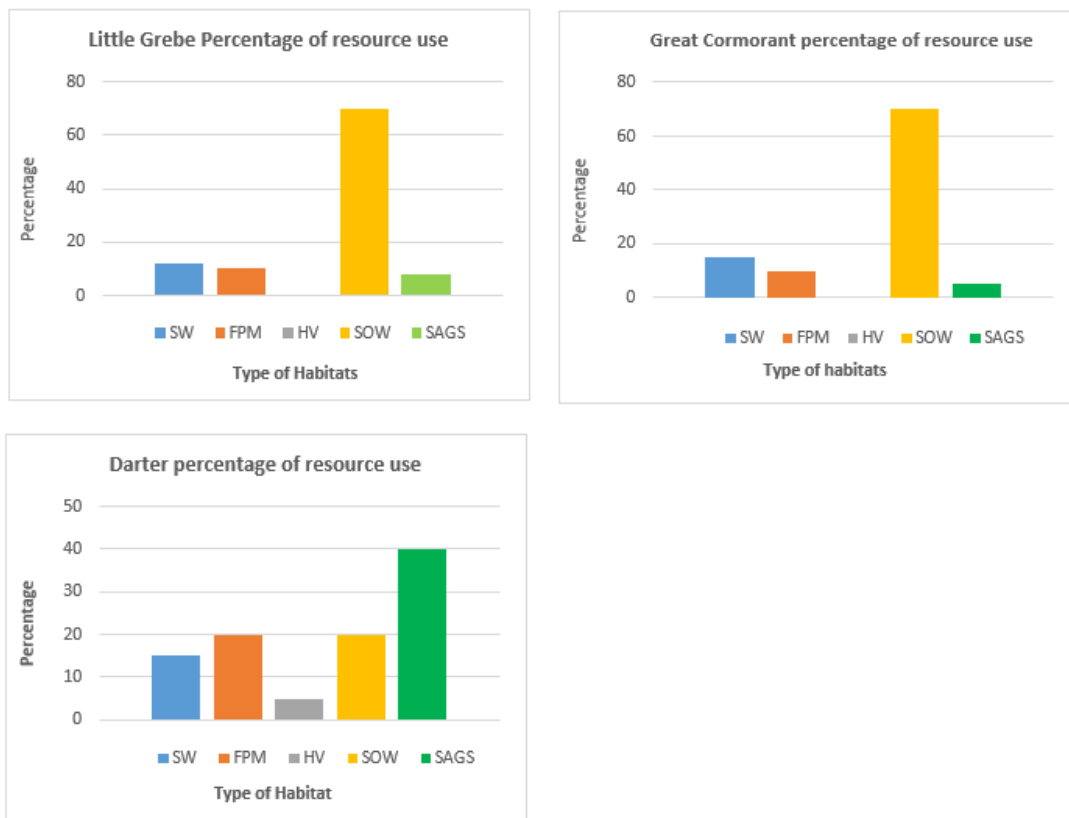


Fig. 3. Resource use patterns in terms of percentage of 1st Guild concerning the type of habitats (Diving)

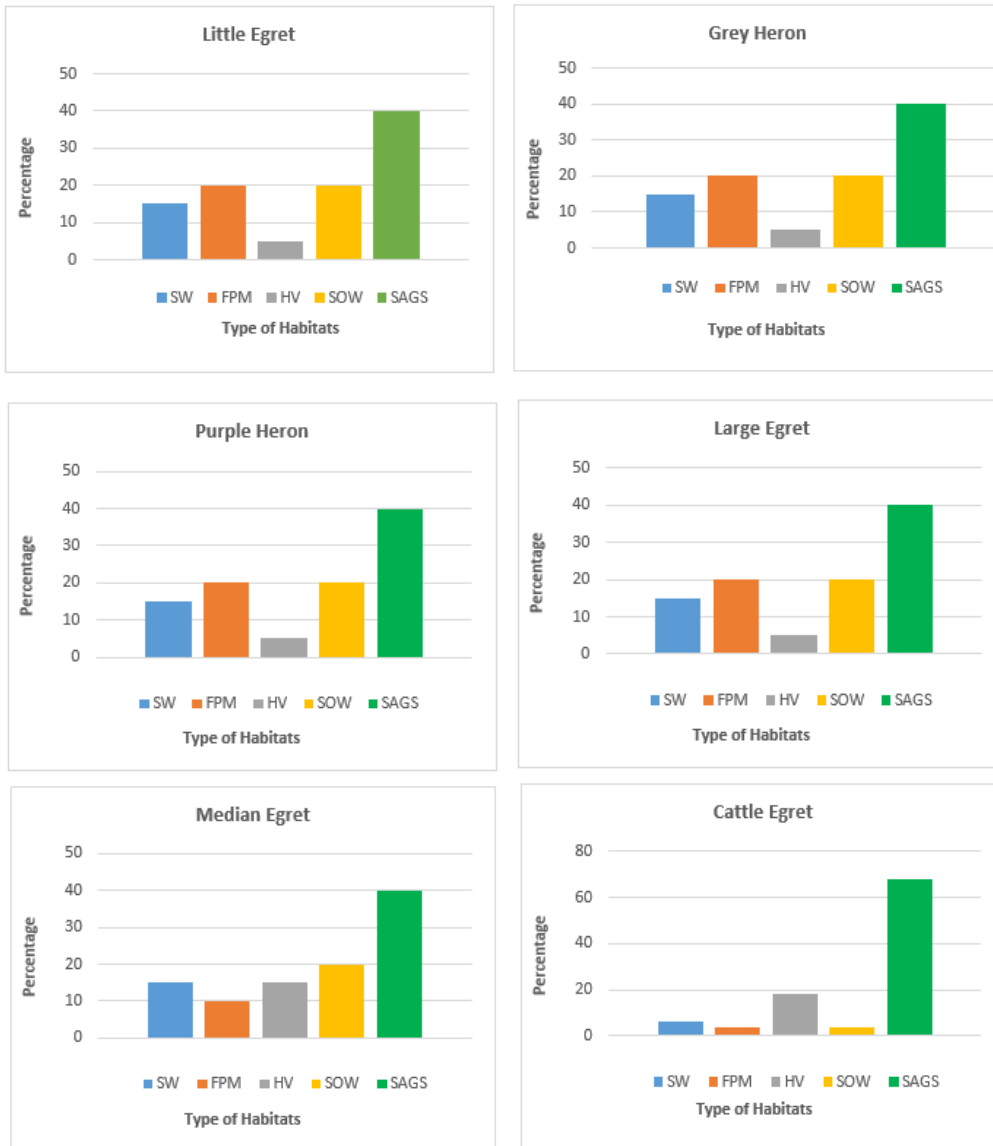


Fig. 4(a). Resource use pattern in terms of percentage of 2nd Guild concerning type of habitats (Pecking feeding mode)

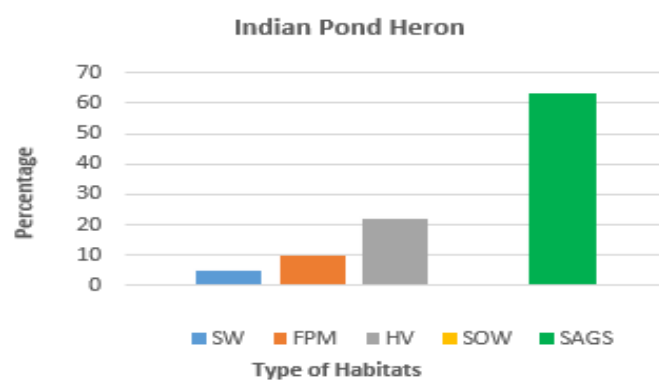
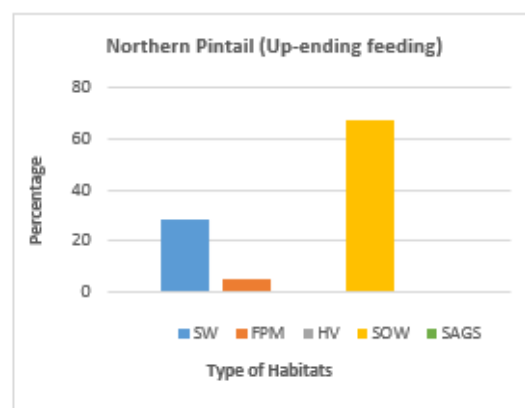
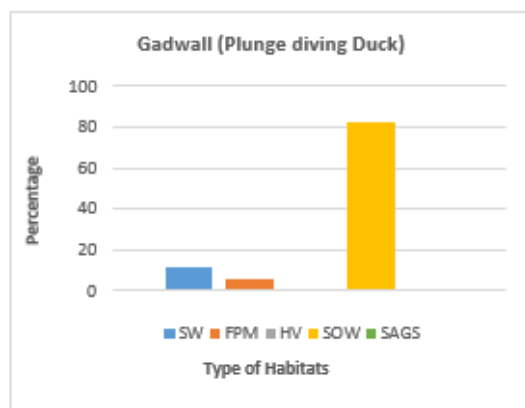
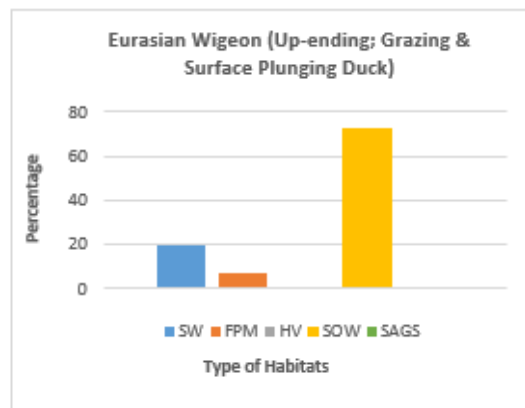
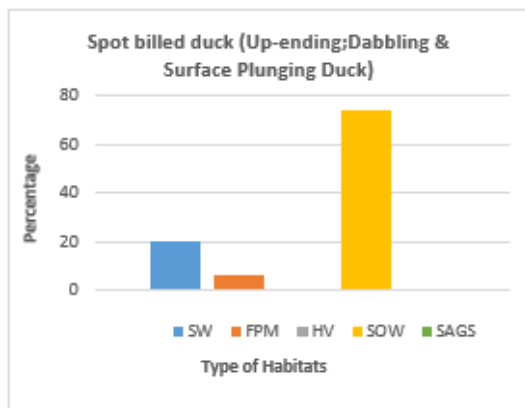
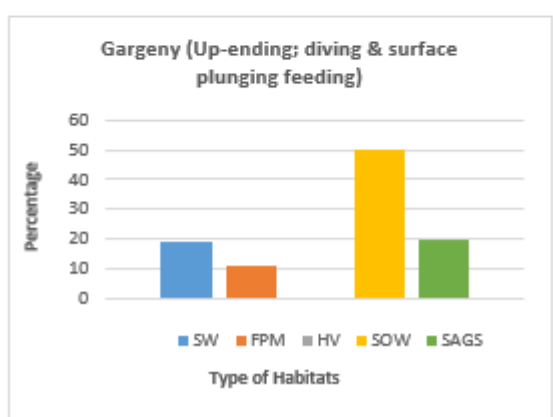
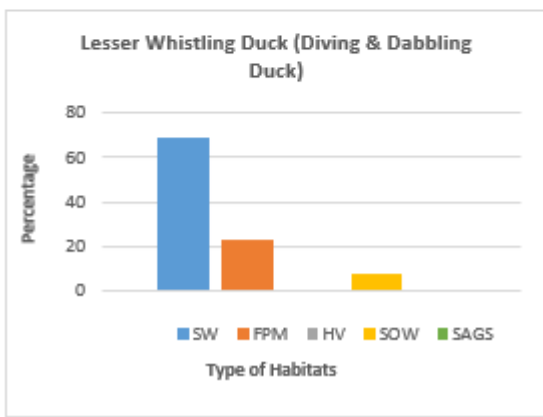
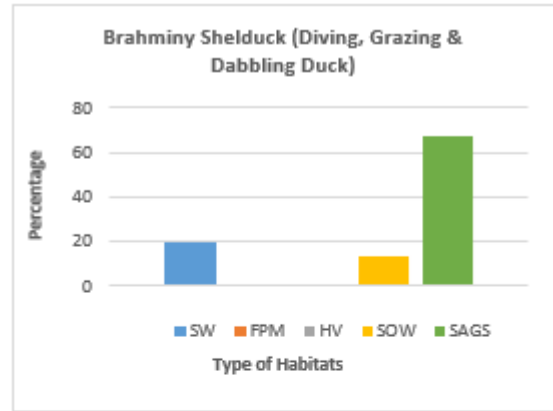
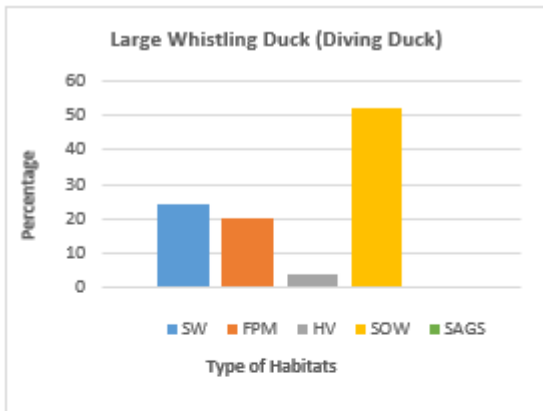


Fig. 4(b). Resource use pattern in terms of percentage of 2nd Guild concerning type of habitats (striking feeding mode)



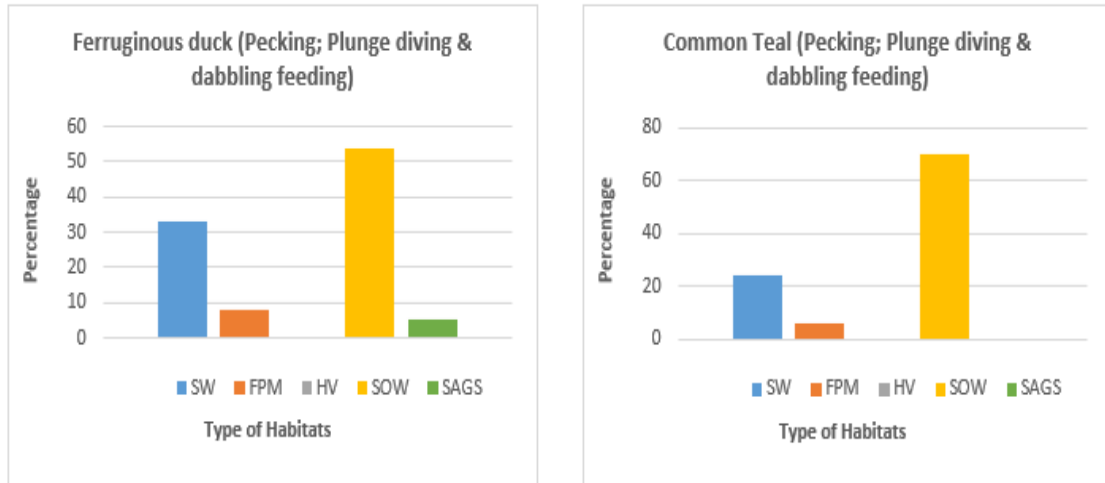


Fig. 5. Resource use pattern in terms of percentage of 3rd Guild concerning the type of habitats

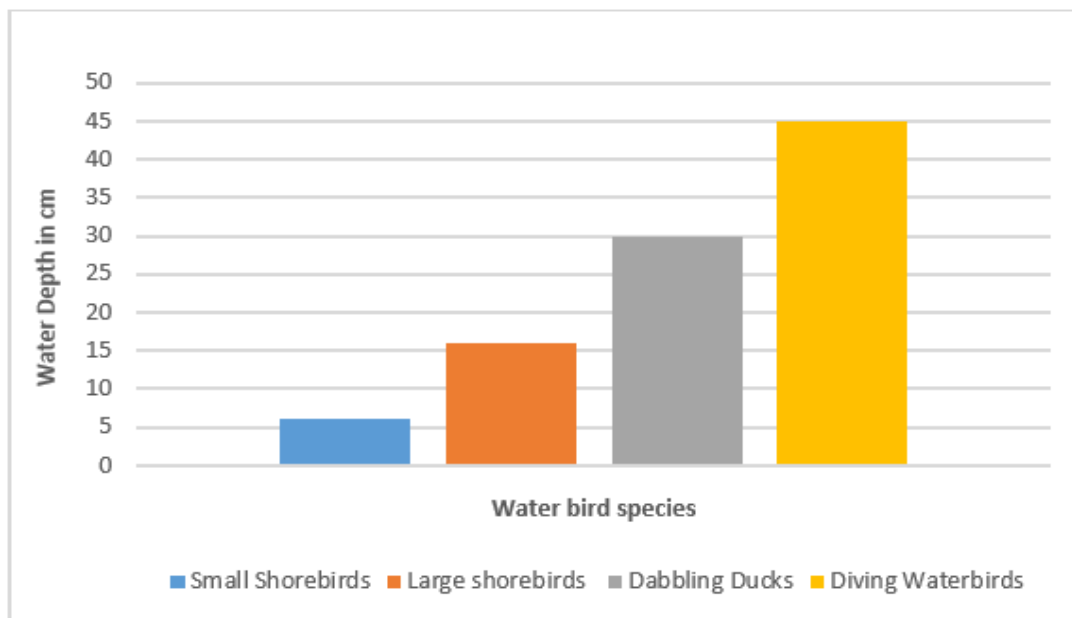


Fig. 6. Variation of water depth at foraging sites

Although this guild uses few foraging habitats but they use diverse feeding techniques. The most common technique of feeding is dabbling and diving. Eurasian Wigeon *Mareca penelope* uses pecking besides grazing and diving. Northern Pintail *Anas acuta*, and Gadwall *Anas strepera* use surface plunging and plunge diving.

Foraging efficiency for the non-diving herbivores may also be reduced in deeper water. When foraging in shallow water, these birds feed by

dipping their heads and necks only (neck dipping), but when feeding in deeper water, they must tilt their entire body forward (up-ending). The latter results in a lower food intake rate and higher energy expenditure. This suggests that water birds obtain a higher net energy intake in shallow water than in deep water, even with the same food abundance. It is also indicated that non-diving herbivores prefer foraging in submerged vegetation until depletion, even when food is more abundant in deeper water.

The larger water bird species generally have longer necks, bills, and legs. They usually can assess a greater range of water depths than smaller species [6], [5]. The range of accessible water depths also depends on foraging behavior. Compared to shorebirds, waterfowls can use diverse foraging behaviors such as dabbling, tipping up, and head submerging, each suitable for foraging at different depths [5]. Therefore, waterfowl and large wading birds can forage a wider range of habitats than small shorebirds.

Besides providing food such as seeds, leaves, tubers, and rhizomes for herbivorous water birds, vegetation is an important habitat element and greatly influences the habitat use of water birds. The effect and importance of vegetation depends on the season and on the water bird group. In the breeding season emergent and floating plants benefit the nest-building of Moorhens *Gallinula*

chloropus and consequently enhance their breeding success. Emergent plants also provide shelter and decrease human disturbance. Dense vegetation also provides habitat and food requirements for invertebrates and improves the viability of eggs or diapausing invertebrates, which increases invertebrates' density, biomass, and diversity. This increases food for water birds. Water level fluctuation creates diverse habitats with diverse water depths (Fig. 6), changing in time and space. This provides more foraging opportunities and consequently supports a high species richness and abundance of water birds but in the case of Loktak artificial impoundment water and maintaining water level nearly all the year round has reduced species richness and diversity except dabbling ducks. Winter season was recorded higher number of species due to influx of migratory birds than summer season.



Pic 1. Little Grebe *Tachybaptus ruficollis*



Pic 2. Indian pond heron *Ardeola grayii*



Pic 3. Lesser whistling duck *Dendrocygna javanica*



Pic 4. Ferruginous pochard *Aythya nyroca*



Pic 5. Cattle egret *Bubulcus ibis*



Pic 6. Purple heron *Ardea purpurea*

4. CONCLUSION

The current study has documented the significance of Loktak wetland, especially as a wintering and migration stopover site for water birds. The present study categorized 20 waterbird species, including migratory resident birds into 3 foraging guilds depending upon the habitat type, food habit, and feeding techniques giving preference to the foraging niche dimensions. Food availability is one of the most important factors determining the distribution of the water bird population and diversity of species which is also directly or indirectly related to the hydrological regime of the lake. Foraging and habitat use, including feeding techniques, are important factors in resource partitioning. Habitat management of water birds in a wetland ecosystem is the fundamental basis for the restoration of an ailing wetland ecosystem. Water level fluctuations induce boom to bust in aquatic life therein whereas in the case of Loktak, as the total hydrological regime of the Lake has already been dictated by Ithai Barrage of NHPC, therefore, the diversity waterbird species has been drastically reduced [12,13]. In deeper marshes or shallow lakes, drying allows decomposition of bottom organic deposits that provides nutrients for a new surge of vegetation that germinate under low water conditions. But such kind of seasonal fluctuation of water level could not be observed anymore.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We, the Author(s), hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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