2016

Contaminants in Massachusetts' Breeding Common Loon Population: Summary Report

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PHOTO CAPTION: Adult Common Loon (*Gavia immer*). Photo provided by Dan Poleschook and Ginger Gumm.

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1.0 EXECUTIVE SUMMARY

In Massachusetts, loons are listed on the Massachusetts Endangered Species Act list as a Species of Special Concern. Breeding loons in Massachusetts were extirpated in the late nineteenth century, until a nesting pair was discovered on Quabbin Reservoir in 1975 (Blodget and Lyons 1988). Forty breeding pairs are now found on 16 lakes in western and central Massachusetts.

The Quabbin and Wachusett Reservoirs, managed by the Department of Conservation and Recreation (DCR), Division of Water Supply Protection (Division) support the core of the Commonwealth's loon population. Biodiversity Research Institute (BRI) and biologists from the Division have been assessing the overall health and status of Massachusetts' breeding Common Loon population on DCR waterbodies since 1999. This is accomplished by sampling whole blood, feathers, and eggs to screen for the presence of mercury (Hg); blood is also analyzed for presence of lead (Pb).

In 2016, we captured, banded and collected blood and feather samples from two adults on Quabbin Reservoir and one adult on Wachusett Reservoir. Four failed eggs were also collected from loon nests on Quabbin Reservoir, as well as two eggs from Wachusett Reservoir, and one egg from Hycrest Reservoir. One dead adult male loon was collected from Quabbin Reservoir by DCR staff on 11/10/2016 and submitted to BRI's lab for analysis. Results indicated that the blood Hg concentration of loons sampled in 2016 were lower than the long-term averages recorded for loons on Quabbin Reservoir and Wachusett Reservoir. Overall, blood Hg concentrations in loons breeding on Quabbin and Wachusett Reservoirs in 2016 were categorized as being at moderate risk for reduced nesting success. Feather Hg concentrations in loons sampled on Quabbin Reservoir were at or below the long-term average and were within the moderate risk category for asymmetrical feather development. Blood lead (Pb) levels in all loons were either at background levels considered to be of low risk to loon health. Mercury concentrations in abandoned eggs collected from Quabbin and Wachusett Reservoirs were all within the moderate risk category for reduced hatchability and survival. One egg was also collected from Hycrest Reservoir, however, and the Hg level detected far exceeded the threshold for the high risk category. Lastly, necropsy results of the adult male loon carcass collected from Wachusett Reservoir in 2016 indicated that the bird died from blunt force trauma related injuries. The exact cause of the trauma is unknown, but, BRI's wildlife veterinarian suggested the possibility of collision with a power line or other structure. The bird was originally banded by BRI staff in 1999, and, it was otherwise in good condition, aside from its trauma-related injuries.

Loons are "bioindicators" of environmental loads of Hg and thus provide valuable information related to the overall health of the water body. Long-term monitoring of the Hg body burden in Massachusetts' loons since 1999 provides necessary information to better understand temporal patterns of biologically available Hg in order to guide regulatory policy and decision making. Therefore, we recommend the continued banding and sampling of Massachusetts' Common Loon population to build upon the long-term data in the region and detect temporal trends of Hg in the reservoir systems.

2.0 INTRODUCTION

Common Loon (*Gavia immer*) populations in the northeastern U.S. have experienced historical declines and range retractions (Evers 2007). Currently, loons breed throughout the northern US, including Alaska and Canada north to the southern edge of the taiga shield. Loons are found wintering along the Atlantic Coast, Gulf of Mexico, Gulf of California, and all along the Pacific Coast. Juveniles usually spend the first three years of life on the ocean before returning to their natal areas to attempt to establish a breeding territory. Competition for breeding territories is intense and the average age of first-breeding is six years (Evers et al. 2001). Established territories are defended both physically and vocally and the breeding period requires sufficient energy reserves to produce a successful nest. Loons are long-lived birds and well-adapted for life in water. The anterior position of their legs inhibits mobility on land but allows for exceptional speed and maneuverability under water. Dense, heavy bone structure facilitates their ability to dive in search of prey fish, particularly yellow perch (*Perca flavescens*), pumpkinseed (*Lepomis gibbosus*) and bluegill (*Lepomis macrochirus*) (Evers et al. 2010).

In Massachusetts, loons are listed on the Massachusetts Endangered Species Act list as a Species of Special Concern. Breeding loons in Massachusetts were extirpated in the late nineteenth century, until a nesting pair was discovered on Quabbin Reservoir in 1975 (Blodget and Lyons 1988). Currently, Quabbin and Wachusett Reservoirs, managed by MA DCR, support the core of Massachusetts' loon population with 22 and five loon territories monitored, respectively.

Threats to state loon populations include: loss of breeding habitat; human disturbance; recreational activities; water level impacts, e.g., fluctuations on water supply reservoirs; contaminants, including lead (Pb) and mercury (Hg); and wintering hazards such as marine oil spills (Evers et al. 2010). Common Loons nest near the water's edge and are particularly vulnerable to water-level fluctuations (Reiser 1988). Nest success may be negatively affected by increasing water levels if nests become inundated and also by decreasing water levels if nests become difficult to access for loons and are more easily accessed by mammalian predators. Natural resources managers, such as MA DCR, have increasingly relied on nesting rafts as a management tool to improve nest success on water bodies prone to fluctuating water levels (DeSorbo et al. 2008). These floating platforms have played a substantial role in the population recovery of loons throughout New England

(Evers 2007). Water level fluctuations associated with reservoirs, however, have also been correlated with loon blood mercury (Hg) levels that are greater than background levels. This is due to the enhanced production of methymercury (MeHg), the bioavailable form of mercury, in exposed substrate after drawdowns and increased transport to open waters following re-inundations (Evers et al. 2008). Long-lived piscivores, such as the Common Loon, are considered important bioindicators of Hg loads within aquatic ecosystems, due to the nature of MeHg to increase in quantity and thus toxicity with increasing trophic level, and bioaccumulate within body tissues over the course of an individual's lifetime (Evers 2006, Wolfe et al. 2007, Atwell et al. 1998, Burgess and Hobson 2006, Evers et al. 1998).

With funding from DCR, 2016 marks the 18th consecutive year (1999-2016) BRI and biologists from DCR have conducted monitoring to assess the overall health and status of Massachusetts' breeding Common Loon population on DCR waterbodies. Tissue samples extracted (e.g. whole blood and feathers) from captured loons combined with abandoned eggs can be analyzed for the presence of bioaccumulative toxins (e.g. Hg, organochlorines, and polychlorinated biphenyls), known to impact breeding loon populations (Evers et al. 2008; Evers et al. 2003; Evers et al. 2002). Marking loons with unique color band combinations through live-capture techniques provides higher resolution in tracking and monitoring, nesting ecology, and behavior in loon populations over a long period of time. Research conducted by BRI has shown that loon behavior can be used as an indicator of chronic stressors (Evers et al. 2008; Evers 2001).

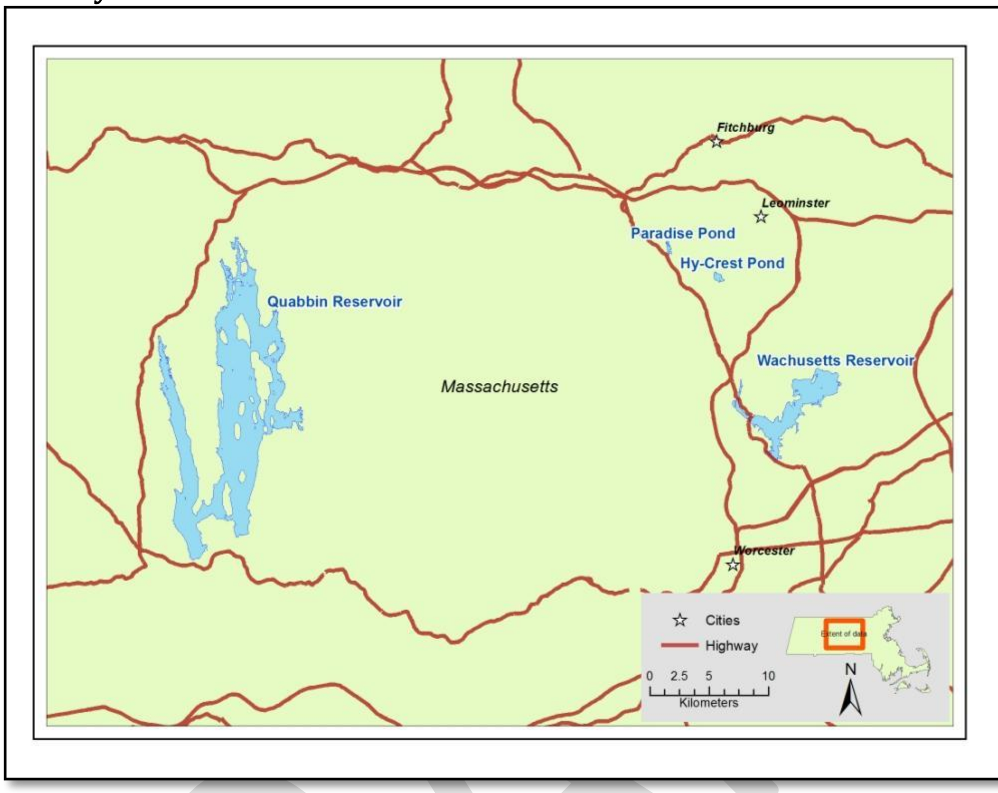
3.0 OBJECTIVES

1. Further development of a color-marked breeding population that can be monitored over time so individuals can be tracked to explicitly determine individual performance;
2. Collect Hg and Pb levels in breeding loons to evaluate risk.

4.0 STUDY AREA

The DCR study area for this project includes the Quabbin and Wachusett Reservoirs in central Massachusetts, Hycrest Pond in Sterling and Paradise Pond in Princeton (Figure 1). Quabbin Reservoir and Wachusett Reservoir watershed systems provide drinking water to the greater Boston area. Quabbin Reservoir is approximately 25,000 acres with 118 miles of shoreline, making it the largest inland water body in Massachusetts. It is part of the Chicopee River Watershed and is within Worcester and Franklin Counties. Wachusett Reservoir is approximately 4,200 acres with 31 miles of shoreline, and is located in Worcester County. Hycrest Pond in the Town of Sterling, Worcester County is 104 acres and within the Nashua Watershed. Paradise Pond is 61 acres and is within the Town of Princeton, Worcester County.

Figure 1. Study area of water bodies sampled for Common Loon banding and Hg exposure analysis.



6.0 METHODS

6.1 LOON CAPTURE AND COLOR MARKING

Loons were captured using well-established nightlighting and playback techniques (Evers 1993). Adult and juvenile birds were banded with US Fish & Wildlife Service aluminum bands and a unique combination of plastic colored bands, enabling identification of individual birds to be made from a distance in future observations. Chicks were not banded if their legs were too small to hold adult-size bands. All sampling was accomplished using non-lethal methods.

6.2 SAMPLE COLLECTION

Prior to release, each captured bird was weighed and sampled for blood and feathers. Blood samples were collected using a leur adapter and vacutainer systems with heparin, and frozen within six hours of collection. The second secondary feather on adult loons was clipped along the calamus (shaft) well below the feather vane (Evers 2008). Abandoned eggs were collected and were measured for size, volume (to determine moisture loss), and weight and were placed in an I-Chem® jar and frozen until analysis.

6.3 TISSUE ANALYSIS

Loon blood, feather, and egg Hg concentrations were analyzed by BRI using a Milestone Direct Mercury Analyzer (DMA), Milestone, Monroe, CT, USA. For the feathers, the average level of detection was 0.40 ppm, fw, and the average limit of quantification was 1.0 ppm, fw. All quality control data was within laboratory acceptances limits. The eggs were analyzed for Hg as they were received, on a dry weight (dw) basis, and the percent moisture was also analyzed. For the egg Hg analysis, the average level of detection was 0.09 ppm, dw, and the average limit of quantification was 0.23 ppm, dw. EPA method 245.6 was used to analyze the samples (EPA600/4-91/010, Methods for the Determination of Metals in Environmental Samples, USEPA, Washington, DC, June 1991).

7.0 RESULTS

This report includes a summary of 2016 capture efforts and results from analysis of loon tissues collected in central Massachusetts.

7.1 LOON CAPTURE AND COLOR-MARKING

Banding efforts of Common Loons were conducted by biologists from BRI and DCR in July 2016, resulting in the successful capture of two adults on Quabbin Reservoir and one adult on Wachusett Reservoir (Table 1). One hatch year loon was also captured and banded by BRI, independent of the MA DCR project, on Pocksha Pond in Middleborough, MA. Additionally, in February 2016, an adult loon was rescued after it landed on a road in Winthrop, MA, and was banded and released. Band combinations for those birds can be found in Table 1. Whole blood samples were collected for contaminant analysis, and a secondary feather from each wing, and two tail feathers were collected from each newly captured adult bird. Lastly, an adult male Common Loon banded in 1999 on Fitchburg Reservoir was recovered by DCR staff at Wachusett Reservoir on 11/10/2016 and BRI's veterinary staff performed a necropsy on the animal on 12/19/2016. Results indicated that the bird died from blunt force trauma related injuries, potentially resulting from collision with a power line or other structure. The individual was in good condition aside from its trauma related injuries. The full necropsy report is attached to this report as Appendix A.

Table 1. Band combinations of Common Loons (n = 5) captured on Massachusetts water bodies, 2016.

Lake	Territory	Band #	Date	Age	Sex	LL Top	LL Bottom	RL Top	RL Bottom
MA DCR Lakes									
Quabbin	Fever Brook	0938-66618	7/7/2016	ATY	M	Red	Yellow Stripe	Red Dot	Silver
Quabbin	Fever Brook	None	7/7/2016	ATY	F	White Stripe	Red	Orange	Orange Dot
Wachusett	South Bay	None	7/7/2016	ATY	M	Green Stripe	Orange	Red	Orange Dot
Non-DCR Lakes									
Pocksha Pond	Pocksha	1118-15836	8/15/2016	HY	U	Green Dot	Silver	Blue	Orange
Winthrop, MA*	None	0938-78875	2/4/2016	ATY	U	Silver	None	Red	Red

*** Individual landed on road and was rescued, banded, and released.**

7.2 SAMPLE COLLECTION AND ANALYSIS

To assess the potential impacts of Hg and Pb on loons, known baseline effects levels can be separated into risk categories based on studies from BRI and their collaborators (Table 2).

Low risk indicates background Hg concentrations that have no known impact on wildlife. Loon territories that fall within the moderate risk category have elevated Hg concentrations but their impact levels on individuals remain undetermined. Loons that are in the high risk category are exposed to toxic levels of environmental Hg that statistically show physiological, behavioral, and reproductive impacts. The extremely high Hg category is based on in-field observable impacts on loons and other birds (Evers et al. 2008). The high and extremely high categories therefore have Hg at levels of concern.

Table 2. Risk categories for assessing Hg and Pb impacts, reported as parts per million (ppm) in wet weight (ww) for blood and egg and fresh weight (fw) for feathers, for the Common Loon.

Contaminant and Matrix	Low	Moderate	High	Endpoint	Reference
Mercury (Hg)					
Adult (blood)	0 to 1.0	1.0 to 3.0	> 3.0	40% fewer fledged young	Burgess and Meyer 2008; Evers et al. 2008
Adult (feather)	0 to 9.0	9.0 to 40.0	> 40.0	Significant asymmetry	Evers et al. 2008
Juvenile (blood)	0 to 0.1	0.1 to 0.3	> 0.3	Lower survival	Evers et al. 2010; unpubl. data
Egg	0 to 0.7	0.7 to 1.3	> 1.3	Significantly smaller egg and reduced hatchability	Evers et al. 2003
Lead (Pb)					
Blood	0 to 0.12	0.12 to 0.24	> 0.24	Probable death	Franson et al. 2003; BRI unpubl. data

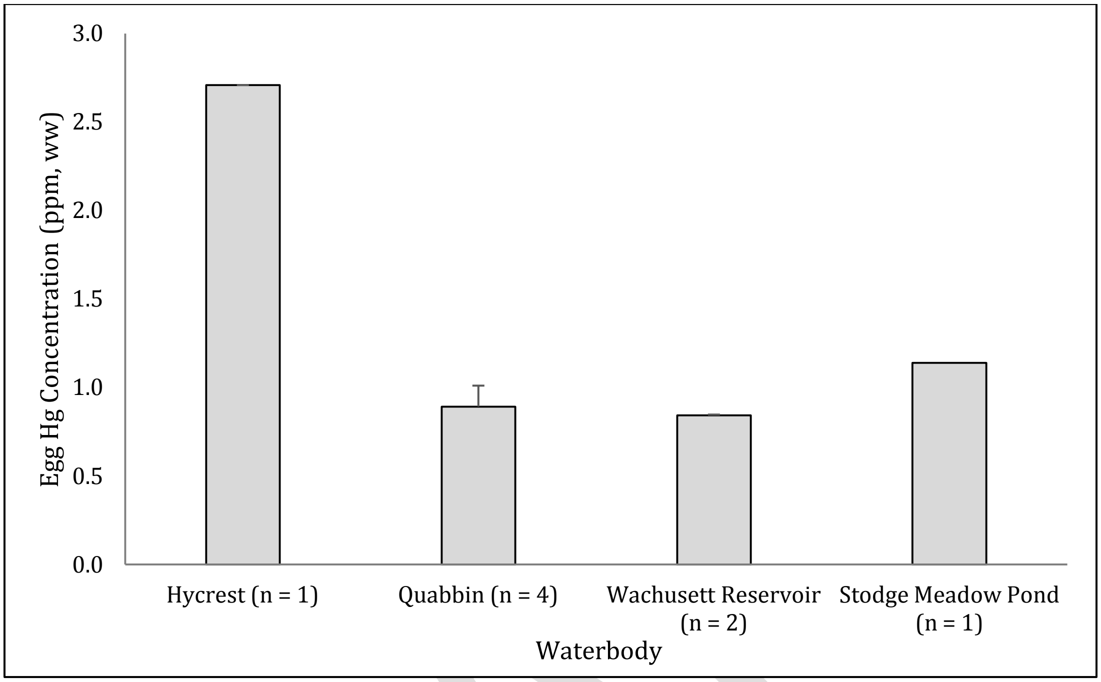
7.2.1. Eggs

Egg mercury results are reported in parts per million (ppm) wet weight (ww). In 2016, seven abandoned loon eggs were collected from DCR waterbodies (Table 3). All samples were shipped to BRI for processing and analysis for total Hg analysis. The mean Hg concentration in eggs collected from nests on Quabbin was 0.89 ± 0.12 ppm (ww) (n = 4), 0.84 ± 0.003 ppm (ww) at Wachusett Reservoir (n = 2), 2.71 ppm (ww) at Hycrest Reservoir (n = 1), and 1.14 ppm (ww) at Stodge Meadow Pond (n = 1) (Figure 2). The Hg levels detected in eggs from Quabbin and Wachusett Reservoirs in 2016 were all within the moderate risk category for reduced hatchability and survival. The egg collected from Stodge Meadow Pond was also within the moderate risk category; however, its Hg concentration (1.14 ppm) was approaching the high risk category threshold of > 1.30 ppm. Moreover, the egg sampled from Hycrest Reservoir greatly exceeded the high risk category threshold with an Hg concentration of 2.71 ppm.

Table 3. List of loon eggs collected in Massachusetts, 2016.

Date Collected	Lake Name	Territory Name	Hg (ppm, ww)
6/30/2016	Quabbin	Russ Mt.	0.80
7/1/2016	Quabbin	Parker	0.90
7/1/2016	Quabbin	Parker	0.81
7/22/2016	Hycrest	Hycrest	2.71
7/24/2016	Stodge Meadow Pond	Stodge Meadow	1.14
8/4/2016	Quabbin	Phragmites	1.06
9/8/2016	Wachusett	Cemetery	0.85
9/8/2016	Wachusett	Cemetery	0.84

Figure 2. Comparison of Hg concentrations in Common Loon eggs sampled from Stodge Meadow Pond, Hycrest, Quabbin, and Wachusett Reservoirs, Massachusetts, 2016.



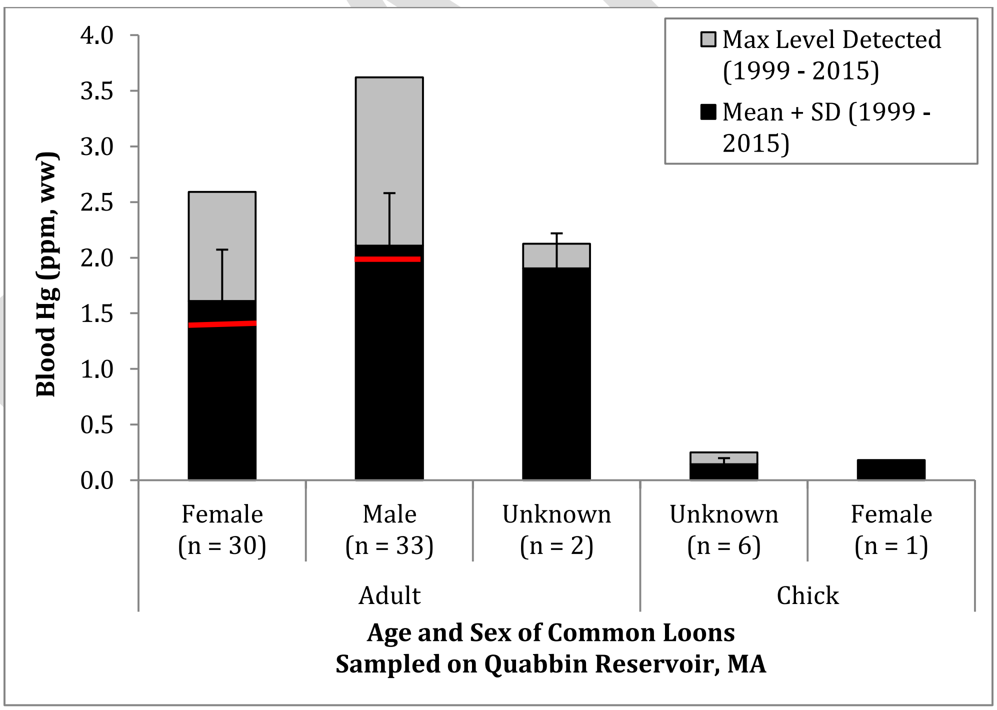
7.2.2. Blood

Blood Hg results are reported in parts per million (ppm) wet weight (ww). In 2016, the blood Hg levels of the Feverbrook territory pair on Quabbin Reservoir was 1.42 (ppm, ww) for the female and 2.04 (ppm, ww) for the male (Table 4). These levels are associated with a moderate risk for reduced nesting success and are comparable to the long-term mean blood Hg level on Quabbin Reservoir for males ($\bar{x}$ = 2.07 ± 0.47 ppm, ww; n = 33), females ($\bar{x}$ = 1.59 ± 0.45 ppm, ww; n = 30), and chicks ($\bar{x}$ = 0.58 ± 0.82 ppm, ww; n = 8) (Figure 3). Little variation was observed in blood Hg levels among loons occupying the different breeding territories on Quabbin Reservoir (Figure 4). One male, however, in the Moosehorn territory in 2008 had a blood Hg level of 3.62, which was considerably higher than other males sampled over the course of the study. Males consistently had higher blood Hg levels on Quabbin Reservoir compared to females (Figure 4). One male loon was sampled in the South Bay territory on Wachusett Reservoir in 2016 with a blood Hg level (2.65 ppm (ww)) that was lower than the long-term mean for this waterbody ($\bar{x}$ = 2.99 ± 0.74 ppm (ww)) (Figure 5). This level is in the moderate risk category. Territory means among both males and females occupying Wachusett Reservoir territories have been similar over the sampling period; however, one female sampled in 2010 in the Crescent Island territory had a much greater than normal blood Hg level of 4.10 ppm (ww) (Figure 6). Blood Hg levels in loons sampled on non-DCR lakes between 1999 and 2015 (no adult loons sampled in 2016) ranged from 1.30 ppm (ppm, ww) to 6.58 ppm (ppm, ww) with the highest levels observed on Notown Reservoir and Upper Naukeag (Figure 7). Overall blood Hg levels detected in adult loons on all waterbodies sampled in MA between 1999 and 2016 averaged $\bar{x}$ = 2.05 ± 1.04 ppm (ww) in females (n = 49) and $\bar{x}$ = 2.58 ± 1.09 ppm (ww) in males (n = 56) (Figure 8).

Table 4. Blood mercury (Hg), feather mercury, and blood lead (Pb) concentrations of adult Common Loons sampled on Massachusetts DCR reservoirs, 2016.

Date Sampled	Lake	Territory	Sex	Blood Hg (ppm, ww)	Feather (ppm, fw)	Blood Pb
DCR Lakes						
7/7/2016	Quabbin	Feverbrook	M	2.04	12.79	< 0.033
7/7/2016	Quabbin	Feverbrook	F	1.42	11.56	< 0.033
7/7/2016	Wachusett	South Bay	M	2.65	NA	< 0.033

Figure 3. Comparison of 2016 and long-term (1999 – 2015) mean blood Hg concentrations in Common Loons on Quabbin Reservoir, MA.



*Red line (▬) represents 2016 mean blood Hg level [female: x = 1.42 ppm (ppm, ww), n = 1; male: x =2.04 ppm (ppm, ww)].

Figure 4. Blood Hg concentrations detected in Common Loons by breeding territory on Quabbin Reservoir, MA, 1999 – 2016.

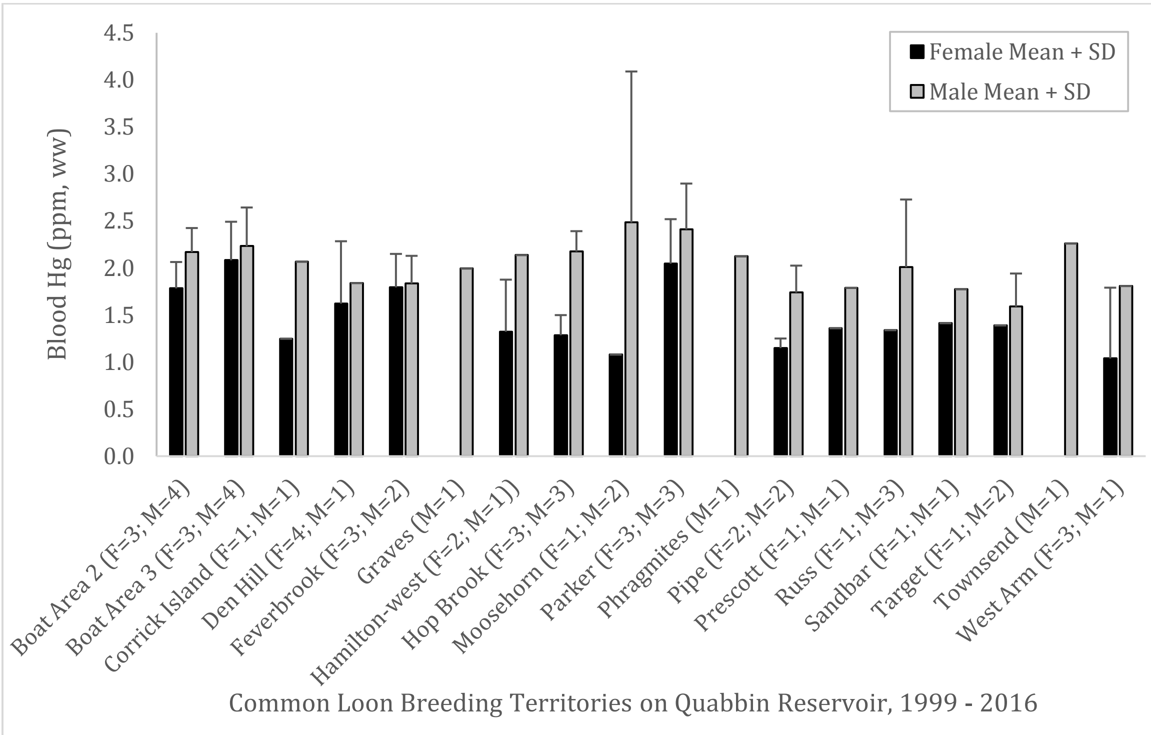


Figure 5. Comparison of 2016 and long-term (2000 – 2015) mean blood Hg concentrations in Common Loons on Wachusett Reservoir, MA.

*Red line (▬) represents blood Hg level of adult male loon sampled in 2016 (2.65 ppm, ww].

Figure 6. Blood Hg concentrations detected in Common Loons by breeding territory on Wachusett Reservoir, MA, 2000 – 2016.

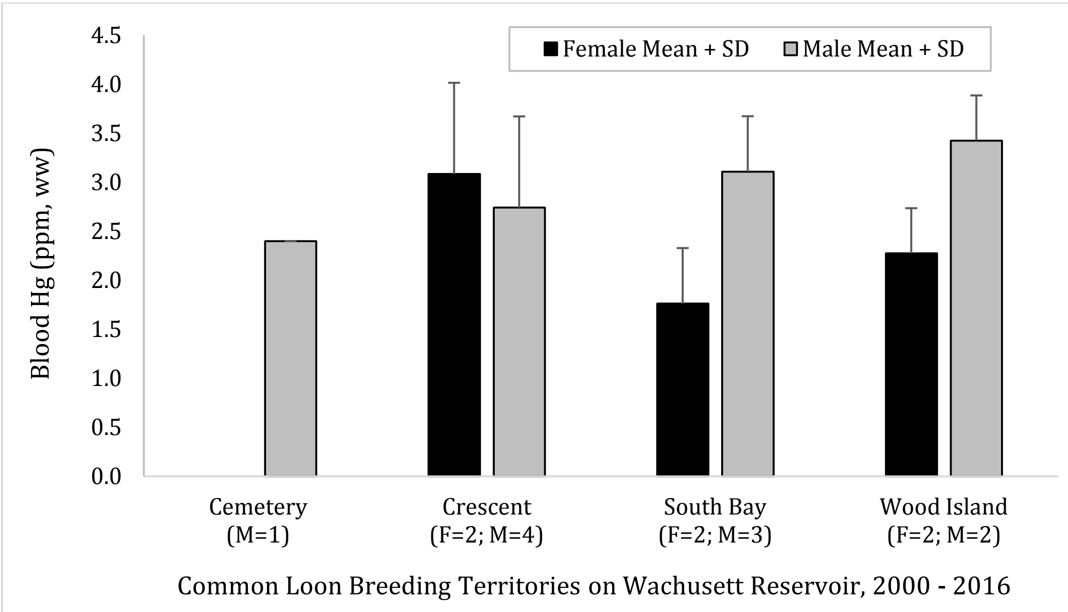


Figure 7. Blood Hg concentrations detected in Common Loons sampled on non-DCR waterbodies in Massachusetts, 1999 - 2015. *No loons sampled on non-DCR lakes in 2016.

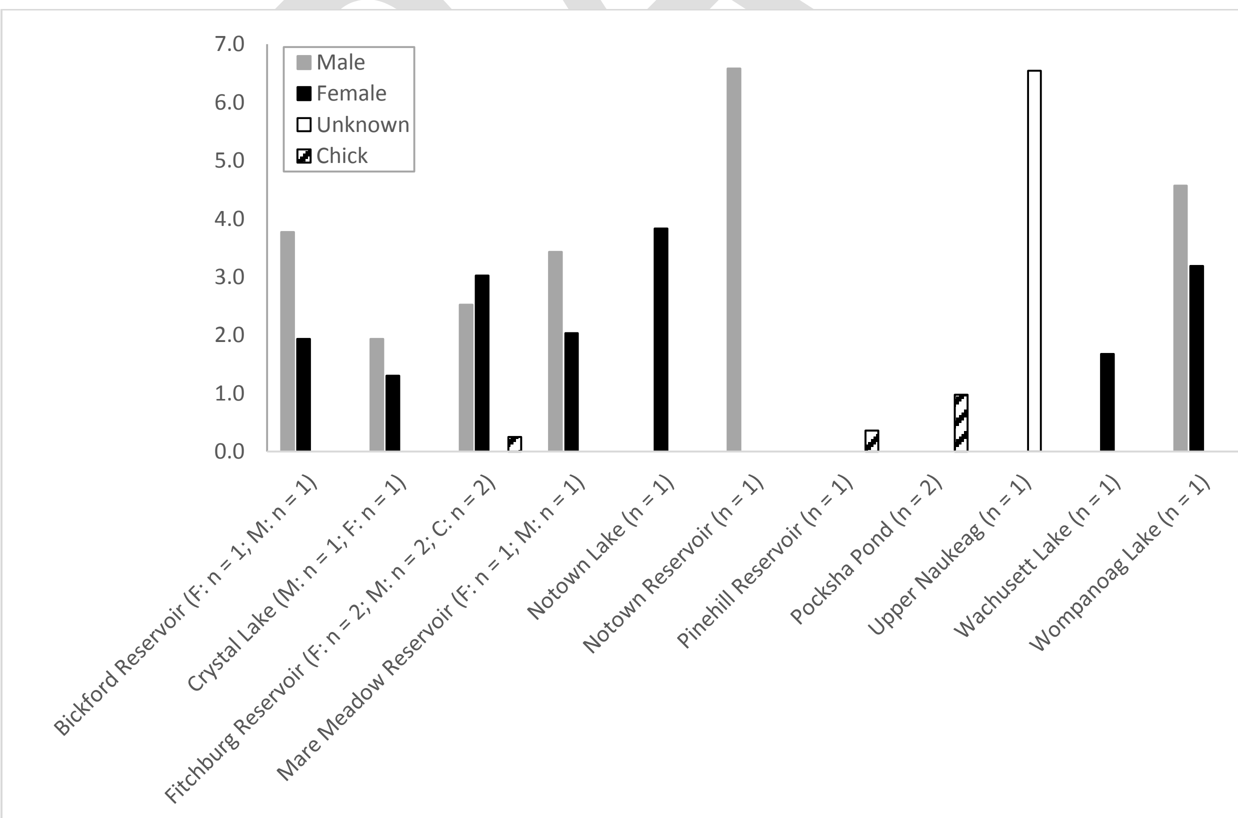
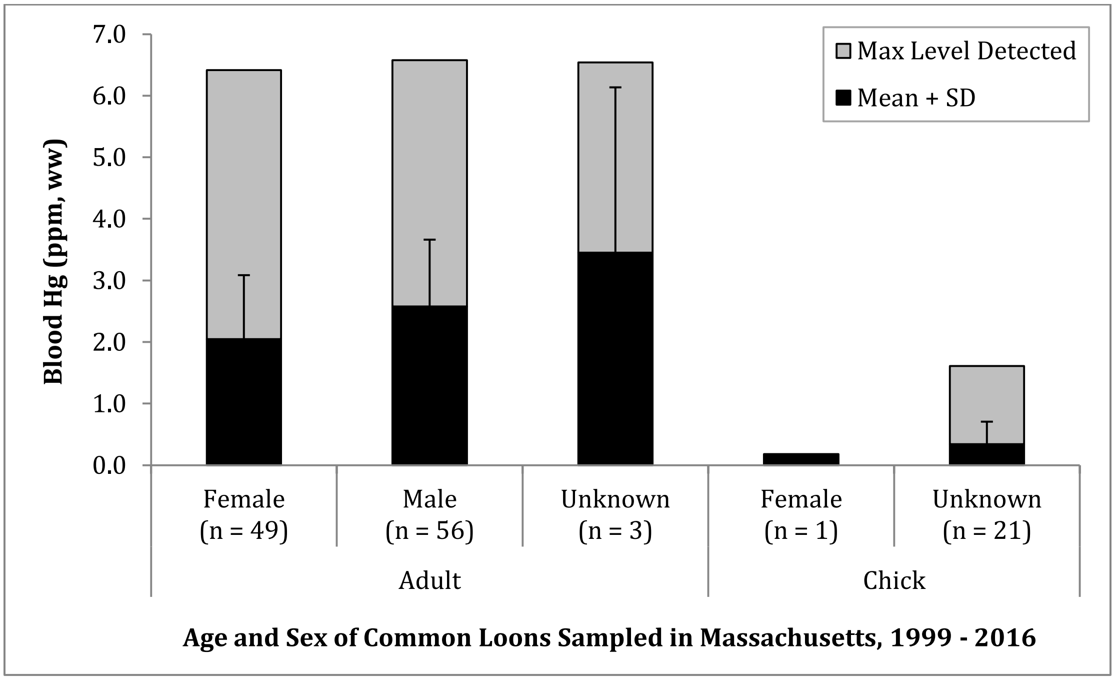


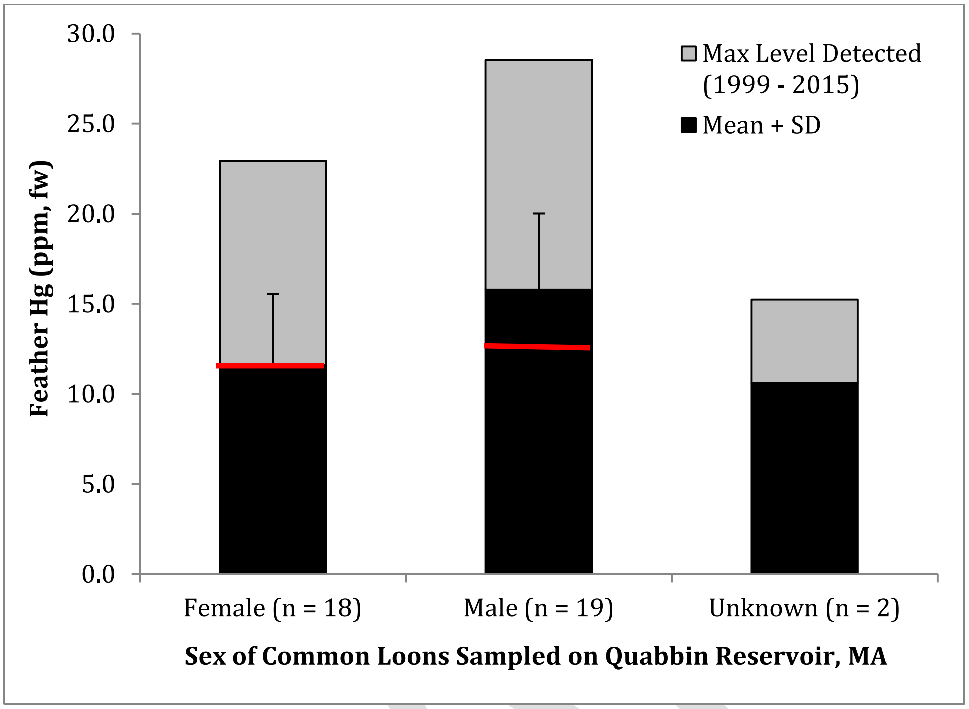
Figure 8. Blood Hg (ppm, ww) concentrations detected in Common Loons on 15 lakes in Massachusetts between 1999 and 2016.



7.2.3. Feather

Feather Hg results are reported in parts per million (ppm), fresh weight (fw). In 2016, we collected feather samples from the loon pair in the Feverbrook territory on Quabbin Reservoir (Table 4). The Hg level of the female's feathers were nearly equivalent to long-term (1999 – 2015) mean feather Hg concentrations for females on Quabbin Reservoir (2016: x = 11.56 ppm (fw), n = 1; 1999 – 2015: $\bar{x}$ = 11.59 ± 3.96 ppm (fw), n = 18). The male's feather Hg level was lower than the long-term (1999 – 2015) mean feather Hg for males on Quabbin Reservoir (2016: x = 12.79 ppm (fw), n = 1; 1999 – 2015: $\bar{x}$ = 15.79 ± 4.22 ppm (fw), n = 19) (Figure 8). The levels detected in the Feverbrook territorial pair in 2016 were within the moderate risk category for asymmetrical feather development. No other feather samples were collected in 2016. Overall, mean feather Hg levels detected in adult loons on Quabbin and Wachusett Reservoirs between 1999 and 2016 were lower than mean feather Hg levels detected in loons on other MA waterbodies during the same time period (Figure 11).

Figure 9. Comparison of feather Hg (ppm, fw) concentrations detected in Common Loons breeding on Quabbin Reservoir, MA in 2016 versus the long-term average (1999 – 2015).



*Red line (—) represents 2016 mean feather Hg concentration).

Figure 10. Mean feather Hg concentrations among adult Common Loons breeding on Wachusett Reservoir, MA, 2000 - 2015. *No sample for 2016.

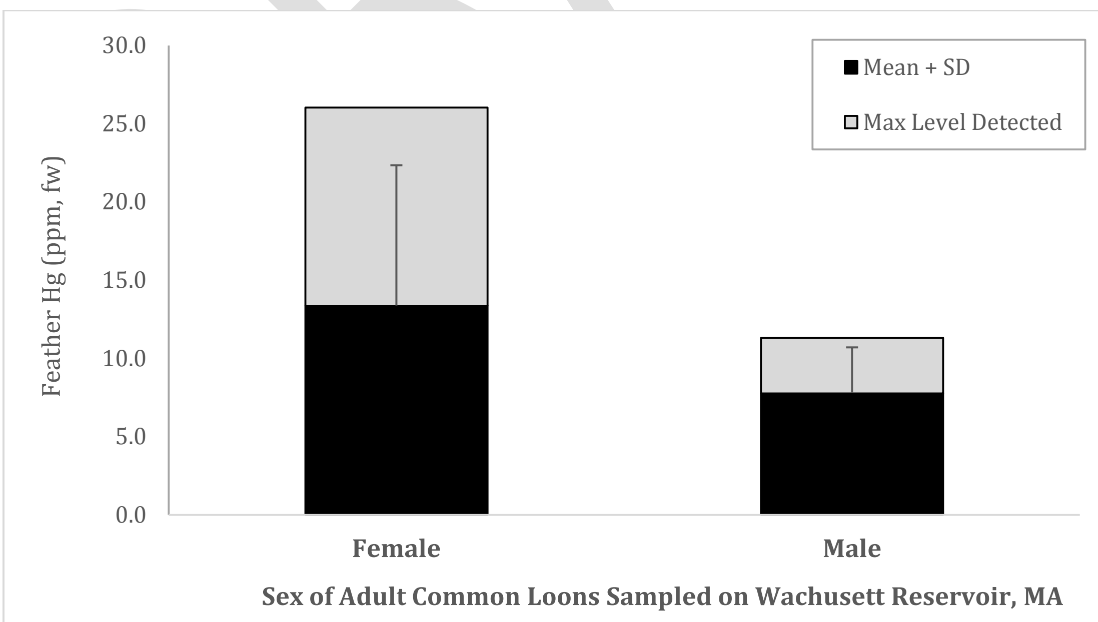
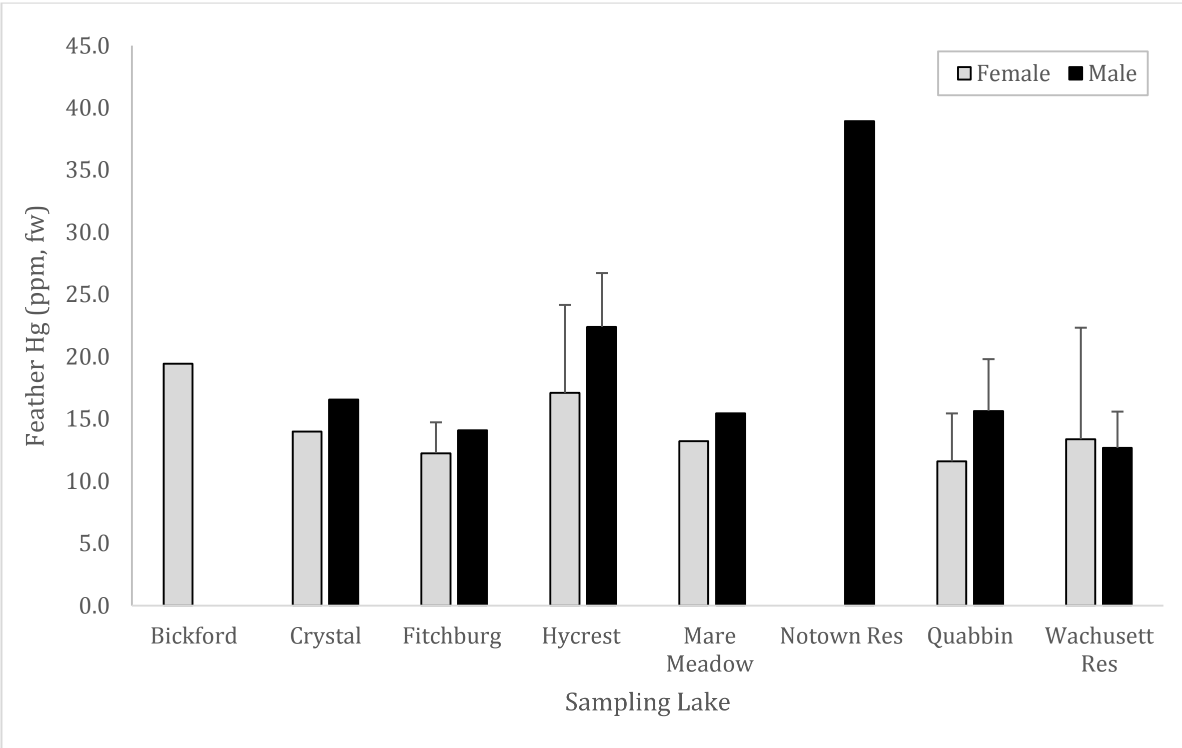


Figure 11. Feather Hg (ppm, fw) concentrations detected in Common Loons on 8 lakes in Massachusetts between 1999 and 2016.



8.0 DISCUSSION

Blood Hg concentrations in Common Loons breeding on Quabbin and Wachusett Reservoir in 2016 were similar or slightly lower than the long-term (1999 – 2015) levels observed on these waterbodies. While on the low end of the category, these levels are still considered to be in the "moderate risk" category for reduced nesting success. Long-lived piscivores, such as the Common Loon, are considered important bioindicators of Hg loads within aquatic ecosystems, due to the nature of methymercury (MeHg) to increase in quantity and thus toxicity with increasing trophic level, and bioaccumulate within body tissues over the course of an individual's lifetime (Evers 2006, Wolfe et al. 2007, Atwell et al. 1998, Burgess and Hobson 2006, Evers et al. 1998). Multiple studies have found that increased Hg loads in loons are associated with adverse neurological, physiological, and reproductive effects (Nocera and Taylor 1998, Counard 2000, Olsen et al. 2000, Evers et al. 2003, Burgess and Meyers 2008). Neurotoxic effects on behavior include decreased time brooding young, thereby potentially increasing predatory threats (Nocera and Taylor 1998), and lowered chick-feeding rates (Counard 2000). Physiological effects include shorter dive times that may be attributable to the heme-inhibiting properties of Hg in the blood that make it harder for loons to stay underwater for extended periods of time, which reduces foraging ability (Olsen et al. 2000). Further, higher blood Hg levels have been found to be correlated with increased lethargy in adults, resulting in reduced foraging time and chick survival (Evers et al. 2008). Total blood Hg levels, approximately 95% of which is MeHg bound to red blood cells, provide a marker of recent dietary uptake of Hg in loons (Evers 1998). Mercury levels detected in Common Loons over multiple seasons in Massachusetts indicate a moderate risk for reduced productivity, i.e., the number of fledged young per territorial pair. Evers et al. (2008) found that breeding Common Loons with comparable Hg levels in Maine and New Hampshire left their eggs unincubated 10% of the time. On average, individual loons produce 4-5 fledged young over their lifetime (modeled by using known national rates for fecundity of 0.26 fledged young per female, 1-3 year annual survivorship of 55%, 3-20 year annual survivorship of 95%, and 20-30 year annual survivorship of 85%) (Evers et al. 2010). Models developed by Biodiversity Research Institute (BRI) in conjunction with the US Environmental Protection Agency and US Fish & Wildlife Service indicate that a long-term average of 0.48 fledged young per territorial pair is needed for a sustainable loon population (Evers 2007, Grear et al. 2009). Unattended nests are at higher risk of predation and/or exposure to hot or cold temperatures, and thus, potentially at increased risk of nest failure.

Stressors, such as Hg exposure, have the potential to suppress long-term productivity of loon populations (Evers et al. 2008). Female loons in New Brunswick, Canada with blood Hg levels of 2.00 ppm, similar to mean concentrations detected in Massachusetts loons, were associated with 23% reduced productivity (Burgess and Meyers 2008). Female loons can sequester some of their body burden of Hg during egg formation and this is likely why long-term mean blood Hg levels are lower in females compared to males in Massachusetts. Transfer of dietary MeHg from females to eggs is rapid and a highly significant positive relationship exists between female blood Hg and egg Hg concentrations (Evers et al. 2003). Eggs collected from Quabbin and Wachusett Reservoirs in 2016 were similar to previous years and fell within the moderate risk category for reduced hatching success (Evers et al. 2008). The Hg concentration detected in an egg collected from Hycrest Reservoir, however, was well above the high risk category threshold of > 1.3 ppm (ww). Kenow et al. (2011) found that the lethal concentration of Hg (LC_{50}) was 1.78 (μg/g, ww) in loon eggs containing both maternally deposited Hg and injected Hg treatments. The same study showed that eggs with Hg levels of 0.50 (μg/g, ww) had 20% lower hatching success compared to control eggs; however, the difference was not significant. Elevated egg Hg concentrations may result in increased incubation time and are strongly correlated with increased Hg levels in chick body tissues (Kenow et al. 2011).

Feather Hg concentrations sampled from breeding loons on Quabbin Reservoir in 2016 were similar or lower than the long-term mean for that waterbody. Overall, Hg levels detected in feathers collected from birds on Quabbin and Wachusett Reservoirs between 1999 and 2016 have been lower than feather Hg levels detected in birds sampled from other waterbodies in MA. Feather Hg concentrations are highly correlated with blood Hg levels and likely reflect Hg exposure at the time of the molt while on the wintering grounds (Evers et al. 1998, Bearhop et al. 2000). They are also a function of previous exposure and age, i.e., feather Hg will accumulate in an individual over time (Meyers et al. 1998). Evers et al. (1998) examined geographic trends of Hg loads in Common Loon feathers across the northern U.S. and found that loons in New England had the highest feather Hg loads, where the mean feather Hg in females sampled was 10.2 ± 4.2 (µg/g, fw) and 15.4 ± 5.1 (µg/g, fw) in males. Loons sampled in Massachusetts show similarly high feather Hg loads. The levels reported place these loons at moderate risk for asymmetrical development of flight feathers (Evers et al. 2008). The ability to develop bilateral characters is an indirect measure of fitness and feather asymmetry has been found to be a sensitive measure of long-term body condition, potentially linked to heavy metal pollution (Clarke 1995, Polak and Trivers (1994), Eeva et al. 2003). Evers et al. (2008) suggested that feather asymmetry may decrease migratory performance in a species with high wing-loading restrictions, such as the Common Loon.

The Northeastern United States is considered a "biological mercury hotspot" due to high levels of Hg deposition and associated methylmercury concentrations in biota in the region (Evers et al. 2007). Recent levels of available methylmercury in aquatic ecosystems of northeastern North America posed significant risks to human and ecological health (New York State Dept. of Health 2007, Scheuhammer et al. 2007, Swain et al. 2007). North-central Massachusetts was identified as an area of concern for Hg contamination based on concentrations detected in fish and piscivorous birds, and aquatic mammals (Evers et al. 2007). In 2000, an EPA study found that 60% of total mercury deposition in the US came from US anthropogenic emissions sources (EPA 2011). Loons are sentinels of MeHg availability within freshwater aquatic ecosystems and non-lethal sampling methods of blood Hg levels provides valuable information related to the overall health of the water body. Long-term monitoring of mercury levels in loons in an area with historically high levels of Hg deposition, such as Massachusetts, provides valuable information regarding temporal patterns of biologically available Hg that can be used to guide regulatory policy and decision making.

9.0 RECOMMENDATIONS

1) Continue to monitor Hg levels in Common Loons occupying freshwater lakes and reservoirs in Massachusetts.
    - Loons are "bioindicators" of environmental loads of Hg and thus provide valuable information related to the overall health of the water body.

- Long-term monitoring of Hg levels in aquatic ecosystems within the Northeast provides an excellent foundation from which to assess newly implemented mercury emissions regulations.

2) Continue banding efforts of Massachusett's loon population.
    - Band return data provide critical information regarding the population dynamics of Massachusetts' recovering loon population information, including survivability, site fidelity, and juvenile dispersal.

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Appendix 1. Summary Necropsy Report