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Foraging and diving pattern of the Little Cormorant *Microcarbo niger* (Vieillot) (Pelecaniformes: Phalacrocoracidae) of Ecopark, Kolkata, India

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Abstract

This study aims to investigate the feeding behavior and diving habits of the Little Cormorant (*Microcarbo niger*) in the vicinity of Pakhibitan, which is a component of Ecopark, the largest urban park located in Newtown, Kolkata, West Bengal, India. The study took place for three days a week starting from September 2021 to February 2022. The Little Cormorant mostly used the Lake as a foraging location in Pakhibitan, with the highest number of dives (1957 dives, 10.78 ± 10.43 sec) and surface pauses (1980 surface pauses, 6.02 ± 5.48 sec) compared to a nearby smaller pond. The pattern of dive bout/surface pause showed considerable variability between lake ($F = 1.055$, $df = 1$, $P > 0.05$) and pond ($F = 0.153$, $df = 1$, $P > 0.05$). There may be a correlation between the average duration of dives and the average recovery time between dives, and the depth of the water bodies. In certain cases, longer dives were associated with longer rest periods, resulting in increased time spent searching for prey. Consequently, the foraging efficiency of the dives may decrease as the diving depth increases. The feeding behavior of the Little Cormorant is subject to the influence of various environmental conditions, necessitating a more comprehensive investigation.

Key words: Diving birds, dive bout, dive cycles, foraging behavior, surface pause

Introduction

The abundance of birds is a crucial measure of a thriving environment, as avian diversity may be used as a valuable tool to assess the importance of a habitat in terms of its conservation value (Mukhopadhyay and Mazumdar, 2019). Birds tend to exhibit a preference for inhabiting settings characterized by heterogeneity (Mukhopadhyay and Mazumdar, 2019). Nevertheless, the extent to which they colonize their region is contingent upon the availability of resources necessary for their survival. During the mating season, their primary objectives revolve around mate attractiveness and nesting (Veech, 2011; Juarez et al., 2020). On a global scale, the number of cormorants and shags (Family Phalacrocoracidae) foraging in marine, freshwater, and brackish waterways is estimated to be approximately 40 species (Sibley, 2001). According to Ovegård et al. (2021), most of the cormorant species exhibit a piscivorous diet. In general dive

behavior plays a crucial role in foraging efficiency, particularly in species inhabiting water bodies. For example, in a study on the diving behavior of the Little Grebe (*Tachybaptus ruficollis*, Pallas, 1764) in a wetland in Central Italy, it was found that these birds tend to avoid deep-water areas exceeding 1 meter, as deeper water could result in higher energetic costs during foraging (Ceccobelli and Battisti, 2010).

The Little Cormorant *Microcarbo niger* (Vieillot) is a cormorant species that is found on the Indian subcontinent, China, and Southeast Asia (Orta, 1992; Johnsgard, 1993; Sarkar and Naher, 2002; Eaton et al., 2016). Little Cormorants are diurnal and consume an average of five main meals during the day. These birds typically inhabit freshwater inland, lakes, and coastal regions (Sarkar and Naher, 2002). They primarily feed on flatfish and crustaceans that live at the bottom of the water or prefer fish that are found in shallow waters along the shore, rather than those that occupy pelagic environments (Coker, 1919; Lack, 1945). Little Cormorants exhibit a preference for foraging on food items that persist in the middle and lower regions of the water column (Besra et al., 2022). There is a total of 27 species of fishes belonging to 6 orders and 12 families reported previously from the Ecopark (Besra et al., 2022). It has been documented that Little cormorants engage in surface swimming, underwater diving, and fish hunting (Alertsam, 1990; Sarkar and Naher, 2002).

Little Cormorants exhibit foot-propelled chase diving behavior (Ashmole, 1971) and engage in foraging activities through a sequence of dives from the water surface, punctuated by short intervals of recovery or surface pauses (Cooper, 1986; Zeenath and Zacharias, 2010). According to Casaux (2004), there exists a positive correlation between the duration of dives and these surface pauses. Environmental characteristics such as bottom heterogeneity and high tide width (on the southeastern coast of Patagonia, Argentina) have been found to influence the diving behavior of cormorants (Frere et al., 2002). It has been documented that the Red-legged Cormorants *Poikilocarbo gaimardi* (Garnot) can minimize their foraging effort by picking the proper tidal state to dive and hunt (Gandini et al., 2005; Zeenath and Zacharias, 2010).

The objective of this study is to gather data and gain insights into the foraging behavior and diving pattern of the Little Cormorant near Pakhibitan, a section of the Ecopark, the largest urban park in Newtown, Kolkata, West Bengal, India and to determine the Little Cormorant's significance in this wetland ecosystem, which is currently facing imminent threats due to increasing development activities.

Material and Methods

Study area

The present study was conducted at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India. There are two designated places in Ecopark where the cormorants forage, these are at the specific coordinates 22°36'09.9"N, 88°28'00.3"E and 22°36'29.9"N, 88°27'49.4"E, and here designated as the pond and the lake, respectively. The lake spans an area of 104 acres, which accounts for almost one-fourth of the total 480 acres in Ecopark. In comparison to the lake, the pond in Pakhibitan is relatively small, but remains undisturbed (Fig. 1). The maximum depth of the main lake is approximately ~35 to 40 feet and the pond is about ~25 to 30 feet. The Ecopark is known for its urban setting and high levels of human activity. Even though the park is in a city, it includes a variety of different natural habitats, such as marshes and small bodies of water. This unique combination of urban infrastructure and natural features provides an ideal environment for investigating the behavioral pattern of birds.

A direct observation approach was employed to conduct the study from September 2021 to February 2022, for three days a week, on every alternate week day (Bibby et al., 2000). For observation and recording time, a stopwatch and binoculars were used. For data analysis, software such as Past (Hammer et al., 2001) and R programming (R core team, 2024) were used and for creating the map of the study area (Fig. 1) QGIS 3.34 was used.

Results

Prior to diving, Little Cormorants sit near the shoreline. Once they enter the water to forage, they dive for submerged aquatic prey. Each dive is succeeded by a brief interval of surface recuperation, commonly referred to as a surface pause. Subsequently, a sequence of alternating dives and surface pauses (rest or recovery periods) are performed for a predetermined duration. Little Cormorants have two designated foraging places in Ecopark, Pakhibitan; the lake and the pond. In the lake, the longest dive lasted for 310 sec and the longest surface pause duration in 61 sec, whereas in the pond the longest dive duration is 178 sec and longest surface pause duration is 212 sec (Fig. 2).

The dive bout/surface pause pattern exhibits considerable variation (Table 1), likely due to the relatively low number of individuals actively foraging on the pond. However, with increased diving frequency, their dive duration decreases, and their surface pause duration increased in both foraging locations, lake and pond (Fig. 3A, B).

The dive bout/surface pause interaction of Little Cormorants in the lake ($F = 1.055$, $df = 1$, $P > 0.05$) and pond ($F = 0.153$, $df = 1$, $P > 0.05$) did not show any significant variation. The correlation plot revealed distinct patterns in cormorant dive-pause behavior across lake and pond environments (Fig. 4).

Table 1: Mean diving parameters of the Little Cormorant in Pakhibitan, at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

Foraging Location	# of Dive Bouts	Dive Bout Duration (sec)	# of Surface Pauses	Surface Pause Duration (sec)
Lake	1957	10.78 ± 10.43	1980	6.02 ± 5.48
Pond	90	11.25 ± 26.89	95	15.08 ± 19.09

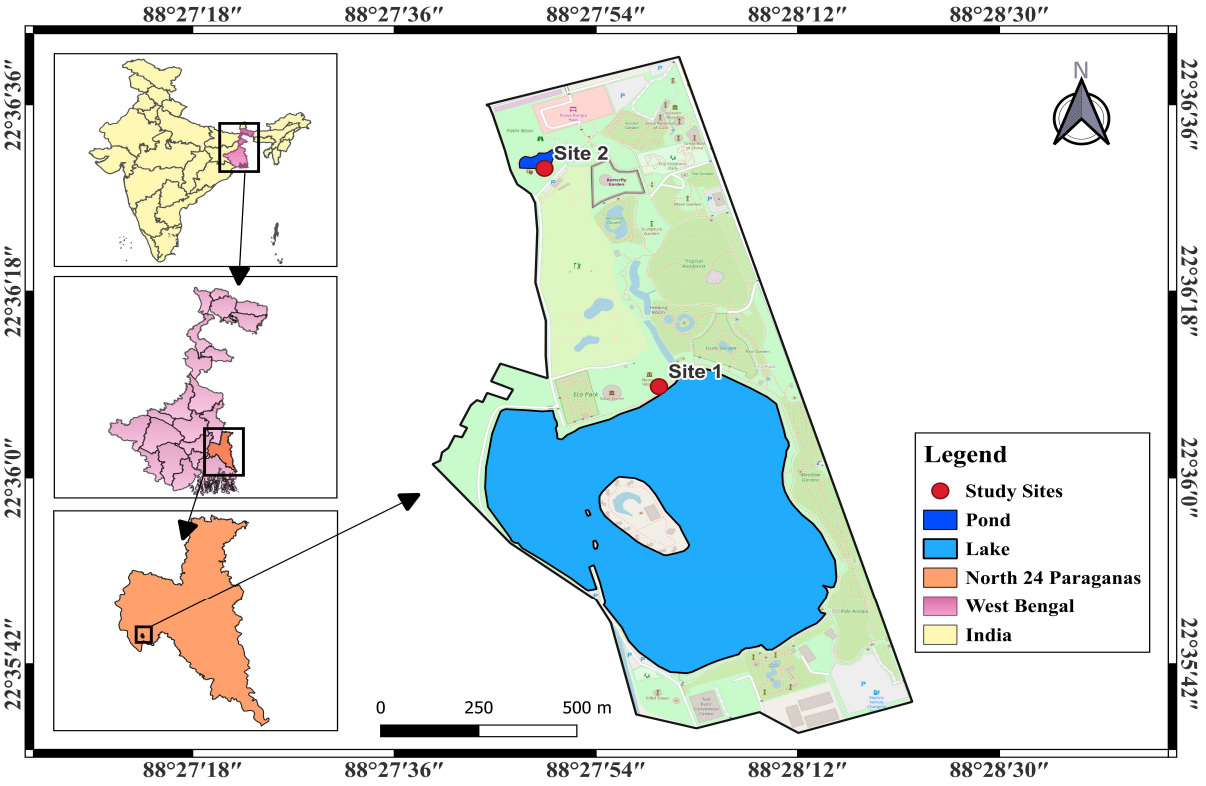

Figure 1: Map of the study area at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

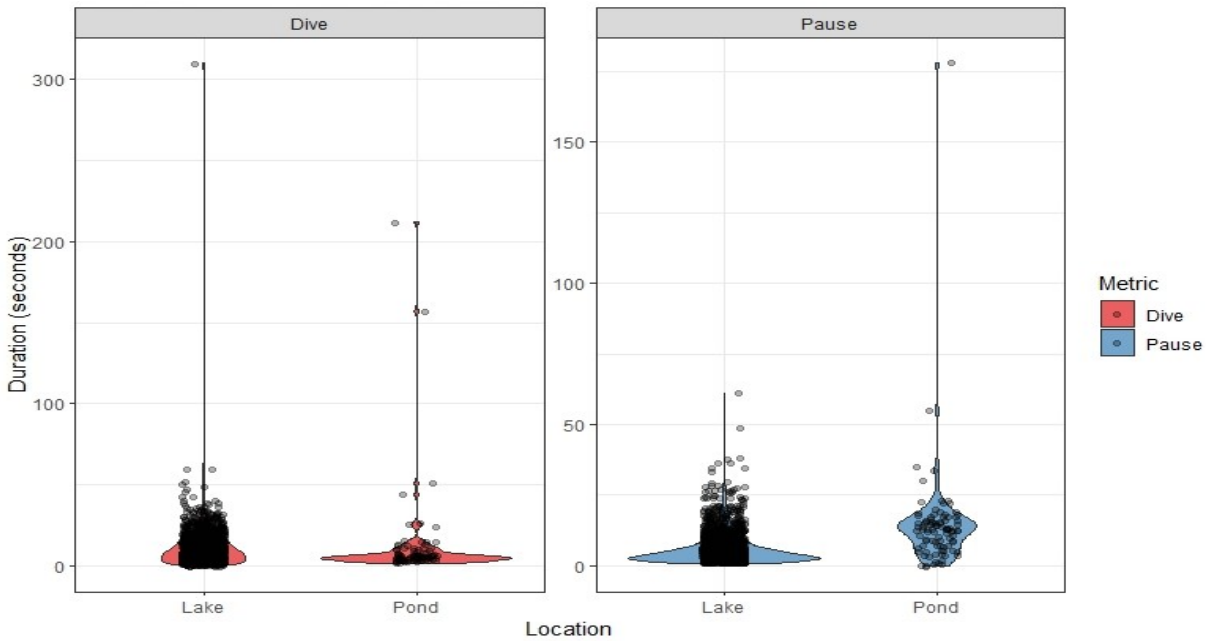

Figure 2: Total dive and surface pause duration of Little Cormorant (*Microcarbo niger*) at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

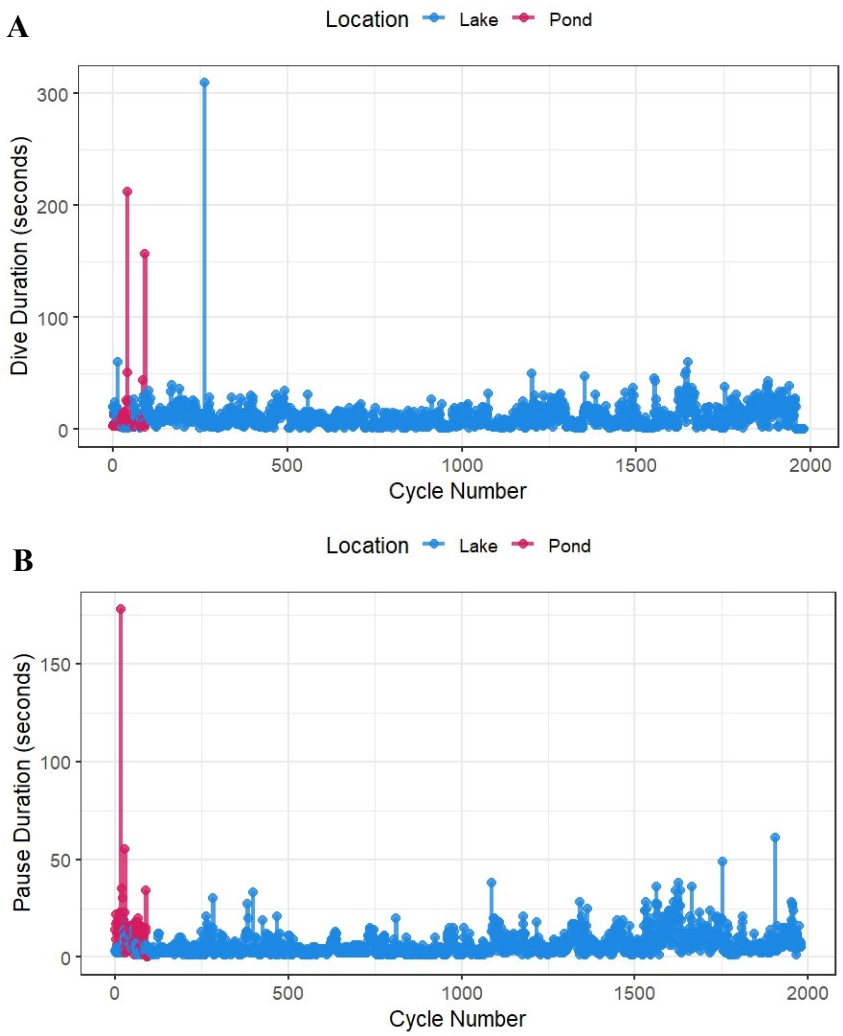

Figure 3: Cycle wise (A) dive duration and (B) pause duration of Little Cormorant (*Microcarbo niger*) in the lake and pond at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

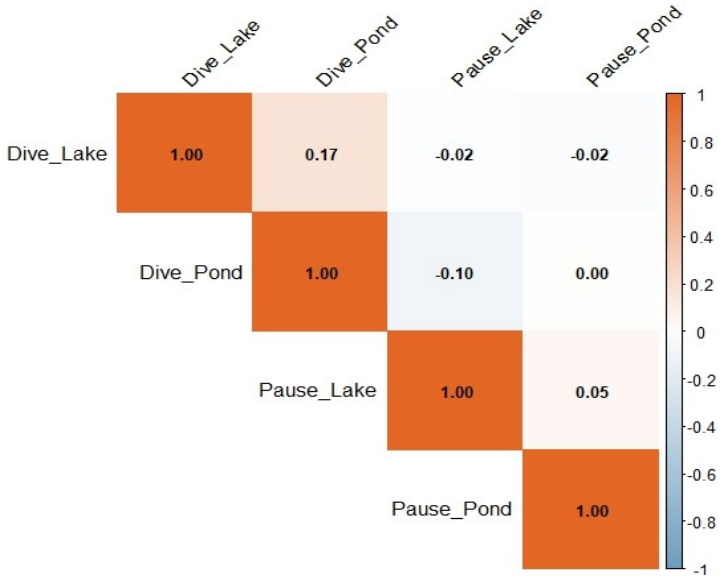

Figure 4: Corr-plot between total dive and total pause duration of Little Cormorant (*Microcarbo niger*) in the lake and the pond at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

Dive and pause durations showed moderate positive correlations within the same habitat (Lake: r= 0.52, Pond: r= 0.48), suggesting prolonged dives often precede longer pauses in both ecosystems. Cross-environment correlations were weaker, with dive durations between Lake and Pond exhibiting minimal association (r= 0.12), highlighting habitat-specific foraging strategies. Notably, Lake pauses correlated negatively with Pond dives (r= −0.19), implying potential behavioral trade-offs. Statistical significance ($p< 0.05$) was observed for within-habitat relationships, reinforcing the ecological link between dive effort and recovery time, while cross-environment interactions lacked significance, underscoring environmental divergence in activity rhythms.

Based on the analysis represented in Figure 5, dives were divided into "Long Dive" and "Short Dive" categories using the median dive duration as the cutoff for each location. The violin-boxplot hybrid clearly shows that pause durations following long dives are consistently longer than those following short dives (Fig. 5A). For instance, in the lake data, the median pause duration for long dives was approximately 25 seconds compared to about 15 seconds for short dives, while in ponds, the corresponding medians were around 30 and 18 seconds, respectively. Moreover, the scatterplot with Locally Weighted Scatterplot Smoothing (LOESS) smoothing revealed a positive association between dive and pause durations (with a correlation coefficient of roughly 0.65, $p < 0.01$), indicating that as dive duration increases, so does the subsequent pause duration (Fig. 5B). These patterns suggest that longer dives incur greater energetic costs, thereby necessitating longer recovery periods.

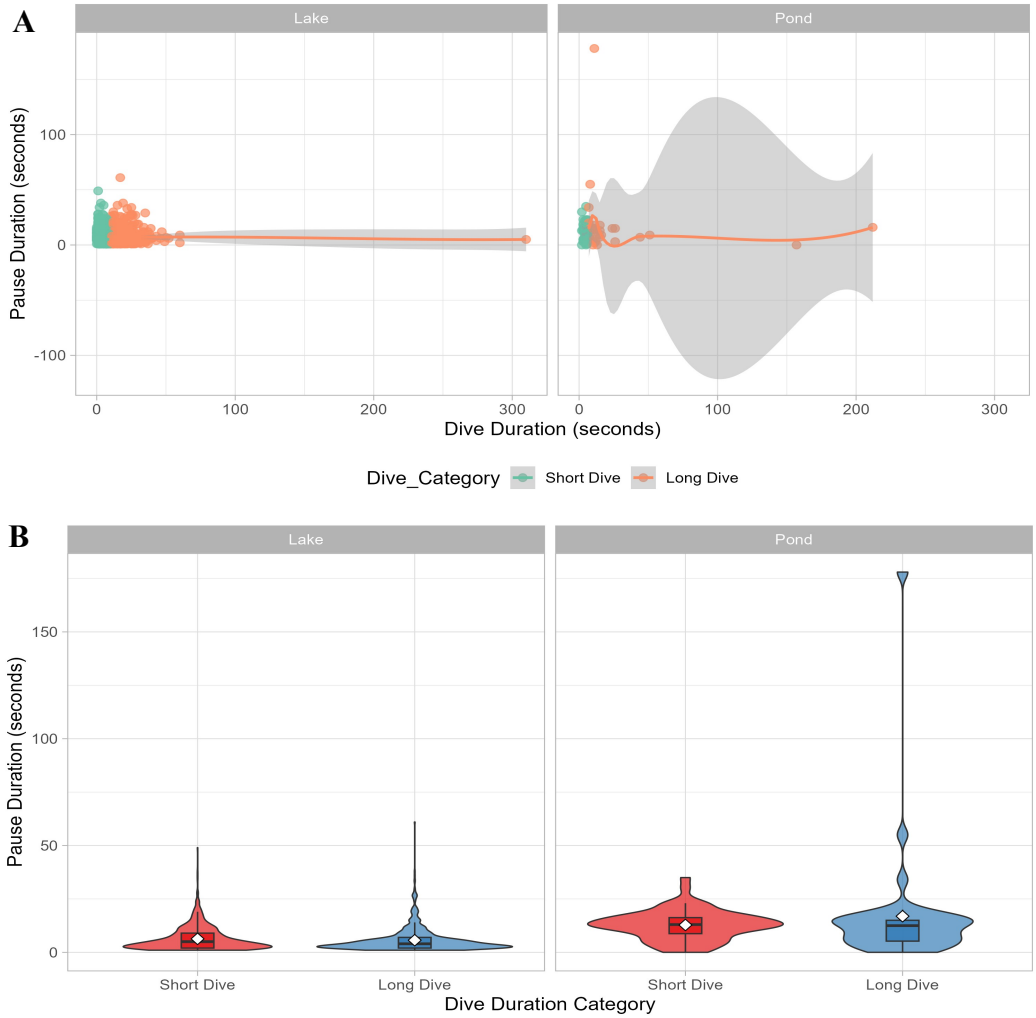

Figure 5: The graphs showing relation between Dive and Pause: (A) Violin plot combined with a boxplot (and a line indicating the mean) compares the distributions of pause durations for long versus short dives and (B) Scatterplot displays the relationship between dive and pause durations with a LOESS smoothing line of Little Cormorant (*Microcarbo niger*) in the lake and the pond at Ecopark in Rajarhat, Newtown, North 24 Paraganas, West Bengal, India.

Discussion

The observed foraging behavior of Little Cormorants in Ecopark exhibits variability in terms of dive and pause durations across the two designated foraging sites. As the number of surface pauses increases, the duration of the dive is reduced. Nevertheless, Little Cormorants have a long dive length in contrast to their

short surface pause, and display a high surface pause count and short surface pause duration, although having a lower overall dive count. The observed disparities in diving characteristics may be indicative of variability in both the depth of diving and the depth of these aquatic habitats. The Little Cormorant demonstrates high efficiency as a diver, as evidenced by its ability to spend a significant amount of time underwater during each dive cycle (Frere et al., 2002).

According to previous studies, diving birds employ distinct foraging strategies to effectively capture prey in both offshore and inshore environments (Gremillet et al., 1998; Tremblay and Cherel, 2000; Zeenath and Zacharias, 2010). The current study suggests a potential correlation between the average duration of dives and the average time it takes to recover between dives, and the depth of the water bodies. In certain cases, longer dives were associated with longer rest periods, indicating increased time spent searching for prey. Consequently, the foraging efficiency of the dives may decrease as the depth of the dives increases (Zeenath and Zacharias, 2010).

Recent studies highlight that environmental factors, such as water depth, significantly affect the diving behavior and foraging efficiency of aquatic birds (Militão et al., 2023). Variation in dive duration may be influenced by prey availability and water conditions such as turbidity, solid wastes, water pH, temperature, etc. which can alter foraging efficiency (Wakefield et al., 2011). Similar research on the diving patterns of various species, including Little Cormorants, reveals that species-specific adaptations play a crucial role in determining foraging strategies (Yoda et al., 1999). The implications of these findings can be valuable for conservation efforts, as the adaptability of diving birds to changing aquatic environments is crucial for their survival (Ainley, 2006).

There is a similar study by Vachanth et al. (2012), where the diving patterns of the Little Grebe *Tachybaptus ruficollis* (Pallas), Common Coot *Fulica atra* Linnaeus, Little Cormorant *Microcarbo niger* (Vieillot), and Darter *Anhinga melanogaster* Pennant were studied. Our study revealed that dive time was significantly associated with pause duration which is similar to the study done by Vachanth et al. (2012). Variation in patterns may be due to changes in foraging conditions, and further research is required to explore these variations in greater depth.

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Author contributions

SS collected the data. CSS and AR performed data analysis and prepared the original draft of the manuscript. TS helped in data management. LC conceptualized the objectives and provided guidance. ABR provided infrastructural facilities and supervision. All authors reviewed the paper.

Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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