TRENDS IN BREEDING PROPENSITY OF COMMON LOONS (*Gavia immer*) IN RELATION TO LAKE WATER CLARITY IN AND AROUND ALGONQUIN PROVINCIAL PARK

By

Lillian McDaniel

Image: Sarah Lamond

FACULTY OF NATURAL RESOURCES MANAGEMENT
LAKEHEAD UNIVERSITY
THUNDER BAY, ONTARIO

April 2023

Trends in Breeding Propensity of Common Loons (*Gavia immer*) in Relation to Lake Water Clarity in and Around Algonquin Provincial Park

by

Lillian McDaniel

An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 2023

__________________ __________________

Major Advisor Second Reader

LIBRARY RIGHTS STATEMENT

Signature: ______________________________

Date: _____April 19th, 2023____________

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or of Lakehead University.

ABSTRACT

McDaniel, L. Trends in breeding propensity of Common Loons (*Gavia immer*) in relation to lake water clarity in and around Algonquin Provincial Park. 33 pp.

Productivity of Common Loons has been in decline across most of Canada for several decades. Many environmental factors and human impacts on the breeding grounds may be causing the decline, and these factors are known to vary regionally. Common Loons are visual predators and rely on the clarity of lake water to forage. The Canadian Lakes Loon Survey and the Algonquin Park Loon Survey are used here to analyze trends in breeding propensity in Algonquin Provincial Park and surrounding area. The Ontario Lakes Partner Program was used to relate lake water clarity measured by Secchi depth to observed occurrence of Common Loon chicks on four lakes with long-term data. No decline occurs from 1982-2018 in the percent of lakes in Algonquin Park or its surrounding area with evidence of breeding observed. There is no correlation between water clarity and breeding propensity on the four chosen lakes. Where declines are occurring, the potential relationship between water clarity and Common Loon productivity should be investigated.

Keywords: Algonquin park loon survey, aquatic ecology, breeding, Canadian lakes loon survey, citizen science, foraging, Secchi depth, waterbirds

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Thank you to Dr. Brian McLaren for guiding me through this undergraduate thesis and providing feedback throughout. I also thank Dr. Doug Tozer of the Long Point Waterfowl and Wetlands Research Program of Birds Canada for providing such valuable data from the Canadian Lakes Loon Survey and the Algonquin Park Loon Survey and valuable insight into my research topic. Additionally, I thank volunteers and park visitors who have contributed to decades worth of Common Loon observations in Central Ontario. Thank you to the Ontario Lakes Partner Program (MECP) for providing water clarity data across Algonquin Park. Lastly, thank you to my parents for their support.

INTRODUCTION

Common Loon (*Gavia immer* B.) productivity has been in decline across Canada for several decades (Bianchini et al. 2021a). As of 1990, approximately one-third of the global Common Loon population was determined to be breeding in Ontario (Wayland and McNicol 1990). Ontario, in particular, has had a downward trend in Common Loon productivity for several decades. In this case, productivity is measured by breeding success determined by evidence of 6-week-old young (chicks). Approximately 1% fewer chicks have been produced per pair per year from 1981 to 2018 in Ontario, which is a decline of ~30% over the entire period (Bianchini et al. 2020). Reasons for the decline in productivity in Ontario include low pH (i.e., high acidity) in lakes (Bianchini et al. 2020) and later ice-off dates (Bianchini et al. 2021b). As the reproductive threshold for population stability is quickly being approached in many regions, it is critical to determine possible factors that are causing declines in productivity (Bianchini et al. 2021a).

Water clarity is an important potential factor that could contribute to fitness in Common Loons, which are diving birds that rely on eyesight to find prey (Cornell 2022). Factors that determine the clarity of lakes include phytoplankton, suspended solids, and organic detritus (Bachmann et al. 2017). Secchi discs are used to measure water clarity by lowering a black and white disk into the water until visibility is lost. The depth at which the disk is no longer visible is the measurement of clarity (Preisendorfer 1986). The Secchi disk depth of lakes in Ontario is recorded annually by the Ministry of the Environment, Conservation and Parks and made available by the Great Lakes DataStream (Great Lakes DataStream 2022). Here, the fitness proxy of Common Loon productivity will be measured as the proportion of lakes on which loon chicks are observed in Algonquin Provincial Park and its surrounding area.

Algonquin Provincial Park is a 7,630-km^2 protected area in Ontario that contains almost 1,300 lakes >5 ha (Ridgway et al. 2017). Common Loons can be heard calling on almost all these lakes (Strickland 2016). Yearly surveys have not indicated that the population of Common Loons in Algonquin Park is in decline. Because of Algonquin's large size and abundance of breeding grounds for the Common Loon, it is important to review local factors that may be hindering their productivity in the park. There are two different datasets useful to evaluate breeding propensity of Common Loons in Algonquin Park: (1) observations of Common Loon adults, chicks, and nests that have been recorded on lakes throughout Algonquin Park since 1987 using the citizen-science Algonquin Loon Survey program run by Park Naturalists; and (2) observations of Common Loon adults and chicks recorded during the nesting, hatching, and chick survival periods by volunteers of the Canadian Lakes Loon Survey, run by Birds Canada since 1981. In the Algonquin Loon Survey and the Canadian Lakes Loon Survey, breeding propensity refers to the proportion of lakes occupied by loons with evidence of breeding defined by the presence of a nest and/or young on a lake. Measuring breeding propensity is important to inform conservation actions if reproductive success drops below the threshold required to maintain the population.

The first objective of this thesis is to evaluate trends in Common Loon breeding propensity in Algonquin Park and its surrounding area from 1982 until 2018. The second objective is to determine whether there is a relationship between lake water clarity and breeding propensity in Algonquin Park comparing data from 2001 to 2020. Waterbirds with better body conditions have better breeding and nesting success than those with poor body condition. The clarity of lakes in the Algonquin region fluctuates annually and throughout the nesting season of the Common Loon. If adult Common Loons depend on water clarity to search for prey, then years with lower water clarity will have fewer loon chicks produced per pair.

LITERATURE REVIEW

COMMON LOON PRODUCTIVITY DECLINE

The breeding range of the Common Loon covers most of Canada, the northern portion of Wisconsin, Michigan, Minnesota, most of Alaska, and the southern edge of Greenland (Cornell n.d; Johnsgard 1987). They are medium-distance migrants, wintering along the Atlantic and Pacific coasts of southern Canada and the United States. There are declines in the productivity of Common Loons in many regions across their range (Piper 2020; Bianchini et al. 2021a). According to the Canadian Lakes Loon Survey, Common Loon productivity has been in decline in Canada since the early 1990s (Bianchini et al. 2021a). Declines have occurred in Prairie and Atlantic provinces, while Quebec remains without decline in recent decades. In Ontario as a whole, productivity has been declining for approximately three decades by ~1% per pair each year (based on six-week-old young; Bianchini et al. 2020). A reproductive rate of 0.48 fledged young per breeding pair per year is the threshold level required to maintain a stable population of Common Loons (Evers 2007). The reproductive rate has been observed between 0.20 and 0.84 in regions including New Hampshire, Minnesota, Saskatchewan, and New York (Johnsguard 1987).

Several environmental changes on breeding grounds of Common Loons have been identified as limitations to their productivity. Most studied is the extent to which acid precipitation causes declines in breeding success across Ontario by acidification of breeding lakes (Alvo et al. 1988; Bianchini et al. 2021c). Climatic conditions can also influence breeding success. Cooler April temperatures decrease the productivity of Common Loons in Ontario (Bianchini et al. 2020). Late ice-off dates of breeding lakes in Ontario result in fewer breeding attempts and reduced breeding success of Common Loons (Bianchini et al. 2021b). The longitudinal location of breeding lakes impacts the extent of breeding success declines, with higher productivity in western regions in Canada, and declines in productivity moving eastwards (Tozer 2013). Environmental changes including climatic changes and disturbances like lake acidification impact Common Loon productivity.

Physical attributes of lakes chosen by breeding individuals can impact Common Loon productivity. Larger lakes have a higher occupancy of breeding Common Loons (Blair 1992; Tozer et al. 2013) and higher productivity (Bianchini et al. 2020). Similarly, deeper lakes result in higher productivity (Blair 1992). Prey abundance is directly linked to the ability to forage and thus the body condition of Common Loons. Lack of fish and concentration of mercury in fish are likely results of lake acidification and contribute to productivity declines (Evers et al. 2007; Bianchini et al. 2020). There is inconsistency in findings regarding the effect of human disturbance and shoreline development on Common Loon productivity (Bianchini et al. 2020). The physical conditions of lakes can directly impact Common Loon breeding and foraging behaviours which can impact productivity.

Other biotic factors can influence the presence of and breeding success of Common Loons. There is increased breeding success for loons on lakes with Bald Eagles (*Haliaeetus leucocephalus*) and Double-Crested Cormorants (*Phalacrocorax auratus*) in Ontario, because of shared niche foraging preferences between the three species (Bianchini et al. 2020). An association between the presence of Bald Eagles and reduced breeding success has been identified in New England due to predation on Common Loon chicks and adults (Cooley et al. 2019). Black Flies (*Simulium annulus*) can be observed feeding on and using the Common Loon as their host. Peak black fly season overlaps with Common Loon nesting season in Ontario. Black fly disturbance on Common Loons can cause nest abandonment (Piper et al. 2018). The impact of flies on Common Loon nesting is largely dependent on annual weather conditions that control the severity of black fly outbreaks (Piper et al. 2018; Bianchini et al. 2021a).

The past several years in loon research have been focused on identifying possible factors for productivity declines. To add to the complexity of this puzzle, factors for declines are likely to depend on the region of focus within the Common Loon range. Many of the factors that are suspected to cause productivity declines have been confirmed for some regions but found to have no correlation with productivity for other regions, especially in the case of human disturbance. Identifying how reasons for productivity vary regionally and to what extent is both important and challenging.

COMMON LOON FORAGING AND DIVING BEHAVIOUR

Common Loons are primarily piscivorous and display opportunistic foraging behaviour. Their diet consists mainly of fish, followed by crustaceans, mollusks, aquatic insects and leeches (Munro 1945; Barr 1995). Adult Common Loons in Algonquin Park have been observed foraging on the following in order of highest occurrence; perch, crayfish, minnows, suckers, trout, bullhead, leeches, and vegetation (Barr 1995). The size of prey fish is most often between 10-70 g (Barr 1995) and 5-20 cm (Barr 1973). They are diving waterbirds, relying on their specialized eyesight to locate prey (Barr 1995; McIntyre and Barr 1997). Average dive duration can range from 5 to >75 s

(Munro 1945; Stewart 1967). Dive duration usually includes time spent ingesting prey, which is typically done beneath the water's surface (Barr 1996).

Common Loons rely entirely on eyesight for the detection of prey species (Barr 1996). When prey is detected from the surface of the water, the Common Loon quickly dives for it, then captures it using mechanisms specialized to quickly capture fast-turning fish species. Dives can be done in up to 70-m depths. The streamlined body of a loon makes for incredible speeds during dives (Strickland et al. 2022). An individual can almost instantly change its swimming direction by rotating its knee and using its webbed foot to propel in an alternate direction (Clifton; Biewener 2018). It will sometimes bob its head as a technique to improve visibility underwater by accelerating its head three times faster than its body, therein also increasing depth perception (Clifton; Biewener 2018). Though this design allows for strong swimming abilities, it costs a loon the ability to move quickly on land.

COMMON LOON BREEDING

Common Loons have been observed nesting on islands, along riparian-area shorelines, on muskrat houses, using floating sites, and on man-made nesting platforms (Munro 1945). The nest site is selected by the male and then built by both the male and female in either May or June. The nest site is typically selected directly on the water's edge and not more than 1.2 m inland (Vermeer 1973). Islands are preferred for nesting (McIntyre 1975). Fluctuating water levels can be harmful to Common Loon breeding success for two reasons. Increases in water level after nest establishment can cause flooding and abandonment of nest and eggs (Kelly 1992; Windels et al. 2013). Declines in water levels can also put nests at increased risk of predation (Windels et al. 2013) and increase the chance of nest abandonment due to reduced access to the nest from water (Titus and VanDruff 1981). Common Loons show high fidelity to nest sites of previous years (McIntyre 1975). Incubation lasts 26-29 d (Cornell n.d.). Clutch size is typically 1-2 eggs (McIntyre 1975). Both parents will care for chicks until they fledge at about 11-12 weeks old and begin to dive themselves (McIntyre 1975; Barr 1996).

EFFECT OF WATER CLARITY ON DIVING PISCIVOROUS WATERBIRDS

Increased abundance of breeding waterbirds is associated with greater clarity of lake water (Newbrey et al. 2005; Fox et al. 2019). Many species of waterbirds have minimum water clarity requirements to forage successfully. The Brandt's Cormorant (*Urile penicillatus*) inhabits only lakes with clarity equivalent to visibility greater than 5 m, because more prey is spotted in clearer water (Henkel 2006). Water clarity is a component of habitat selection by Common Loons and directly influences their foraging efficiency (McIntyre 1975; Kuhn 2011).

Lower foraging efficiency is related to lower body conditions in birds (Schamber et al. 2009). Body condition directly impacts the waterbird's decision to breed and also the egg formation process, like in the case of the Blue Petrel (*Halobaena caerulea*), another diving waterbird (Chastel et al. 1995). Female Mallards (*Anas platyrhynchos*) will nest earlier and produce larger clutch sizes (Devries et al. 2008). Male waterbirds with a larger mass also have higher reproductive success than lighter males (Gibbons 1989). It is unknown how the mass of Common Loon adults impacts breeding success. However, the body conditions of breeding Common Loons are often better than that of non-breeding individuals in the same population (Sidor et al. 2003).

Since Common Loons are visual predators and detect prey by ducking their heads beneath the surface, the depth at which they can spot prey will directly influence the abundance of prey capture. When the clarity of lakes is reduced, Common Loons will shift their diet from primarily fish to easier-to-capture prey, like crayfish (Barr 1995). Common Loons particularly prefer clearer lakes during the breeding season (Alvo et al. 1988; Kuhn 2011). Breeding attempts are reduced by darker-coloured lakes, which are associated with lower water clarity (Alvo et al. 1988). On wintering grounds, diving duration of the Common Loon is longer when water clarity is higher (Thomson and Price 2006). Higher dive durations might be associated with increased prey capture or might be a result of spotting prey at farther distances, requiring longer dives (Thomson and Price 2006). In either case, higher dive duration is a positive sign for the efficiency of foraging behaviour. It is unknown if the association between water clarity and diving duration also occurs on breeding grounds.

Despite several studies on environmental factors that may be causing breeding declines in Common Loons, there have been very few on the relationship between water clarity and breeding propensity in Common Loons. It has yet to be investigated if water clarity, measured by the depth of visibility, reduces the breeding success of Common Loons in Ontario.

MATERIALS AND METHODS

STUDY AREA

Algonquin Provincial Park is in South-Central Ontario. It was established in 1893 and is now 7,630 km^2 (Friends of Algonquin 2022). This study considers the surrounding area of Algonquin Park in a 100 km buffer around the Park boundaries (Figure 1).

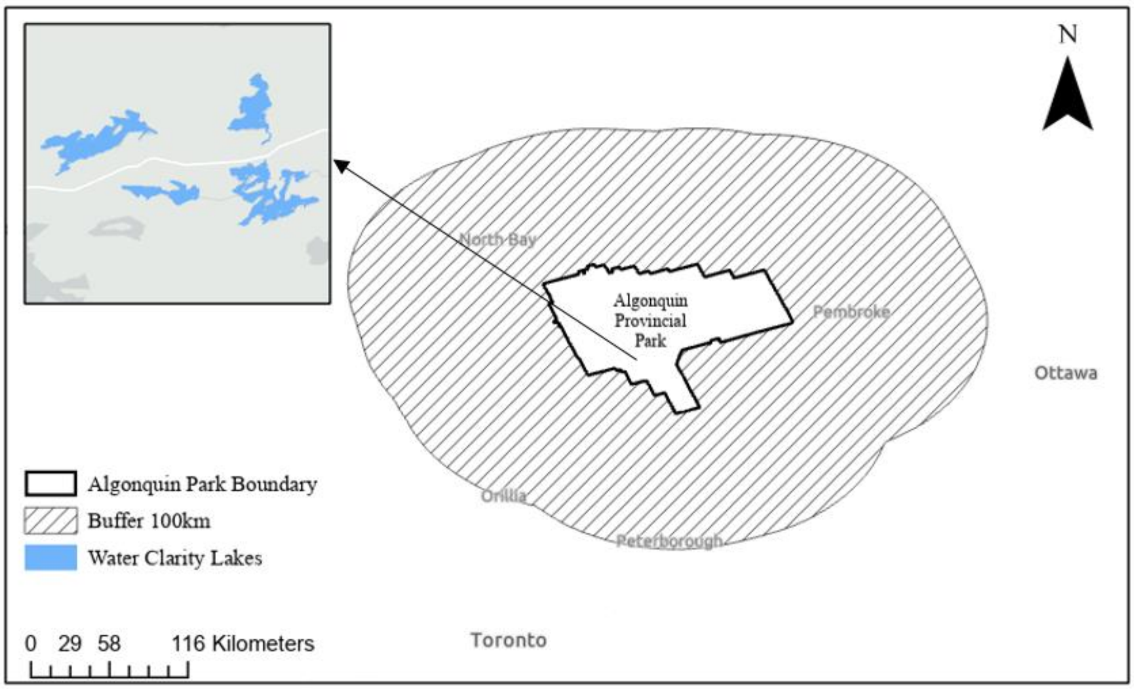

Figure 1. Map of Algonquin Provincial Park boundary and the surrounding area (100km buffer) and four lakes chosen for water clarity investigation (Source Lake, Tanamakoon Lake, Cache Lake, Canisbay Lake).

DATA COLLECTION

1. Algonquin Park Loon Survey

Data were obtained from the Algonquin Park Loon Survey corresponding to surveys in 1987 to 2018. Observations of Common Loons from various sources were brought together to produce yearly results, including reports from backcountry rangers, Park Naturalist sightings, and eBird observations in the later years of the survey (Table 1). An annual summary was created of lakes in Algonquin Park with presence of Common Loon adults and evidence of Common Loon breeding, by the presence of either a nest or young. There was a total of 5929 observations across all annual summaries.

2. Canadian Lakes Loon Survey

Data were also obtained from the Canadian Lakes Loon Survey from 1982 to 2018 (Table 1). Volunteers are trained to identify Common Loons and chick age classes and given a standardized approach to gathering data. Volunteers survey their assigned lake three times per year: during nesting, after hatching, and at a time identified to confirm chick survival. The number of days surveyed per month, the maximum number of adult Common Loons, the maximum number of mated pairs, the maximum number of young chicks (less than 6 weeks old) and the maximum number of chicks older than 6 weeks are recorded. If a lake is only partially surveyed, the surveyed section is specified. For some larger lakes, more than one volunteer is assigned. Data were summarized to show the number of annual adult Common Loon pairs and the number of large young on each surveyed lake in Algonquin Park and the surrounding area. There was a total of

9105 observations, 338 of which were located within Algonquin Park and the rest in the surrounding area.

3. Water Clarity

Water Clarity data were made available by the Ontario Lake Partner Program (LPP) run by the Ministry of the Environment, Conservation and Parks. Secchi depths are recorded at the deepest part of each lake as a measurement of the depth of visibility or water clarity. The dataset spans 41 lakes in Algonquin Park over 20 years (Table 1).

Table 1. Summary of the 3 datasets including the duration of the program and the data collated.

Dataset	Years	Data
Algonquin Park Loon Survey	1987 - 2021	Presence of adults, young, and nests
Canadian Lakes Loon Survey	1981 - 2021	Presence of adults, young, large young, and nests
Ontario Lake Partner Program	2001 - 2021	Secchi depth (m)

There was some overlap between lakes surveyed across the two loon datasets within the same year and thus, an observation of Common Loon chicks or nests from either dataset was accepted as breeding evidence in Algonquin Park. Where provided, the number of chicks produced was disregarded to provide consistency between datasets. Not every lake was surveyed every year that the two loon datasets span, with lakes being surveyed anywhere from 1 to 37 years (Table 2). Lakes with no Common Loon adults observed for any given year were removed from the dataset for analysis to assume that every lake analyzed was a potential breeding lake. Each lake in each year had Common Loon adults present and Common Loon chicks either present or absent.

Table 2. Distribution of Common Loon observations across two survey types within Algonquin Park and the surrounding area.

Area	Survey Type	No. of Lakes	No. of Years	No. of Observations
Algonquin Park	APLS[a]	772	31	5929
Algonquin Park	CLLS[b]	137	36	338
Surrounding Area	CLLS	750	36	8767

[a] Algonquin Park Loon Survey
[b] Canadian Lakes Loon Survey

Four lakes were chosen for water clarity investigation: Source Lake, Tanamakoon Lake, Cache Lake, and Canisbay Lake. All four lakes were along the highway 60 corridor due to accessibility for sampling and thus, a large span of water clarity data over several decades. Not every lake was sampled every year and lakes that were sampled for water clarity more than once per year were averaged for an annual water clarity value, representative of the clarity level for the given year. Lake water clarity values were sorted into three bins: low, medium, and high, based on the Secchi depth value. Water clarity ranged between 2 and 7m and were split into three even bins. Low water clarity includes Secchi depth measurements from 2.00-3.67m, medium water clarity includes 3.68-5.34m, and high water clarity includes 5.35-7.01m.

Observations from the four replicate lakes were combined to determine how productivity is correlated to water clarity in general, independent of the individual lake. The percentage of lakes with Common Loon chick and/or nest observations was calculated for each water clarity bin. For the second part of the water clarity analysis, an average water clarity value was calculated for each of the four replicate lakes. Again, the percentage of years with Common Loon chicks was calculated for each of the four lakes.

RESULTS

In Algonquin Park, the lowest observation of Common Loon breeding was in 1999, with 33% of lakes with evidence of Common Loon breeding, compared to a high of 51% in 2013. In the surrounding areas, breeding evidence was lowest in 1997 at 40% of lakes. Breeding evidence was highest in 1994 at 67% of lakes. Trends in breeding fluctuate from year to year in both Algonquin Park and the surrounding area. There did not appear to be a significant decline or increase in Common Loon breeding in either Algonquin Park or its surrounding area (Figure 2). There was greater variation in the breeding measure in the surrounding area than in Algonquin Park.

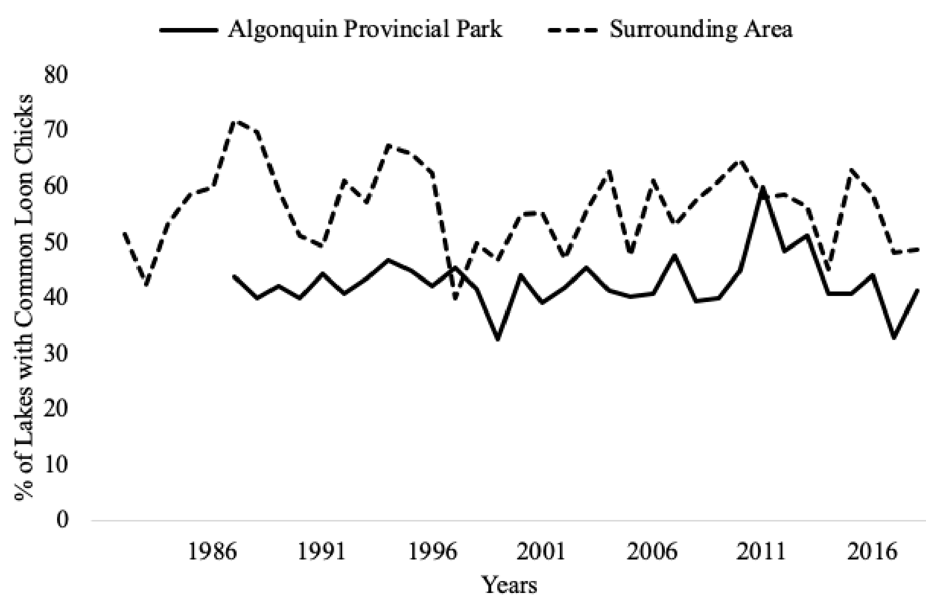

Figure 2. Percent of occupied lakes with evidence of Common Loon breeding (nests or chicks) from 1982-2018 in Algonquin Provincial Park and its surrounding area.

Medium-clarity lakes and years with medium clarity had more than double Common Loon chick observations than both low and high clarity years. Years with low water clarity always had observations of Common Loon chicks. Years with medium and high water clarity only had observations of Common Loon chicks a little over half of the years surveyed (Table 3).

Table 3. Percentage of years with Common Loon chicks produced on Cache Lake, Canisbay Lake, Tanamakoon Lake, and Source Lake across three categories of annual water clarity.

Water clarity	Secchi depth (m)	No. of years with loon observation data	% years with chicks
Low	2.00-3.67	13	100.00
Medium	3.68-5.34	29	62.07
High	5.35-7.01	8	62.50

Source Lake had the highest average water clarity of the four lakes, followed by Tanamakoon, Cache, and Canisbay lakes. Canisbay Lake had the lowest average water clarity, and it had the highest percentage of years with Common Loon chicks produced from the ten years of observation data (Table 4).

Table 4. Distribution of water clarity data measured by Secchi depth (m) and the percentage of years with Common Loon chicks produced.

Lake	No. of years with Loon observation data	Average water clarity	% years with chicks
Canisbay	10	3.21	100.00
Cache	14	4.01	92.86
Tanamakoon	11	4.59	45.45
Source	15	5.45	53.33

DISCUSSION

TRENDS IN BREEDING PROPENSITY

Common Loon productivity has been in decline in Ontario as a whole for several decades (Bianchini et al. 2020). The lack of significant decline in breeding propensity observed in this study in Algonquin Park and the surrounding area is a sign that this part of their range may provide some refuge from the declines experienced across most of their range. Central Ontario may be providing the ideal habitat for the Common Loon to breed like the abundance of large lakes and clear water. If the decline is not evident in Algonquin Park and the surrounding area, the decline observed in previous studies may be elsewhere within the province (Bianchini et al. 2020; Bianchini et al. 2021a).

The Algonquin region may be lacking factors known to cause Common Loon breeding decline that are likely present elsewhere in Ontario. Factors that are characteristic of Northern Ontario, such as lake acidification observed in Sudbury (Alvo 1988), later ice-off dates (Bianchini et al. 2021b), and cooler April temperatures (Bianchini et al. 2020) may contribute to declines. Factors known to cause declines that are characteristic of Southern Ontario include lack of lakes and loss of wetlands and shorelines due to urban development, declines in productivity moving eastwards in longitude (Tozer 2013), smaller lakes (Tozer et al. 2013), and more shallow lakes (Blair 1992). Algonquin Park and the surrounding area may be a place of stability for Common Loons because of its ideal habitat, climatic conditions, and minimal human disturbance.

The sampling methods of either dataset may result in missed Common Loon observations of adults and/or young. Thus, the actual number of breeding lakes is likely higher than observed in this study. However, since the sampling methodology remained unchanged over nearly four decades across such a large span of lakes, these numbers should provide accurate trends in relative breeding between years. While the surrounding area had a higher percentage of breeding lakes than in Algonquin Park, this outcome may be representative of a more rigid survey protocol in the Canadian Lakes Loon Survey than in the Algonquin Park Loon Survey.

WATER CLARITY

When grouping annual clarity of four lakes into three categories of Secchi depth measurements, water clarity did not influence the presence of Common Loon chicks and when observing average water clarity by lake, higher water clarity lakes did not result in a greater number of Common Loon chicks produced. Canisbay Lake's ability to produce loon chicks in all ten years despite having the lowest clarity may reflect several factors. For example, Canisbay is the only lake of the four replicates that does not have cottage leases or a children's camp along its shoreline. Cache Lake has 62 cottages, a children's camp, and boat-access lodging accommodations, Tanamakoon Lake has two canoe-access sites and a children's camp, and Source Lake has 15 cottages and a children's camp (MECP 2013). Because the four replicate lakes were not surveyed in synchronous years, the difference in breeding might be a result of yearly fluctuations in ice-off dates (Bianchini et al. 2021b) and April temperatures (Bianchini et al. 2020). Additionally, Canisbay is the deepest lake of the four surveyed with a maximum depth of 24.9 m which may explain the high breeding propensity (OMNRF n.d.; Blair 1992). The difference between the lowest and highest mean water clarity ~2 m and may not be a large enough difference in water clarity to except a change in breeding. Additionally, the limited sample size of only four lakes for water clarity investigation may have limited the ability to find a correlation between water clarity and breeding propensity. While it is true that higher water clarity increases the abundance of waterbirds (Newbrey et al. 2005; Fox et al. 2019), there is no evidence that water clarity also affects breeding propensity of Common Loons.

CONCLUSIONS AND RECOMMENDATIONS

I recommend that further analysis of water clarity's effect on Common Loon breeding propensity be done. It is no doubt the daily habits of Common Loons are impacted by clarity and as such, the extent to which clarity impacts breeding practices should be further investigated across a greater geographic extent beyond Algonquin Park. I also recommend further studies be done to understand the implications of other unique characteristics of Algonquin Park lakes to Common Loon breeding propensity. Characteristics as such may include shoreline infrastructure, public beaches, number of canoe-access sites, and motorboat traffic may all be factors potentially impacting Common Loon breeding. Knowledge of these impacts can inform ways to ensure the Algonquin Park Common Loon population remains stable.

There is no evident decline in Common Loon breeding propensity within Algonquin Park or the surrounding area. Breeding trends in this region should continue to be closely monitored. Further studies of impacts of shoreline infrastructure in the park should be investigated. Factors that may contribute to the success of Common Loons in Algonquin Park should be identified and then recognized by other regions where loons are experiencing declines.

LITERATURE CITED

Alvo, R., Hussell, D.J.T., and M. Berrill. 1988. The breeding success of common loons (*Gavia immer*) in relation to alkalinity and other lake characteristics in Ontario.

Bachmann, R.W., M.V. Hoyer, A.C. Croteu, D.E. Canfield Jr. 2017. Factors related to Secchi depths and their stability over time as determined from a probability sample of US lakes. Environmental Monitoring and Assessment. 189: 206.

Barr, J.F. 1995. Aspects of Common Loon (*Gavia immer*) feeding biology on its breeding ground. Hydrobiologia 321: 119-144.

Betz, C.R. and P.J. Howard. 2022. Wisconsin Citizen Lake Monitoring Training Manual. University of Wisconsin-Stevens Point.

Bianchini, K., D.C. Tozer, R. Alvo, S.P. Bhavsar, and M.L. Mallory. 2021a. Canadian lakes Loon Survey: Celebrating 40 years of conservation, research, and monitoring. Birds Canada, Port Rowan, Ontario, Canada. 30pp.

Bianchini, K., R. Alvo, D.C. Tozer, and M.L. Mallory. 2021b. Late ice-off negatively influences breeding in Common Loons (*Gavia immer*). Northeastern Naturalist 28(1): 65-76.

Bianchini, K. R. Alvo, D.C. Tozer, and M.L. Mallory. 2021c. The legacy of regional industrial activity: Is loon productivity still negatively affected by acid rain? Biological Conservation 225.

Bianchini, K, D.C. Tozer, R. Alvo, S.P. Bhavsar, and M.L. Mallory. 2020. Drivers of declines in common loon (*Gavia immer*) productivity in Ontario, Canada. Science of the Total Environment 738.

Blair, R.B. 1992. Lake features water quality, and the summer distribution of Common Loons in New Hampshire. Journal of Field Ornithology 63(1): 1-9.

Burgess, N.M. and M.W Meyer. 2008. Methylmercury exposure associated with reduced productivity in common loons. Ecotoxicology 17: 83-91.

Chastel, O., H. Weimerskirch, and P. Jouventin. 1995. Influence of body condition on reproductive decision and reproductive success in the Blue Petrel. The Auk 112(4): 964-972.

Clifton, G.T. and A.A. Biewener. 2018. Foot-propelled swimming kinematics and turning strategies in common loons. Journal of Experimental Biology 221(19).

Cooley, J.H., D.R. Harris, V.S. Johnson, and C.J. Martin. 2019. Influence of nesting Bald Eagles (Haliaeetus leucocephalus) on Common Loon (*Gavia immer*) occupancy and productivity in New Hampshire. Wilson Journal of Ornithology 131(2): 329-338.

Devries, J.H., R.W. Brook, D.W. Howerter, and M.G. Anderson. 2008. Effects of spring body condition and age on reproduction in Mallards (Anas platyryhnchos). The Auk 125(3): 618-628.

Evers, D.C. 2007. Status assessment and conservation plan for the Common Loon (*Gavia immer*) in North America. BRI Report 2007. U.S. Fish and Wildlife Service, Hadley, Massachusetts, USA.

Evers, D.C., L.J. Savoy, C.R. DeSorbo, D.E. Yates, W. Hanson, K.M Taylor, L.S. Siegel, J.J.Cooley Jr., M.S. Bank, A. Major, K. Munney, B.F. Mower, H.S. Vogel, N. Schoch, M. Pokras, M.W. Goodale, and J. Fair. 2007. Adverse effects from environmental mercury loads on breeding common loons. Ecotoxicology 17: 69-81.

Fox, A.D., H.E. Jorgensen, E. Jeppesen, T.L. Lauridsen, M. Sondergaard, K. Fugl, P. Myssen, T.J.S. Balsby, and P. Clausen. 2019. Relationships between breeding waterbird abundance, diversity, and clear water status after the restoration of two shallow nutrient-rich Danish lakes. Aquatic Conservation 30(2): 237-245.

Great Lakes DataStream. 2022. Ontario Lake Partner Program. https://greatlakesdatastream.ca/explore. Accessed October 16, 2022.

Gibbons, D.W. 1989. Seasonal reproductive success of the Moorhen Gallinula chloropus: The importance of male weight. International Journal of Avian Science 131(1): 57-68.

Henkel, L.A. 2006. Effect of water clarity on the distribution of marine birds in nearshore waters of Monterey Bay, California. Journal of Field Ornithology 77(2): 151-156.

Johnsgard, P.A. 1987. Diving birds of North America: Species accounts – Loons (Gaviidae). University of Nebraska.

Kelly, L.M. 1992. The effects of human disturbance on common loon productivity in northwestern Montana. Montana State University.

Kuhn, A., K. Copeland, J. Cooley, H. Vogel, K. Taylor, D. Nacci, and P. August. 2011. Modelling habitat associations for the Common Loon (*Gavia immer*) at multiple scales in Northeastern North America. Avian Conservation and Ecology 6(1): 4.

Kuraji, K. and H. Saito. 2022. Long-term changes in the relationship between water level and precipitation in Lake Yamanaka. Water 14(14).

McIntyre, J.W. 1975. Biology and behaviour of the common loon (*Gavia immer*) with reference to its adaptability in man-altered environment. Ph.D. dissertation, University of Minnesota, Minneapolis, MN.

Ministry of the Environment, Conservation and Parks. 2022. "Ontario Lake Partner Program (LPP)" (dataset). 6.0.0. DataStream. 10.25976/fxsw-ym39.

Ministry of the Environment, Conservation and Parks. 2013. Ecological impacts of cottages in Algonquin Provincial Park.

Ministry of Natural Resources and Forestry. n.d. Ontario Map Viewer. Retrieved April 12, 2023, from https://www.lioapplications.lrc.gov.on.ca/fishonline/Index.html?viewer=FishONLine.FishONLine

Munro, J.A. 1945. Observations of the loon in the Cariboo Parklands, British Columbia. The Auk 62(1): 38-49.

Newbrey, J.L., M.A. Bozek, and N.D. Niemuth. 2005. Effects of lake characteristics and human disturbance on the presence of piscivorous birds in Northern Wisconsin, USA. Waterbirds: The International Journal of Waterbird Biology 28(4): 478-486.

Piper, W.H., K.B. Tischler, and A. Reinke. 2018. Common Loons respond adaptively to a black fly that reduces nesting success. The Auk 135(3): 788-797.

Piper, W.H., J.S. Grear, B. Hoover, E. Lomery, L.M. Grenzer. 2020. Plunging floater survival causes cryptic population decline in the Common Loon. Ornithological Applications 122(4): 1-10.

Preisendorfer, R.W. 1986. Secchi disk science: Visual optics of natural waters. Limnology and Oceanography 31(5): 909-926.

Ridgway, M., T. Middel, and A. Bell. 2017. Aquatic ecology, history and diversity of Algonquin Provincial Park. Ministry of Natural Resources and Forestry. 203 pp.

Rose, K.C. S.R. Greb, M. Diebel, and M.G. Turner. 2016. Annual precipitation regulates spatial and temporal drivers of lake water clarity. Ecological Applications 27(2): 632-643.

Schamber, J.L., D. Esler, and P.L. Flint. 2009. Evaluating the validity of using unverified indices of body condition. Journal of Avian Biology 40(1): 49-56.

Sidor, I.F., M.A. Pokras, A.R. Major, R.H. Poppenga, K.M. Taylor, and R.M. Miconi. 2003. Mortality of Common Loons in New England. Journal of Wildlife Diseases 39(2): 306-315.

Stewart, P.A. 1967. Diving schedules of a common loon and a group of oldsquaws. The Auk 84: 122-123.

Strickland, D. 2022. Birds of Algonquin Provincial Park. The Friends of Algonquin Park. 40pp.

Thompson, S.A. and J.J. Price. 2006. Water clarity and diving behaviour in wintering Common Loons. Waterbirds 29(2): 169-175.

Titrus, J.R. and L.W. VanDruff. 1981. Response of the Common Loon to recreational pressure in the boundary waters canoe area, Northeastern Minnesota. Wildlife Monograph 79: 1-59.

Tozer, D.C., M. Falconer, and D.S. Badzinski. 2013. Common Loon reproductive success in Canda: the west is best but not for long. Avian Conservation and Ecology 8(1): 1.

Vermeer, Kees. 1973. Some aspects of the nesting requirements of Common Loons in Alberta. The Wilson Bulletin 85(4): 429-435.

Wayland, M. and D. McNicol. 1990. Status of the effects of acid precipitation on Common Loon reproduction in Ontario: The Ontario Lakes Loon Survey. Technical Report Series No. 92. Ontario Region.

Windels, S.K., E.A. Beever, J.D. Paruk, A.R. Brinkman, J.E. Fox, C.C. Macnulty, D.C. Evers, L.S. Siegel, and D.C. Osborne. 2013. Effects of water-level management on nesting success of common loons. Journal of Wildlife Management 77(8): 1626-1638.

APPENDIX

Table 4. Percentage of lakes with adult Common Loon presence in Algonquin Provincial Park and in the surrounding area (100km buffer) with presence of Common Loon chicks from 1987 to 2018.

	% Successful Breeding Lakes	
Year	Algonquin Provincial Park	Surrounding Area
1982		51.61
1983		42.35
1984		53.70
1985		58.49
1986		60.00
1987	43.73	71.95
1988	40.08	69.94
1989	42.26	59.36
1990	40	51.11
1991	44.4	49.26
1992	40.85	61.01
1993	43.5	57.35
1994	46.74	67.26
1995	44.84	65.88
1996	42.08	62.37
1997	45.4	39.88
1998	41.71	49.70
1999	32.63	46.94
2000	43.98	55.06
2001	39.29	55.19
2002	41.96	47.06
2003	45.45	55.48
2004	41.38	62.77
2005	40.13	47.73
2006	40.79	60.94
2007	47.66	52.99
2008	39.41	57.50
2009	40	61.16
2010	44.85	64.81
2011	60	58.04
2012	48.44	58.68

2013	51.24	56.44
2014	40.79	45.24
2015	40.77	63.04
2016	43.97	58.51
2017	32.93	48.28
2018	41.45	48.75