Diurnal Time-Activity Budget of the Common Loon *(Gavia immer)* in Northern Michigan

by

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Abstract

Animals must navigate trade-offs in many areas, including how they spend their time. These trade-offs can be measured with time-activity budgets, which can vary between species and within them. In July of 2021, I collected observational data on the common loon (*Gavia immer)* at Douglas Lake in Pellston, Michigan primarily during morning and evening activity time periods, with some data collected during afternoon counted toward overall activity budget, and analyzed differences between these periods, particularly with regards to foraging behaviors. I found that loons were far less likely to forage during the evening (7%) rather than morning (55%), and that the most common activity during the morning period was diving, while the most common activity during the evening period was resting. Knowing the activity patterns and foraging habits of common loons can help researchers protect the common loon, which is a threatened species in Michigan, by helping to predict how they may be impacted by environmental change.

Acknowledgments

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Introduction

In order to successfully survive and reproduce, an animal must spend its time wisely. This concept is known as time-activity budgeting. Knowing these time-activity budgets can help researchers predict how a given species may adapt to a change in habitat conditions or resource availability, react to anthropogenic disturbance (Greggor et al. 2019) as well as serve as a basis for comparison in experimental studies (Asplund 1981). Activity budgets can vary greatly across different species. Activity budgets have also been observed to vary within the same species based on a variety of factors including weather (Draidi et al. 2019), season (Turnbull and Baladassere 1987, Evers 1994), prey availability and presence of competitors (Rizzuto et al. 2018), time of day (Evers et al. 2000), and sex and breeding status (Asplund 1981).

This study examines the time-activity budget of a non-breeding pair of common loons (*Gavia immer)* during the brood season in Northern Michigan. *Gavia immer* is the only species of loon found in North America (McIntyre 1994), and has been listed as threatened in Michigan since 1987 following population declines (Michigan Loon Recovery Committee 1992). Loons are a migratory species, (McIntyre 1994) and the study area is at the southern end of the common loons' summer range (Evers 2004). During the winter, they migrate to the coastal areas of the Atlantic Ocean (Bianchini et al. 2021), so they are protected by the federal Migratory Bird Treaty Act. In contrast to their winter habitats, where they occupy mainly saltwater habitats, during summer, they typically occupy only freshwater environments (McIntyre 1994). They return annually to the same sites (Evers et al. 2000), and that their range is constricting due to climate change causing warming temperatures in their northernmost habitats (Bianchini et al. 2021).

This study was conducted in July, which would typically be brood season for the common loon (Evers 1991). Nevertheless, the only pair that regularly occupied the lake was not observed with chicks that year. However, remote cameras placed by a local organization at a nest box occupied by the pair recorded two eggs present during breeding season, but these eggs were lost (Douglas Lake Improvement Association, 2021). Although I recorded all behaviors exhibited by the birds (see Methods for ethogram), I was particularly interested in time spent feeding and foraging, since this can determine an animal's long-term fitness (Rizutto et al. 2018). Because loons typically consume their prey underwater, it is impossible to distinguish between feeding and foraging, or between a successful and an unsuccessful dive (McIntyre 1988).

In terms of diet, common loons are mainly piscivorous, with a diet composed mainly of various fish with some invertebrates (McIntyre 1994). Fish present in the study area frequently consumed by loons include yellow perch (*Perca flavescens),* bluegills (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*) and white suckers (*Catostomus commersonii*) (Godfrey and Cwlanski 2004, Barr et al. 1996).

Loons hunt by diving, submerging completely for reported average dive time ranging from 41.1 seconds in open water (Reimchen and Douglas 1980) to 71.3 seconds for solitary individuals (Paruk et al. 2021). Their dive duration may be affected by water clarity (Thompson and Price 2006), and so they prefer clear lakes where they can easily see their prey (Thompson and Price 2006, McIntyre 1998). Like all strategies, diving has trade-offs. While loons' relatively heavy bodies with solid bones make them skilled underwater swimmers (McIntyre 1988), they are far less capable of walking on land, can only take off in flight from water, and require a "runway" of sorts to do so (McIntyre 1988). These trade-offs may affect time spent on certain activities, as well as the time of day the activities are conducted.

There are few studies comparing the activity patterns of *Gavia immer* at different times of day. Daub (1989) and Ford and Gieg (1995) did not observe any significant correlation between time of day and loon activity budget during winter, however, Reimchen and Douglas (1980) found that foraging activity was highest at mid-morning and dusk. Because previous researchers have observed some differences in activity patterns throughout different times of day during summer, I predict that there will be a difference in activity patterns. In addition to time spent foraging, I was also interested in social behavior. During the summer, loons are paired, and I predict that there will be a difference in the amount of time spent alone, paired, and in flocks of three or more birds based on time of day.

Like many species, in recent decades, common loons have experienced population declines and range constriction (Bianini et al. 2021), which may be attributed to climate change. Loons were listed as a threatened species in the state of Michigan in 1987 and are still listed today. The Michigan Loon Recovery committee listed toxic contamination, such as from mercury, diseases like botulism, deaths in commercial fish traps, and human interference with the breeding process (Michigan Loon Recovery Committee, 1992) as threats to loons. Tip of the Mitt Watershed Council, a watershed protection organization working in the area, conducts a monitoring program to monitor for poor water quality that cause botulism outbreaks or otherwise affect loons (Douglas Lake Improvement Association).

Since research about how animals naturally may help scientists protect them (Evers 1994), this research may help protect common loons in the future by allowing researchers to infer how looms might adapt to anthropogenic change or disturbances that affect them, such as warming water, pollution, habitat destruction, or a decline in the availability of prey based on how activity budgets can be used to help researchers predict animals' adaptations to anthropogenic change (Greggor et al. 2019) .

Methods

Study site

This study was conducted at the University of Michigan Biological Station in Pellston, MI (45.5594° N, 84.6738° W). The animals were observed on Douglas Lake, and specifically within North Fishtail Bay and South Fishtail Bay (Figure 1). Douglas Lake is a mesotrophic lake with a surface area of 3,395 acres and which reaches a depth of up to 80 feet (Godby and Cwalinski 2016). The water is clear, which loons prefer. The lake contained four pairs for the present season, according to local observers, although others were present at other parts of the lake, including Maple Bay and Manitou Bay (Douglas Lake Association). Active data collection occurred during a period of three weeks in July 2021.

Map of Douglas Lake:

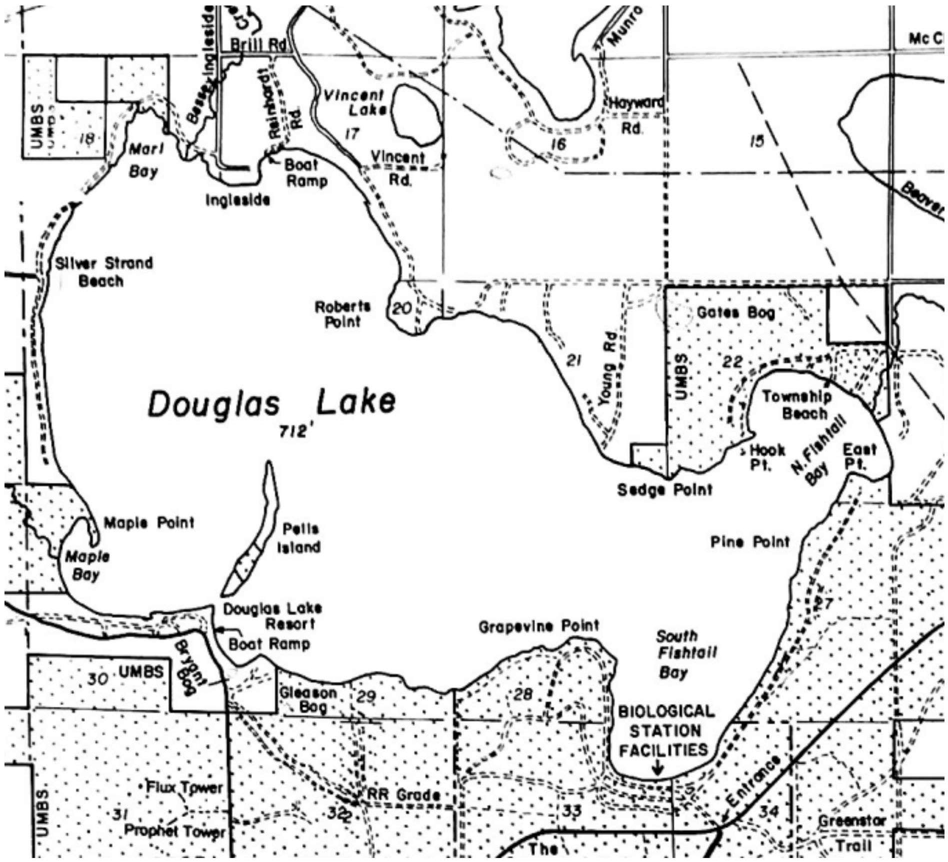

Figure 1. Douglas Lake (University of Michigan Biological Station)

Behavioral observations

I observed the animals from a canoe using 10x50 Nikon binoculars for 15 minute bouts at times from 7 a.m. to 9 p.m.. Sufficient distance to avoid disturbing the animals was maintained. I recorded the following aspects: behavior type (see ethogram for description of behaviors), number of dives, and presence or absence of other individuals other than the focal animal. Next, I noted whether the bird was alone, within a relatively close range (approx. <20 m) of the other bird (paired), or with two or more other birds (flock). Finally, I recorded the number of dives within a 15 minute period. If the animal was not visible for 3 or more minutes, the number of dives was not included in analysis (though it was still recorded).

For behavioral observations, an activity budget was compiled using focal animal instantaneous sampling with one minute intervals (Daub 1988) within each 15 minute period (Lehner 1991, Martin and Bateson 2015). This method was chosen over scan sampling or continuous sampling (Martin and Bateson 2015) because I was mainly interested in the proportion of time an animal spends on a given activity, rather than the number of times it occurred. In addition, loons are fast moving animals, and recording the number of instances of individual behaviors in a set time period could be too difficult or subjective. A focal animal was chosen at random, and this animal was followed either until the 15-minute period ended or until the animal was not visible, at which point I chose a different focal animal if one was present. If another individual was not present, "not visible" was recorded for the rest of the bout, and no additional bouts were conducted until the animals could be relocated. If only one individual was present, that animal was followed for multiple bouts until it was out of view. A timer was set for one minute intervals, and the animal's behavior was recorded according to an ethogram (see below) in bouts of 15 minutes. Because I was the only observer, the risk of observer bias was eliminated.

I used an ethogram based on behaviors observed in several previous studies (Evers 2004, Rummel and Goetzinger 1978, Pettingal 1985, Paruk et al. 2021) as well as based on my own observations during practice observations.

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Ethogram:

Foraging behaviors

Diving: body completely submerged under the water (after having previously observed a dive) or entering or emerging from a dive. It was assumed that diving was for foraging purposes because this is the main function of diving, though it can occasionally be used for predator avoidance.

Locomotion: Appearing to move under own power (swimming).

Rest (called drifting in some studies): Remaining stationary and floating in the water, not moving under own power, or sleeping with head under wing.

Self-maintenance (called comfort behaviors in some studies)

- bill-dipping (repeatedly dipping the head in the water) (Pettingal 1985)
- stretching (rising from water and beating wings without engaging in flight) (Pettingal 1985)
- foot waggle (sticking out foot behind body and moving it back and forth) (Evers 1994)
- preening (using the beak to clean or oil the feathers and fluffing feathers) (Pettingal 1985)

Social behaviors:

Affiliative behavior: pair bonding displays, parental care

Aggressive behavior: General: actual fighting or aggressive displays

The "yodel" call may be heard (male only), wings beat against the water, individuals circle each other. "Vulture" position may be assumed the wings are arched above the body, while the head, neck, and body arch forward (Rummel and Goetzinger 1978).

Flight/ flight takeoff: Loons skimming the water with feet while taking off for flight or actively flying

Not visible: The animal has not been observed for more than two minutes after diving (because Paruk et al. 2021 found that dive duration could be up to 219 seconds, and that 22.2% of solitary dives were over two minutes) or has flown away.

Analysis

Activity budgets were compiled using 961 total minutes of observation: both for listed behaviors (See below) and foraging vs. non-foraging behaviors across all time periods (morning, afternoon, and evening). "Not visible" codes were then excluded from analysis, leaving 810 minutes to analyze. I then compared activity budgets and number of dives between morning (7 a.m. to 12:30 p.m.) and evening (5 p.m. to 9 p.m.) observations. Afternoon behaviors were included in the overall activity budget, but I did not analyze them separately since I rarely observed animals in the afternoon within the study territory.

Additionally, I also recorded whether the focal animal engaged in a foraging bout or non-foraging bout. The focal animal was considered to be within a foraging bout if it engaged in locomotion, resting, or self-maintenance behavior within two minutes of a dive (Nocera and Burgess, 2002 and Strong and Bissonette, 1989).

Results

Overall activity budget: Behavior across all time periods

When overall activity budget is considered (7 a.m. to 9:30 p.m.), Resting was the most common behavior (38% of time). Diving and Locomotion made up nearly equal proportions of time, at 27% and 26% of time, respectively (Figure 2). Self-maintenance behaviors made up 7% of the overall activity budget, while social behaviors (1% of time) and flight behaviors (1% of time) were rarely observed.

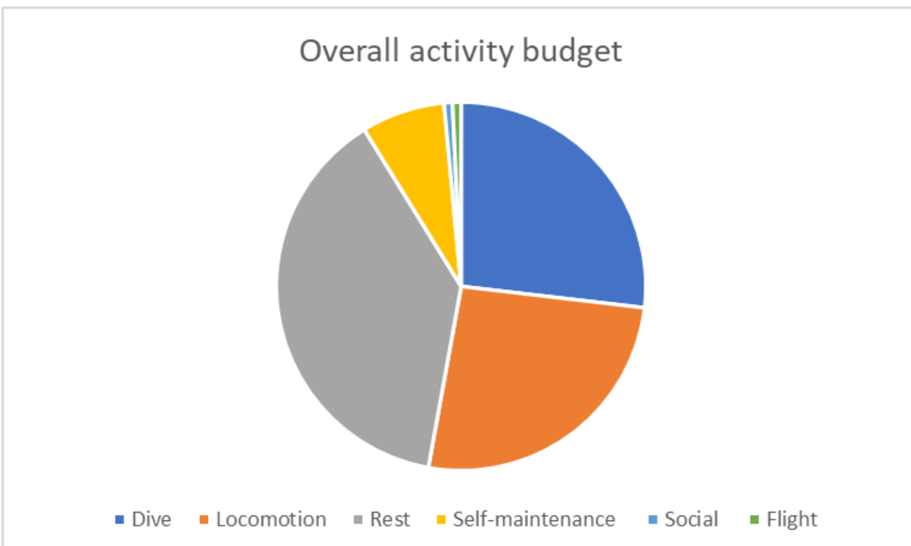

Figure 2. Activity budget for all behaviors from 7 a.m. to 9:30 p.m., N=810 minutes of observation.

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Daily variation in activity budget: Comparing morning to evening

Activity budgets were examined by ethogram category (Figure 3). When only morning behaviors are included (7 a.m. to 12:30 p.m.), Diving was the most common behavior (51% of time). Resting was the next most common, at 32% of time. Self-maintenance and Locomotion made up equal proportions of time at 7% of time each. Social behaviors (2% of time) and Flight (.3% of time) were rare.

When only evening behaviors are included (5 p.m. to 9:30 p.m.), Resting was the most common behavior, at 47% of time, while Locomotion was the next most common, at 40% of time. Self-maintenance behaviors (8% of time) and Diving (5%) were relatively uncommon Figure 3). Flight was rarely observed (.5% of time)and social behaviors were not observed during this time period.

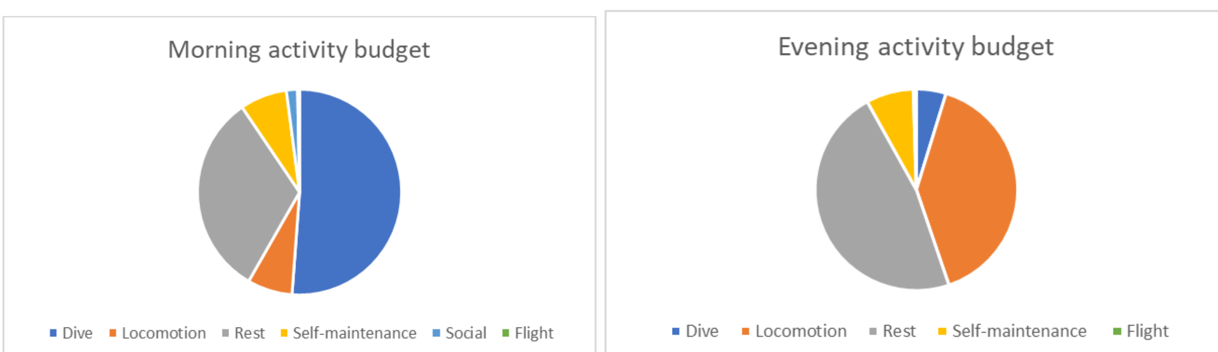

Figure 3. Activity budget broken down by ethogram:a) morning behaviors (7 a.m. to 12:30 p.m.)(N= 336 minutes); b) evening behaviors (N=422 minutes).

Number of Dives per 15-minute period

When comparing the average number of dives per 15-minute period (others excluded as described in methods) far more dives were observed during the morning, with an average of 8.83 dives per 15 minute period, and only 2.68 during the evening (Figure 4). This provides additional evidence that foraging was more common during the morning compared to the evening.

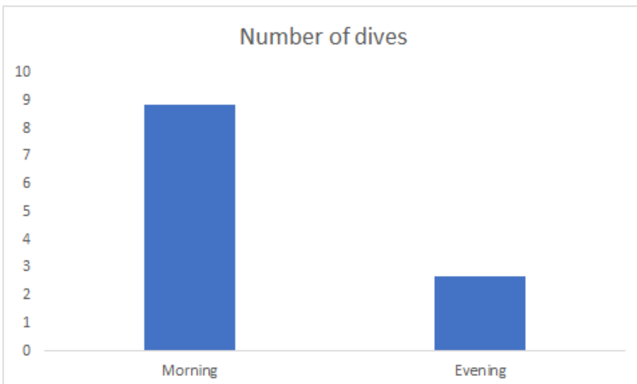

Figure 4. Average number of dives per 15-minute period during morning and evening periods.

Social Behavior

Whether the bird was observed alone or with one or more nearest neighbors also varied by time. When considering all time periods from 7 a.m. to 9 p.m., the percentage of time the focal individual spent alone, meaning that no birds were observed within approximately a ten-meter radius, was 41% (Figure 5). Time spent paired, meaning that only one bird besides the focal individual was present in an estimated fifteen-meter radius, was 51%. Since Douglas Lake is known to have one pair occupying North Fishtail and South Fishtail Bay, the birds observed were most likely this one. However, occasionally other birds were observed, and a flock or three or more birds was observed 8% of the time.

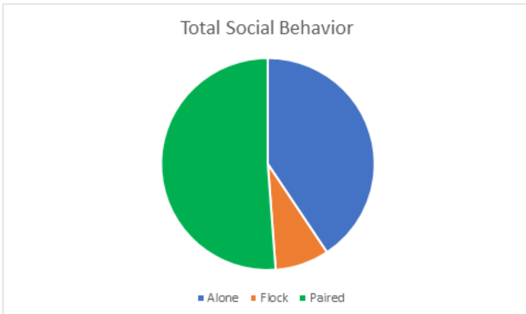

Figure 5. Social behavior observed from 7 a.m. to 9 p.m. N=810 minutes

When examining social behaviors comparing morning and evening time periods, the focal animal spent more time alone in the morning (27%) when compared with evening (20%) (Figure 6). Similarly, the focal animal was more likely to be in a pair during the evening (75%) when compared to morning (62%), however, it was less likely (5% of total in evening vs. 11% in morning) to be observed in a flock. Overall, I observed that when birds were in pairs, they often did similar activities. However, there was some variation within the behaviors of different individuals.

Figure 6. Social behavior observed during a) morning and b) evening periods.

Discussion

Activity budget - does it vary throughout the day?

My results suggest that the loon activity budget does vary throughout the day. Diving was more common in the morning than the evening, while locomotion was more common in the evening, although self-maintenance made up approximately the same amount of time during morning and evening periods. My results differ from those of Daub (1989), who found that loon activity budgets did not vary significantly depending on time of day, although they did vary depending on the tidal levels. This difference may be because Daub's study was conducted in a body of water where tides were present, while mine was not, and the tides may have influenced loon behavior more than time of day in that study. Also, Daub's study was conducted during winter, while mine was conducted during summer when the daylight period is longer. meaning that loons may have already met their energy needs earlier in the day, and did not need to forage at dusk. Moreover, loon pairs do not remain together during the winter (McIntyre 1978) and this may affect their behavior. No other studies investigated diel period differences in loon activity budgets.

Overall activity budget - comparing to other studies

In terms of overall activity budget, my findings are somewhat different from most other studies. I observed that loons spent less time diving (also called feeding) (27% of total activity budget) than in most other studies. McIntyre (1978) found that overall 55% of time was spent feeding (diving). Similarly, Evers (1994), found that loons spent 53%-57% of time diving during the pre-nesting stage. The only other study (Nocera and Taylor 2000) that was conducted on common loons that had laid eggs that did not hatch successfully found that loons spent 56% of time diving. However, my observations of time spent diving were similar to Daub's findings (23%). Other studies also differed from mine in finding that loons spent different amounts of time engaged in resting and locomotion, compared to my findings of 38% of time resting and 26% of time spent engaged in locomotion. McIntyre (1978), Evers (1994), and Nocera and Taylor (2000) combined locomotion and resting into one category, and observed loons engaging in these behaviors 14.8%, 29-32%, and 30% of time, respectively. Daub's results were most similar to mine, finding that loons spent 37% of time resting and 9% of time swimming.

The main differences in my activity budget compared to those in other studies seem to come from my observations during the evening. Considering only the morning period, I found that loons foraged a similar proportion of time (51%) as they did throughout total time in other studies. However, in the evening, I found that they spent very little time foraging (only 5%). Like McIntyre, I found that loons rested more in the afternoon, and did not forage after dusk. However, McIntyre observed a burst of foraging activity just before dusk, which I did not observe (except for one isolated observation near dusk where the focal animal engaged in nearly 60 short dives near the same spot in a period of around ten minutes). It is possible that the shorter daylight period during winter, when McIntyre's study was conducted, meant that loons had less time to forage overall, causing a burst of activity before daylight ended.

There are several possible explanations for why my activity budget results are different from others that have investigated budgets. Since my study involved post-nest failure loons, which behave similarly to birds at other times of year (Nocera and Taylor 2000), differences with other studies cannot be explained by the time of year they were conducted. A potential explanation is differences in the water depth of my site compared to others. For example Evers (1994) study was conducted in pools that reach depth of 2 m, while North and South Fishtail Bay can reach up to 20 m and has a steep drop-off near shore. With the exception of a few shallow patches, there was little shallow water present at my study site. Daub found a significant difference in foraging rates when comparing behavior between shallow (1.5-5.5m) and deeper (5.5-9m) waters, with foraging behavior far more common in shallow waters (51% of time), and Evers (1994) also found that loons are more likely to spend time foraging in shallow water. Thus deeper waters may explain why I saw less foraging than other studies - the loons' primary environment was one where loons naturally forage less.

Finally, some of these differences can be explained by differences in sampling method. I used instantaneous sampling like Daub (1988) while other studies used continuous sampling (Nocera and Taylor 2000). The differences between the way the two methods count occurrences of behaviors influence the results. For example, since continuous sampling records the number of behaviors in a given time period, a high number of short dives within a recording period might count for more time spent in the activity budget than fewer long dives, while the duration of dives would not make a difference in my activity budget. Nonetheless, since I used one-minute sampling intervals which were relatively short compared to the duration of the behaviors (Lehner 1991), interval sampling still provides an accurate picture of the frequency and duration of the loon behaviors I observed, and the results from my study and others using continuous sampling can still be compared.

Conservation challenges and activity budgets

Activity budgets, also called energy budgets, have been studied in numerous wild and captive species other than loons, including diving ducks (Draidi et al. 2019), primates (Schrier et al. 2021), and even fish (Beltramino et al. 2018). Knowing these activity budgets can contribute to understanding the overall ecology of a species because they allow researchers to understand how animals make necessary trade-offs in order to maximize chances of survival. These trade-offs may vary when an animal is faced with environmental changes. For example, Schrier et al. (2021) found that mantled howler monkeys (*Alouatta palliata*) did not alter their activity budgets in edge zones when faced with increasing human-caused forest fragmentation, indicating they were not able to adapt to increasing danger. Just as these animals experience changes in their behavior in response to environmental changes, so too might common loons.

Loons are visual predators, and require lakes with water clear enough to catch their prey (McIntyre 1994), which may be a reason Douglas Lake is used by loons. Therefore, eutrophication currently occurring in the Great Lakes region, including harmful algal blooms (Schindler et al. 2016) may be expected to affect loon activity budgets. Water clarity is affected by turbidity associated with eutrophication, and this turbidity can also filter out shorter wavelengths of light (Leech and Johnsen 2009). Therefore, if eutrophication occurs in the loons' environment, they may need to spend more time diving or engaged in locomotion in order to find prey because visibility will be lower. Alternatively, like juvenile loons that are unskilled foragers, adult loons faced with low visibility might keep the amount of time spent foraging the same, but compensate by consuming lower quality prey (Hoover et al. 2021).

In addition to difficulties finding prey due to visibility, loons might also experience changes to activity budgets caused by decreasing availability of prey. While fish consumed by loons would be advantaged by lower visibility, they are disadvantaged by other effects of anthropomorphic change, such as rising water temperatures. Freshwater coldwater fish that loons consume, such as yellow perch, are declining in abundance in relation to a warming climate (Jacobson et al. 2017). Like with eutrophication, loons would need to alter their activity budget by increasing time spent diving or by traveling longer distances to obtain prey.

My results can contribute to an understanding of how common loons may adapt to environmental change by providing a more recent baseline of common loon behavioral ecology, since nearly all general activity budget studies of common loons were conducted at least twenty years ago. As a whole, the most important difference I found compared to previous research is that time spent foraging (diving) is greater in most other studies. However, the result that loons spent less time diving in this study than in the past would imply that loons are more efficient, not less, so the idea that loons have changed their activity budget in response to climate change is not currently supported. While I could not definitively determine that loons are affected by these issues from my data, it is possible that they will be in the future, and understanding their current ecology will be helpful for determining whether loons will be able to adapt to these environmental changes.

Unlike other studies, I observed little foraging in early or late evening, which influenced the overall activity results. Therefore, although more data on the availability of prey is needed, it is possible that in Douglas Lake, the deeper water within available within the relatively small small space of the bays mean that loons are able to satisfy their energy needs earlier in the day, and did not need to continue foraging in the evening. Alternatively, it could indicate that they were resting additionally to save energy. I do not think that I can conclude from my data that the

Douglas Lake loons or other common loons are currently facing problems related to environmental change. However, if future research at this site or similar sites indicated that the birds were spending an inordinate amount of time foraging overall compared to the total literature, or that they sharply decreased foraging, this could indicate a negative effect of environmental change. I do not think that increased foraging in the evening would necessarily indicate an issue, since it is found in the literature, but a large increase in foraging in the afternoon might indicate one.

This study was limited by a few practical issues. Because I did not have permission to band the birds, and it is impossible to identify individuals as male and female as the breeding plumage is identical, I was unable to identify individuals and sex the birds. However, most other studies also did not identify individuals. The study was also limited by a small sample size of only one pair.

Social behavior and other observations

Social behavior did differ between morning and evening periods, but these differences were not as large as the differences between foraging and non-foraging behavior rates , which may demonstrate plasticity in behavior. Nevertheless the result is not conclusive because I was not able to demonstrate a significant difference.

Qualitatively, I observed that when pairs were together, they often did similar activities, such as diving synchronously within ten seconds of each other as in Paruk et al. (2021), or moving across the lake as a pair. On two occasions (within the same hour, but separated by a period of synchronous diving and resting without aggression) where there were three or more individuals, I observed aggressive territorial behavior, including vulture position (Rummel and

Goetzinger 1978) and vocalizations. On one of these occasions, I observed six individuals in a circle engaging in this behavior, which resulted in all of the individuals eventually flying away. My observations of synchronous behavior are supported by data from McIntyre (1988) showing that pairs often fed, traveled, and preened together during summer. Although common loon breeding pairs are apart during winter (McIntyre 1978), they are seasonally monogamous, with the same pairs usually reuniting every spring and summer during the pre-nesting, nesting, and post-nesting stages (Gostomski and Evers 1998). Additionally, Paruk et al. (2021) found that in winter, loons foraged in flocks 35% of the time and that this varied by whether the transect had a river mouth, suggesting foraging plasticity which may increase foraging efficiency. This was in contrast to Daub (1978) who found that loons primarily foraged as individuals during winter. In my study, variation in social behavior with time period could also suggest foraging plasticity (Paruk et al. 2021), which could be used to support conservation goals by providing an understanding of how loons may have the ability to vary their behavior based on changing conditions.

Future directions

New technology provides new options for common loon monitoring. In the future, it would be helpful to attach a tracking sensor to birds, as was done in Paruk et al. (2021), to monitor whether distance traveled changes throughout the day. Studies could also be done at various geographic locations with different ice-off times (Bianchi et al. 2021), or in areas where loons are being reintroduced after having previously disappeared from the area, to determine if activity is abnormal in these areas. Additionally, continuous monitoring of environmental conditions is needed, including monitoring of water and air temperatures and nutrient levels, as well as legislative action to prevent runoff causing eutrophication.

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