Adirondack Loons: Have they benefitted from mercury emission controls?

The Common Loon (*Gavia immer*) is a symbolic and charismatic icon of New York's Adirondack Park. Many people are deeply captivated by loons because of their beautiful calls and their haunting presence. Researchers, however, appreciate them for an entirely different reason. Loons are a long-lived (*20-30 years!*) predator at the top of the aquatic foodweb, which makes them a valuable indicator species for the health of the lakes and ponds where they breed. Thus, loons are utilized as a biotic sentinel to study trends in environmental factors, such as mercury, an airborne pollutant, affecting Adirondack lakes.

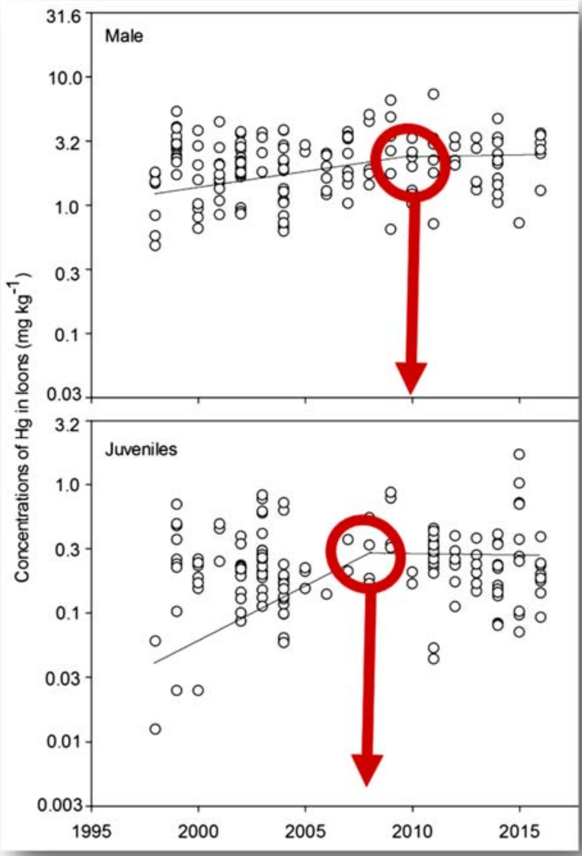
Mercury is a neurotoxic pollutant that is released from coal-burning power plants, mining, and other industrial sources. Once in the atmosphere, mercury can travel long distances and is deposited across the landscape, where it accumulates in aquatic environments.

Loons ingest mercury in the fish that they eat. Mercury exposure causes loons to become lethargic and affects their ability to incubate their eggs and protect and feed their chicks. Adults with high mercury levels can be less aggressive when defending their territories and hunting for food. Chicks with high mercury levels become weak and may not ride on their parents' backs as much as they should, and so, are more susceptible to becoming chilled or eaten by predators.

Since 1998, the Adirondack Center for Loon Conservation and its partners, including Biodiversity Research Institute, the Wildlife Conservation Society, and the New York State Department of Environmental Conservation, with support from the New York State Energy Research and Development Authority, have utilized Common Loons as a sentinel of the impact of environmental mercury pollution on Adirondack aquatic ecosystems. Mercury concentrations and the reproductive success of uniquely color-banded loons have been monitored each summer to evaluate trends over time to provide an assessment of the effectiveness of mercury emission regulations.

Emissions Regulations Take Effect

In response to concerns about airborne pollutants, such as acids and mercury, the Environmental Protection Agency (EPA) passed the Clean Air Act of 1990 and the Mercury and Air Toxics Standards Rule of 2012 to reduce emissions from electric utilities. These regulations have led to significant reductions in mercury and acid emissions. For example, anthropogenic (*human-caused*) mercury emissions in North America declined by 77% between 1990 and 2014, resulting in significant decreases in atmospheric mercury concentrations and mercury deposition across the US and Canada (Zhang et al. 2016).



Changes in Adirondack loon mercury levels over time, 1998-2016.

~ Implications for Adirondack Loons ~

A study on common loons in New Hampshire found that loon blood mercury concentrations decreased by 64% from 1999 to 2002 following a 45% decrease in upwind mercury emissions from a coal–fired power plant.

In the Adirondacks, however, based on data collected from 760 loons in 116 lakes over 19 years by the Adirondack Center for Loon Conservation and its partners, recovery has not been as rapid.

Mercury levels increased significantly in Adirondack adult loons from 1998 to 2010, then leveled off between 2010 and 2016. Juvenile loons and loon eggs showed an earlier response to reduced deposition of atmospheric mercury, with their mercury levels increasing from 1998 to 2008, and then remaining stable through 2016. This is likely because adults have more exposure to mercury since they are eating older larger fish who have higher mercury levels than the fish consumed by loon chicks, and eggs had only been exposed to whatever mercury was deposited in them by the female loon when they were laid.

~ Understanding the Science ~

Mercury Methylation: Elemental mercury cannot be absorbed into living tissue. However, when it is deposited in wetlands and aquatic environments, it is converted by bacteria to methylmercury, a form that can easily enter the foodweb, bioaccumulate and biomagnify in animals, and at high levels, impair their nervous systems.

Bioaccumulation: Bioaccumulation is the buildup of a substance in an animal's body over its life time. When a fish eats macroinvertebrates, algae, and smaller fishes, it accumulates trace amounts of methylmercury in its body. Since methylmercury stays in the fish's tissues, concentrations increase as the fish gets older.

Biomagnification: Biomagnification is a measure of the increase in a substance across levels of the foodweb. For example, if a fish builds up 1 unit of mercury over its lifetime, it may be a low enough concentration that the fish shows no negative side effects. However, when a loon eats that fish and four others, it accumulates 5 units of mercury in that meal. Thus, over its lifetime, a loon that eats many high-mercury fish can accumulate a very high concentration of mercury in its body.

Looking to the Future: Climate Change and Mercury

Although mercury concentrations in Adirondack loons did not decrease in response to emission regulations, they did stabilize. The fact that loon mercury levels plateaued with no increase in nearly a decade provides an assessment of the effectiveness of the regulations. It also highlights the vulnerability of aquatic ecosystems to environmental pollutants, as well as the long-term impacts of our choices.

A changing climate will likely limit the forest and watershed's ability to buffer atmospheric mercury deposition. The greatest uncertainty will be in how mercury dynamics interact with changes in the food webs of lakes that will be impacted by climate change and other compounding factors.

With the effects of climate change already being felt in New York's Adirondack Park, it is difficult to predict the long-term recovery of the loon population from mercury pollution. Increasing air temperature and precipitation in the Northeast cause earlier snowmelt, smaller snowpack, changing stratification in lakes, extended dry spells, torrential rain events, changes in mercury dynamics, and more extreme runoff events that will impact loons in new ways.

Thus, it is essential that we continue long-term monitoring of Adirondack loon mercury levels, and that emission regulations are maintained and enhanced on local, national, and global scales, such as the Minamata Convention on Mercury (*for more information, visit www.mercuryconvention.org*), to best protect all living beings, including loons. It is imperative that we continue to grow our understanding of Common Loons and their complex environment, so that we can do everything possible to minimize the impacts of climate change and other anthropogenic threats to loons and their aquatic habitats.

How Do We Know How Many Loons to Monitor?

Monitoring loons is a time and resource intensive process, and capture can be a short-term stress for the birds. Thus, it is essential to determine the most efficient way to detect changes in loon fledging success and mercury concentrations over time. To do this, the Adirondack Center for Loon Conservation and its partners conducted a statistical technique, called a power analysis, on Adirondack loon data collected from 1998 to 2016 to determine three sampling factors: the number of loons per lake, the number of lakes, and number of years each lake is surveyed.

The results of this analysis showed that there is a tradeoff between the number of lakes sampled per year and the number of years needed to detect a particular rate of change. To detect a 5% change/year in loon mercury levels, the Adirondack Center for Loon Conservation would need to sample either 15 lakes for 10 years, or 5 lakes for 15 years. A 2% yearly change in fledging success could be detected by monitoring either 40 lakes/year for 15 years, or 30 lakes/year for 20 years. In addition, for more acidic lakes, the results indicated that either more lakes or more years of sampling were needed to detect rates of change in loon mercury concentrations.

This information will provide guidance for the Adirondack Center for Loon Conservation to efficiently allocate time and resources in its loon sampling and monitoring efforts in future years.

Summary of New York's Mercury Synthesis Project*

In 2018, to inform policy efforts and advance public understanding, the New York State Energy Research and Development Authority, sponsored a synthesis of scientific information on mercury in air, water, fish, and wildlife in New York's ecosystems, which resulted in the publication of over 20 papers in the journal *Ecotoxicology*.

1. New York State's natural areas are widely contaminated with mercury and the scope of the impact of mercury on fish and wildlife in New York State is much greater than had previously been thought, exceeding human and ecological risk thresholds in many areas, especially in freshwater habitats.

2. Landscape characteristics of the Adirondack and Catskill Parks, and areas of Long Island, exacerbate the impacts of mercury emissions. Forests facilitate mercury deposition, while wetlands are hotspots for methylation, leading to elevated levels in aquatic and terrestrial food webs.

3. Overall, environmental mercury concentrations in New York State have decreased in recent decades. However, in some areas such as the Adirondacks, the mercury levels in some fish and birds have only stabilized or even increased, thus indicating that environmental mercury recovery can be complex.

4. It is expected that further controls on mercury emission sources will continue to lower mercury concentrations in the food web, particularly in inland lakes.

**For more information, visit www.adkloon.org/research and www.briloon.org/nymercury*

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