1981-2012

The Canadian Lakes Loon Survey

32 years of monitoring Common Loons as indicators of ecosystem health

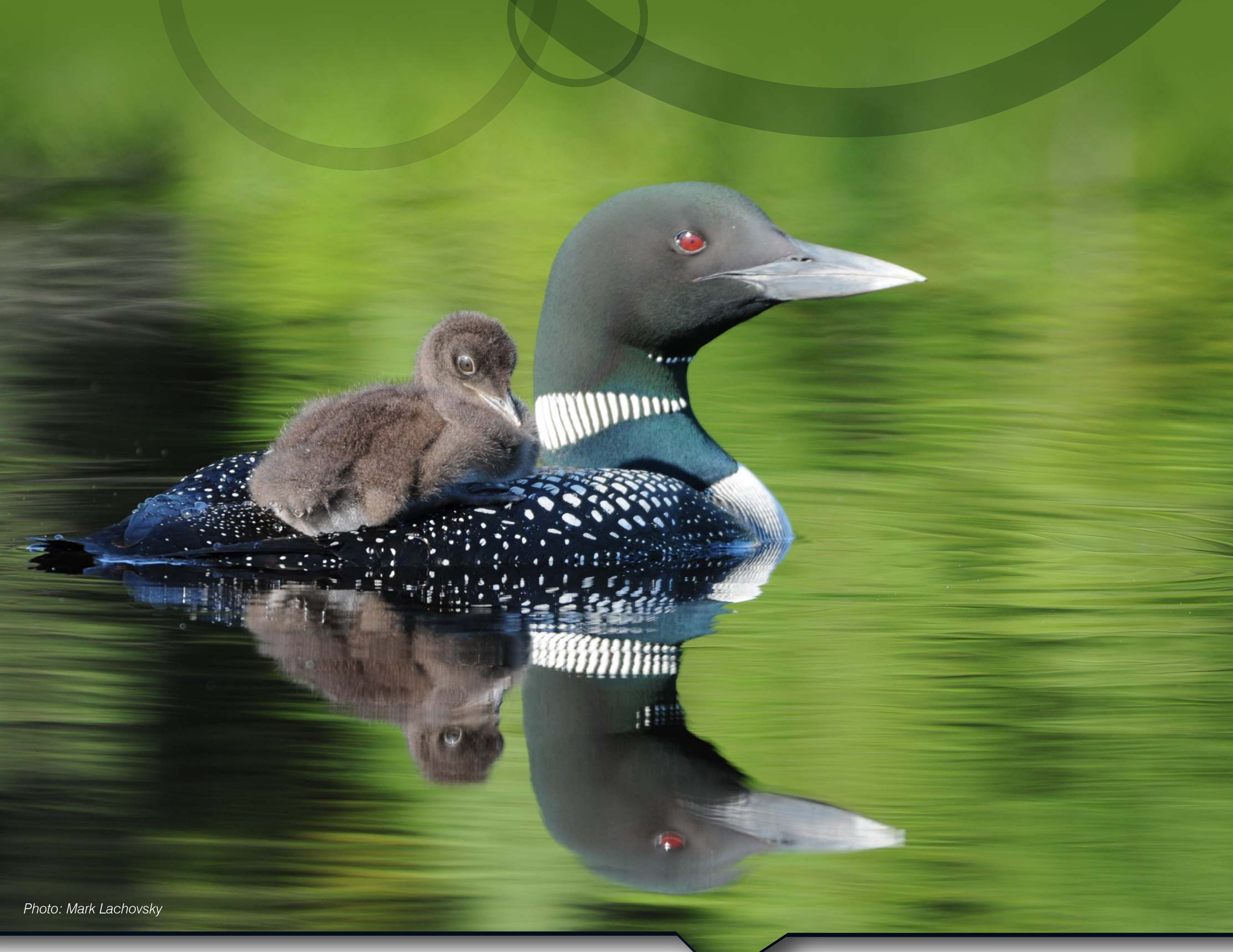

Photo: Mark Lachovsky

BIRD STUDIES CANADA
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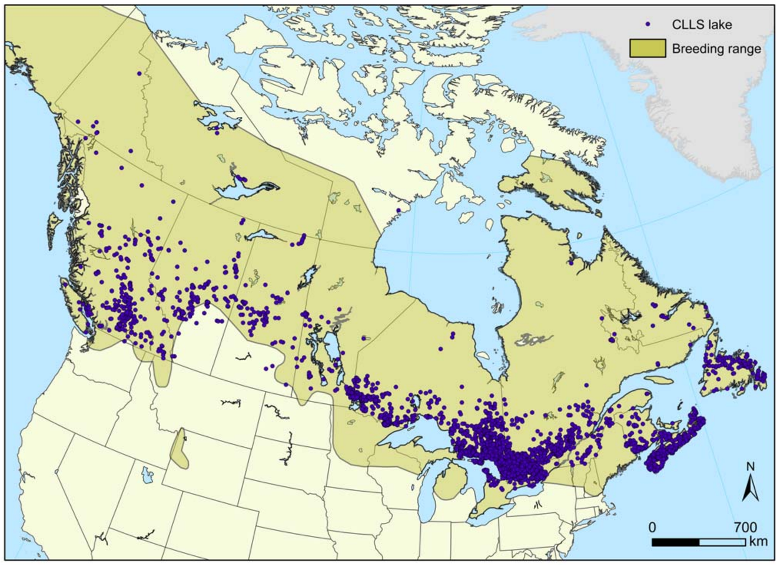
Canadian Lakes Loon Survey

ABOUT THE PROGRAM

The Canadian Lakes Loon Survey was launched in Ontario in 1981 by Bird Studies Canada (then Long Point Bird Observatory) with support from various partners. It went national in the early 1990s. In 32 years, 3200 participants have monitored breeding Common Loons on 4500 lakes (Fig. 1, 2). This impressive effort allows us to achieve many important outcomes, including:

1. Assess Common Loon reproductive success at different scales;
2. Investigate links between reproductive success and habitat;
3. Contribute to conservation management and planning; and
4. Increase public awareness of the importance of lake conservation.

Fig. 1. Lakes monitored between 1981 and 2012 by participants in Bird Studies Canada's Canadian Lakes Loon Survey (CLLS). The breeding range of the Common Loon is also shown.



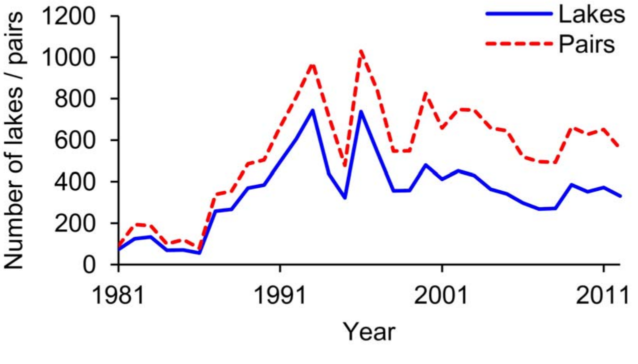
Breeding range data provided by NatureServe in collaboration with Robert Ridgely, James Zook, The Nature Conservancy - Migratory Bird Program, Conservation International - CABS, World Wildlife Fund - US, and Environment Canada – WILDSPACE

SUMMARY

This report summarizes patterns in Common Loon reproductive success across Canada between 1992 and 2010 (prior to the early 1990s data were only available for Ontario; see Tozer et al. 2013 for the original analysis*). Our goal was to indirectly describe patterns in the health of Canadian lakes with respect to mercury and acid precipitation, justified by the well established link between the pollutants and Common Loon reproductive success. Measured as the annual number of young produced per pair, reproductive success was higher in the west than in the east, decreased over time, was higher on larger lakes than on smaller lakes, and increased as acidity decreased. These patterns were likely linked to acid- or temperature-related exposure to mercury and/or acid-induced reductions in food supply. Our results support further action to reduce emissions of mercury and the harmful components of acid precipitation throughout North America and globally. The results also show the importance of using citizen science programs to monitor wildlife as indicators of environmental stress.

* Tozer, D. C., C. M. Falconer, and D. S. Badzinski. 2013. Common Loon reproductive success in Canada: the west is best but not for long. Avian Conservation and Ecology 8(1): 1. [online] URL: http://dx.doi.org/10.5751/ACE-00569-080101

Fig. 2. Number of lakes or pairs of Common Loons monitored per year between 1981 and 2012 by participants in Bird Studies Canada's Canadian Lakes Loon Survey.



THE COMMON LOON IS A POWERFUL INDICATOR OF LAKE HEALTH

The Common Loon breeds on lakes throughout most of mainland Canada. Adults are long-lived (>20 years in the wild), typically return to the same breeding territory year after year, and feed their young almost exclusively with fish from the nesting lake. Loons are connected to most animals in their nesting lake because of their high position in the food chain. Every time an individual animal eats another one, pollutants, if present, can increase or biomagnify. When the pollutants finally reach loons, the final link in the chain, they are at their highest concentrations. These characteristics make the Common Loon a powerful indicator of lake health, especially in relation to mercury pollution and acid precipitation.

Adult Common Loon on nest with newly-hatched chick. Photo: Mark Lachovsky.

Lakes in eastern Canada and smaller lakes have lower pH, higher methylmercury, and lower Common Loon reproductive success.

Competing for food brought by parents is normal among Common Loon chicks. Photo: Mark Lachovsky.

BREEDING LOONS ARE ESPECIALLY SENSITIVE TO MERCURY AND ACID PRECIPITATION

Mercury is a potent toxin. Adult Common Loons with higher mercury are slower and spend less time doing activities that require a lot of energy like collecting food for chicks and defending breeding territories. Chicks with higher mercury seek energy-saving rides on the backs of adults less often, have compromised immune systems, and are less able to avoid predators. Common Loon reproductive success drops to 50% on lakes where mercury is high. Mercury clearly impairs Common Loon reproductive success.

The same is true for acid precipitation. Acids, and the toxic metals they mobilize, interfere with fish gill function. This, in turn, reduces fish growth, reproduction, and survivorship, and results in lower fish abundance in more acidic lakes. As a result, Common Loons produce fewer young on lakes with low pH and produce more young on lakes with high pH (see box). Acid precipitation, like mercury, directly impairs Common Loon reproductive success.

What is pH and acidity?

These terms indicate the concentration of acids in lake water. pH values range from 0 to 14. Low pH means high acidity, and high pH means low acidity. A drop of 1 pH value indicates that acids are 10 times more concentrated. pH less than 6 in lake water is generally considered harmful to wildlife.

Common Loon pair with chicks, one of which is nearly asleep while back-riding. Photo: Barry Peyton.

ACIDS AND HIGHER TEMPERATURES CREATE EVEN MORE MERCURY

Most mercury makes its way up the food chain to loons in the form of methylmercury. Acid from acid precipitation promotes the creation of methylmercury, in part because it increases the activity of bacteria that convert mercury to methylmercury. Higher water temperatures also promote the creation of methylmercury by increasing the activity of the bacteria and by favouring other methylation pathways. Methylmercury is more abundant and loons are at greater risk of mercury toxicity in lakes with lower pH and higher water temperatures.

Mercury and acid precipitation continue to threaten Common Loon reproductive success.

Known as rushing, Common Loons run along the water with their wings raised when charging an opponent. Photo: Darwin Park.

THE WEST SHOULD BE BEST

There are now extensive data that describe where and when mercury and acid deposition occur. Combined with the negative effects described earlier, these data allow us to make predictions of where and when mercury and acid precipitation may negatively affect the number of young produced by Common Loons. Mercury and the harmful components of acid precipitation are released to the atmosphere during the combustion of fossil fuels—the largest source being coal-fired power plants. Canada receives airborne mercury from all over the globe, primarily because mercury persists in the atmosphere for up to a year or more before returning to the earth's surface. During that time, it is carried long distances by prevailing winds. As a result, mercury deposition is only slightly higher in western than in eastern Canada. By contrast, the harmful components of acid precipitation are mostly produced in the middle of the continent and are carried eastward and northeastward by prevailing winds. This means lakes in eastern Canada typically receive more acid and have lower pH than lakes in western Canada, explaining why methylmercury increases in Canada from west-to-east in lake water, fish, and loons. This is also why we can expect to see Common Loon reproductive success decrease from west-to-east in Canada.

Common Loon chicks. Photo: Mark Lachovsky.

BIGGER IS PROBABLY BETTER

Smaller lakes tend to be shallower and therefore warmer than larger lakes. Moreover, some smaller lakes receive relatively more acid precipitation and hold fewer substances that neutralize acids compared to larger lakes, so smaller lakes generally have lower pH than larger lakes. This explains why methylmercury is more abundant in smaller lakes. By virtue of their volume, smaller lakes also have lower total numbers of fish than larger lakes. All of these factors in turn explain why we can expect to see higher Common Loon reproductive success on larger lakes than on smaller lakes.

THE CLOCK IS PROBABLY STILL TICKING

Emissions of mercury and the harmful components of acid precipitation increased throughout most of the 20th century and are now declining, yet deposition of these pollutants remains well above both historical inputs and the amount deemed safe for aquatic wildlife. As of the mid-1990s acid deposition still exceeded critical levels in as much as 75% of eastern Canada because the acid neutralizing capacity of most lakes remained insufficient to buffer acid deposition. In addition, methylmercury increased in fish and loons in some locations in the 1990s and early 2000s, even though deposition of mercury declined. The reasons for this remain unclear. Mercury and acid precipitation continue to threaten Common Loon reproductive success and associated lake health in Canada, explaining why Common Loon reproductive success has declined in Ontario, and why we can expect to see reproductive success decline over time across Canada.

Photo: Sandra Horvath

METHODOLOGY

Surveys

Participants selected survey lakes, and surveyed either the entire lake or a specific portion of it each year. At least one survey was made in June to determine the number of territorial pairs, in July to determine the number of hatchlings per pair, and in mid-to-late August to determine the number of six-week-old young per pair, which were ~70% of adult size. On average, participants surveyed each lake or lake portion on 35 different days throughout each summer.

Analyses

We used statistical procedures to quantify the importance of west-versus-east (longitude), year, lake area, and pH (acidity) for explaining variation in Common Loon reproductive success across Canada, based on the annual number of six-week-old young per pair (see box). We concluded that Common Loon reproductive success was negatively influenced by mercury pollution and acid precipitation when and where statistically important patterns followed the expectations outlined above. To place negative effects in context, we highlighted when and where reproductive success was less than the minimum required to maintain a stable population.

What is reproductive success?

For this report, we used the number of six-week-old young produced per pair each year as a measure of reproductive success. Six-week-old Common Loons are ~70% of adult size and have a much lower chance of being eaten by a predator, making them representative of the number of young raised to independence. Average annual reproductive success of at least 1 young every other year (equivalent to at least 0.48 six-week-old young per pair each year) is considered good. If reproductive success is above this amount, the number of territorial breeders is unlikely to decline.

Loon surveyor. Photo: Jack Greening

The annual number of six-week-old young per pair is a reasonably good indicator of reproductive success; at least 1 young every other year (equivalent to at least 0.48 six-week-old young per pair each year) is considered good.

Watching Common Loons from a safe distance; juvenile on left and adult beginning to moult to winter plumage on right. Photo: David Gignac.

Reproductive success was higher in the west, but declined more steeply over time, perhaps due to climate warming.

Watching loons. Photo: Frank Horvath

WHAT PATTERNS DID WE FIND AND WHAT DO THEY MEAN?

West versus east (longitude) and year

Annual reproductive success across Canada was higher in the west than in the east and declined over time (Fig 3). Surprisingly, the decline over time was steeper in the west than in the east (Fig. 4).

Explanation: Methylmercury concentrations are higher and pH is lower in the east than in the west, explaining why reproductive success was lower in the east. Methylmercury is increasing over time in some lakes and pH is remaining stable over time in most lakes in the east, explaining why reproductive success decreased over time. Even though methylmercury concentrations are higher in the east than in the west, concentrations could be increasing faster over time in the west. A possible explanation for this is that western Canada is heating up faster than eastern Canada. This may be increasing methylmercury production more in the west by increasing microbial activity or by favouring other methylation pathways.

Context: Assuming that the same rate of decline continues into the future, annual reproductive success across Canada may drop below the minimum required to maintain a stable population around 2016; but it is important to note, that due to statistical uncertainty, the value could be anywhere between 2009 and 2029.

Fig. 3. Reproductive success of Common Loons across southern Canada between 1992 and 2010. The lines show results from the best statistical model for longitude, year, lake area, and pH. The dots represent average annual reproductive success. Note that lake area is shown on a log scale.

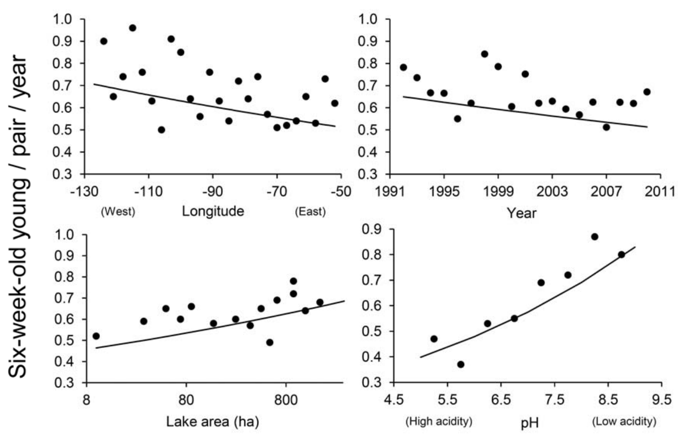
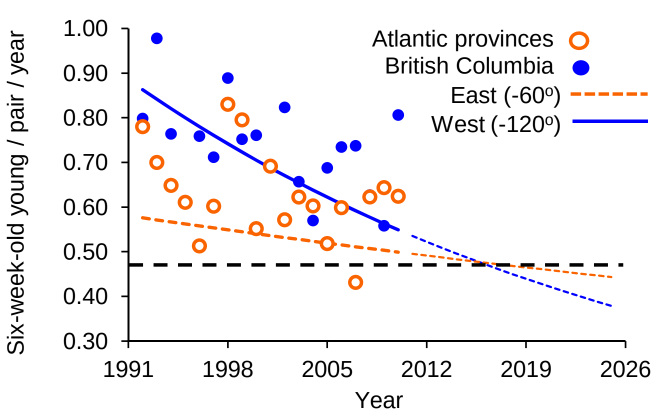
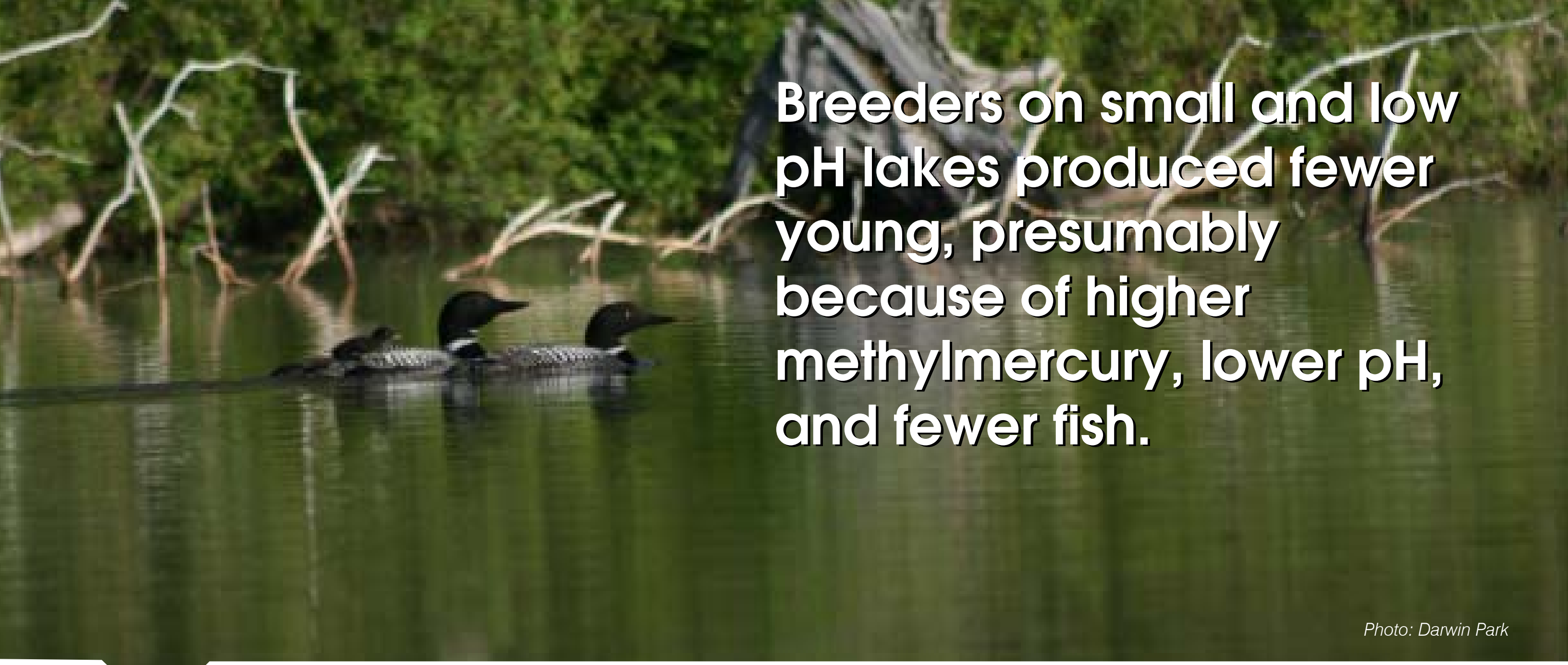


Fig. 4. Reproductive success of Common Loons across southern Canada between 1992 and 2010. The diagonal lines show results from the best statistical model for lakes in the east and the west and are projected into the future as fine dashed lines. The dots represent average annual reproductive success. The horizontal dashed line is the minimum number of young required to maintain a stable population.





Breeders on small and low pH lakes produced fewer young, presumably because of higher methylmercury, lower pH, and fewer fish.

Photo: Darwin Park

Lake area and pH (acidity)

Breeders on large lakes produced more young per year than breeders on small lakes, and breeders on high pH lakes produced more young per year than breeders on low pH lakes (Fig. 3).

Explanation: Small lakes have higher methylmercury concentrations, lower pH, and fewer forage fish than large lakes, explaining why reproductive success was lower in small lakes. Low pH lakes have higher methylmercury concentrations and fewer forage fish than high pH lakes, explaining why reproductive success was lower on low pH lakes.

Context:

We found that on small lakes reproductive success dropped below the minimum required to maintain a stable population at a pH of 6.4 (range due to statistical uncertainty: 5.8 - 7.1), whereas reproductive success on large lakes dropped below the minimum required at a pH of 5.5 (range due to statistical uncertainty: 4.1 - 6.6; Fig. 5). Reproductive success on lakes with low pH may have dropped below the minimum required to maintain a stable population as early as ~2001 (range due to statistical uncertainty: 1995-2009), whereas reproductive success on lakes with higher pH may not drop below the minimum until ~2034 (2019-2062; Fig. 6).

Fig. 5. Reproductive success of Common Loons across southern Canada between 1992 and 2010. The diagonal lines show results from the best statistical model for small and large lakes. The dots represent average annual reproductive success. The horizontal dashed line is the minimum number of young required to maintain a stable population.

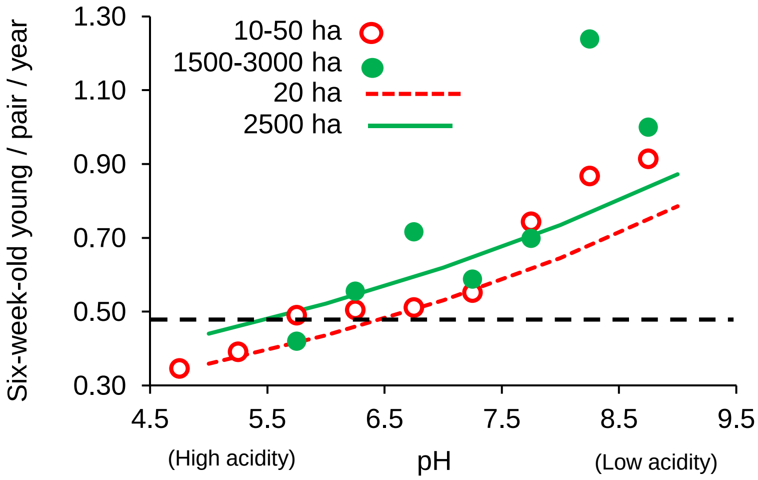
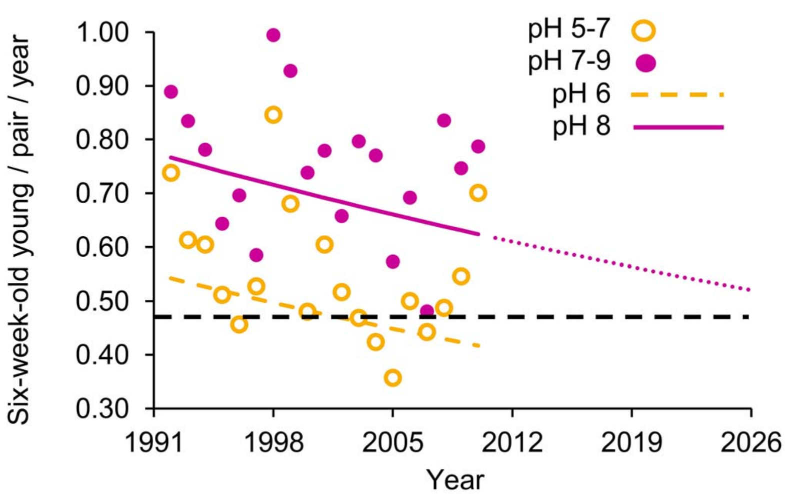


Fig. 6. Reproductive success of Common Loons across southern Canada between 1992 and 2010. The diagonal lines are results from the best statistical model for low pH and high pH lakes, projected into the future for high pH lakes as a fine dashed line. The dots represent average annual reproductive success. The horizontal dashed line is the minimum number of young required to maintain a stable population.



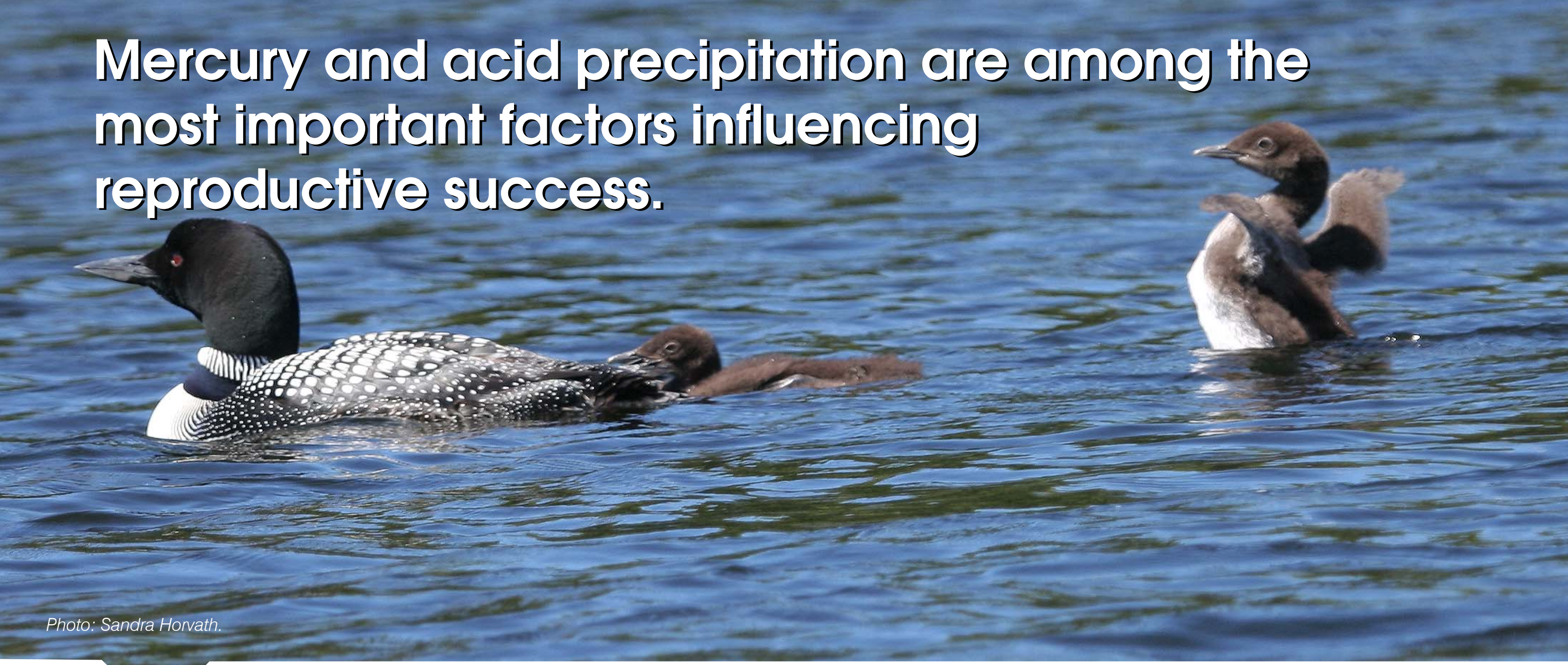


Photo: Sandra Horvath.

CONCLUSIONS

The geographically consistent link between low pH, associated methylmercury exposure, and reduced Common Loon reproductive success shows that mercury and acid precipitation are among the most important factors influencing Common Loon reproductive success in Canada. The decline in Common Loon reproductive success that we observed across Canada between 1992 and 2010 and in Ontario between 1981 and 1999 (see box) suggests that lake health is not improving in Canada despite commendable and successful efforts by Canada and the United States to reduce emissions of mercury and the harmful components of acid precipitation.

Adult Common Loon sitting on nest. Photo: Jennifer Howard.

What happened in the 1980s and what about human disturbance?

Previous analyses using Canadian Lakes Loon Survey (CLLS) data from Ontario between 1981 and the 1990s found relationships similar to those reported here: reproductive success decreased over time, increased with increasing lake area, and increased with increasing pH (McNicol et al. 1995, Weeber 1999). Human disturbance and shoreline development had relatively little effect. This was also the case according to CLLS data in Nova Scotia (Badzinski and Timmermans 2006). However, this does not mean that human disturbance is unimportant; the number of Common Loon breeding pairs is much lower where there are high levels of human activity or where nest sites have been eliminated by development. Reproductive success data may not reflect the negative effects of human disturbance and development on loons because most breeding pairs avoid disturbed areas.

Badzinski, S. S., S. T. A. Timmermans. 2006. Factors influencing productivity of Common Loons *(Gavia immer)* breeding on circumneutral lakes in Nova Scotia, Canada. Hydrobiologia 567:215-226.

McNicol, D. K., M. L. Mallory, H. S. Vogel. 1995. Using volunteers to monitor the effects of acid precipitation on Common Loon *(Gavia immer)* reproduction in Canada: The Canadian lakes loon survey. Water, Air, and Soil Pollution 85:463-468.

Weeber, R. C. 1999. Temporal patterns in breeding success of Common Loons in Ontario, 1981-1997. Unpublished report to Environment Canada, March 1999. [online] URL: http://www.bsc-eoc.org/download/cllstrndrpt.pdf.

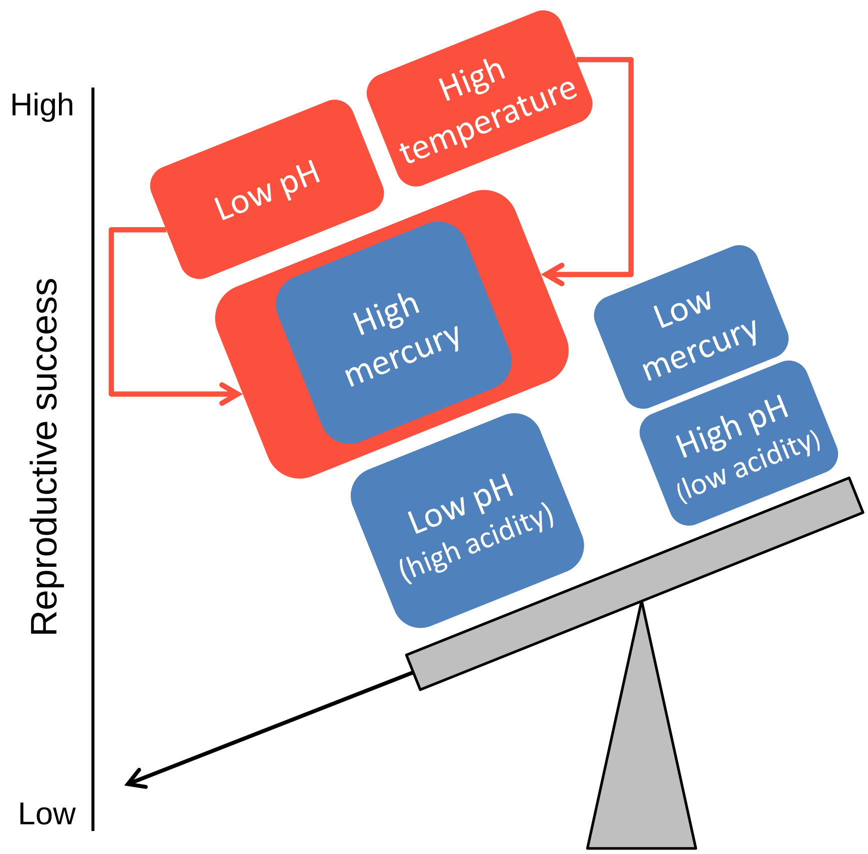
Further action to abate emissions of mercury and acid is needed.

Juvenile Common Loon. Photo: Sandra Horvath.

Teasing apart the complex negative effects of mercury and acid precipitation on Common Loon reproductive success is challenging (Fig. 7). Acid precipitation causes reductions in fish abundance, reducing loon reproductive success. Acid precipitation also increases methylmercury availability, which also reduces reproductive success. However, acid precipitation is not known to be increasing faster in the west than in the east, but temperature is. Therefore, our finding that reproductive success is declining more rapidly in the west than in the east suggests that increases in methylmercury due to climate warming might be important for explaining patterns in Common Loon reproductive success and associated lake health in Canada.

Our results support further action to abate emissions of mercury and the harmful components of acid precipitation throughout North America and globally. Over the last three decades, participants of Bird Studies Canada's Canadian Lakes Loon Survey have gathered a huge volume of extremely valuable data. This research—and large-scale monitoring of wildlife as indicators of environmental stress—would not be possible without ongoing citizen science programs.

Fig. 7. Conceptual diagram showing the complex negative effects of mercury, acid precipitation (low pH), and water temperature on Common Loon reproductive success.



LOON ECOLOGY

Common Loons lead surprisingly complex lives. Here we overview some less-familiar aspects of loon ecology, which we hope will increase fascination and respect for this species.

Migration: Common Loons return to nesting lakes as soon as open water patches are available in spring. Non-breeders and failed breeders probably depart first in autumn, perhaps as early as August in some locations, followed by successful breeders and juveniles. Some juveniles remain until freeze-up.

Mates: Individuals often pair with the same mate as previous years; however, each year one in four loons switch mates, often after a nest with the previous year's mate fails to produce chicks.

Territories: Males vigorously chase other males out of their breeding territory, and females chase away other females; mixed-sex chasing is rare. If an intruder evicts a territory-holder, the intruder is accepted by the remaining territory-holder as a new mate.

Sibling rivalry: If two young are produced, they compete with each other for food. If the parents are unable to bring enough, one of the young perishes.

Nurseries: Parents move just-hatched young away from the nest to a shallow well-vegetated section of the lake known as a nursery where there are plenty of small fish and protection from wind. Small chicks benefit from the nursery's food and hiding places and are less likely to be blown from their protective parents than on more open parts of the lake.

Non-breeders: One in five adults on the breeding grounds is a non-breeder with no territory.

Age at first breeding: Young birds first return to the breeding grounds when they are at least 3 years old. However, they do not obtain a territory and breed for the first time, on average, until they are 6 years old (range: 4 to 11 years old).

Photo: Mark Lachovsky

Nesting frequency: Up to half of territorial adults do not nest each year.

Nests: Nests are typically shallow mounds of vegetation, within 1-2 m of the lake. Island sites are preferred. If the first nest of the season is lost, re-nesting at a different location within the territory is attempted.

Eggs: Two eggs are usually laid. Incubation lasts 26-29 days, and is shared between males and females, as are all other parental duties.

Common Loon nest and eggs. Photo: Mark Lachovsky.

Aggression: Territorial loons frequently chase other fish-eating birds, including mergansers and gulls. Contests between males for breeding territories often result in the death of the territory holder (never the intruder).

Social gatherings: Adults form groups of up to several dozen throughout summer. They swim in highly ritualized ways, in circles and perfectly straight lines, but apparently do not cooperatively forage. How they benefit remains a mystery. However, they may be assessing potential future mates.

Calls: Wail sounds like a wolf howl, given when the caller wishes to unite with another loon. Tremolo sounds like laughter, given in response to a threat; also the only call given in flight. Yodel is given only by males to defend territories, and in subtle ways each male's yodel is unique and identifiable. Hoot is a quiet call given between close individuals.

Population size and trend: Canada has about 250,000 Common Loon breeding pairs, roughly 95% of the world's Common Loons. The number of breeders increased steadily between 1970 and 1990, and then remained stable over the next decade.

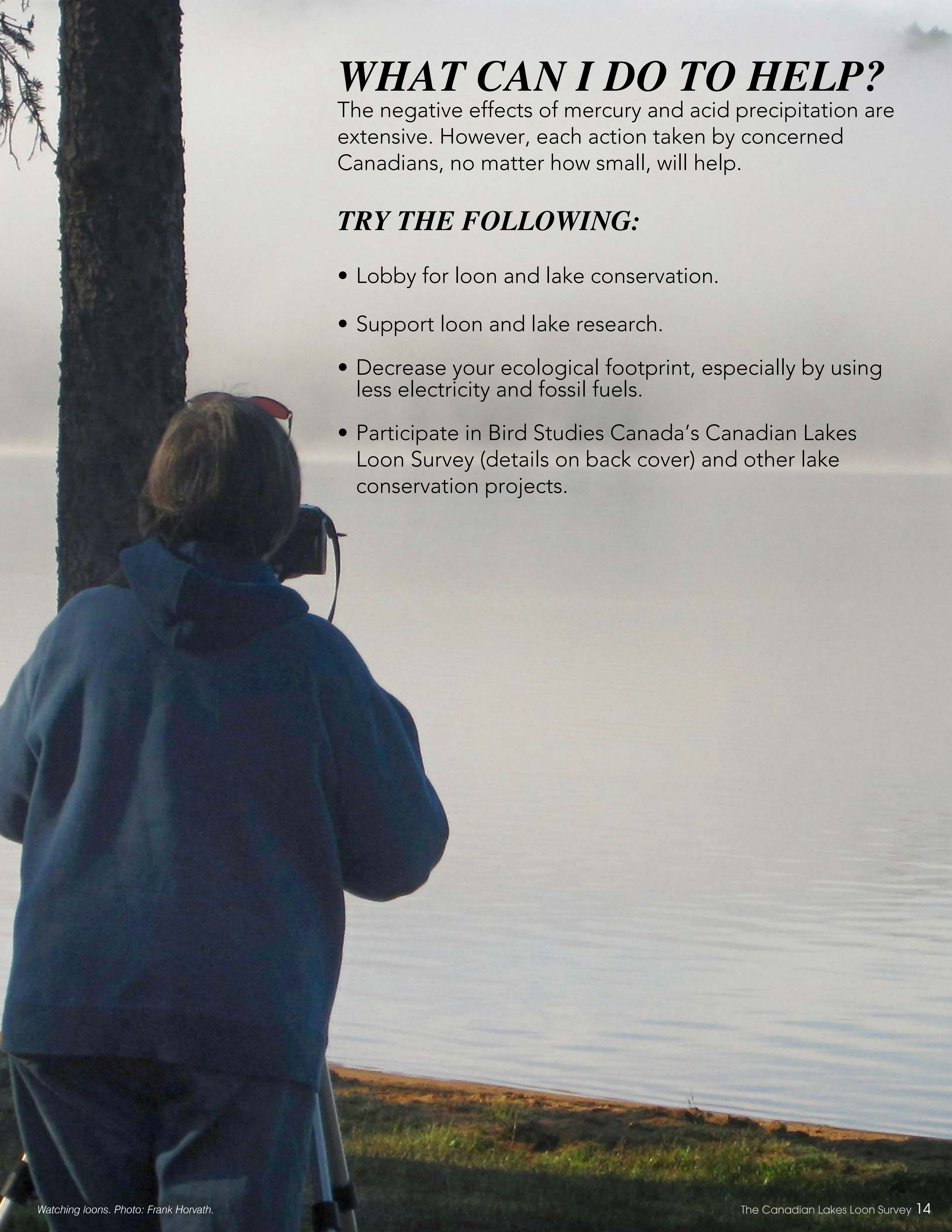
Photo: Mark Lachovsky.

WHAT CAN I DO TO HELP?

The negative effects of mercury and acid precipitation are extensive. However, each action taken by concerned Canadians, no matter how small, will help.

TRY THE FOLLOWING:

- Lobby for loon and lake conservation.
- Support loon and lake research.
- Decrease your ecological footprint, especially by using less electricity and fossil fuels.
- Participate in Bird Studies Canada's Canadian Lakes Loon Survey (details on back cover) and other lake conservation projects.



Watching loons. Photo: Frank Horvath.

If you would like to participate in the Canadian Lakes Loon Survey (CLLS), or you would like more information, please contact:

CLLS Volunteer Coordinator
P.O. Box 160, 115 Front Street
Port Rowan, ON, N0E 1M0
519-586-3531 Ext. 124
Toll-free 1-888-448-BIRD(2473) Ext. 124
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www.birdscanada.org/volunteer/clls/

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Citation:

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