Maine Loon Mortality: 1987-2012

February 2013

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MAINE AUDUBON

Introduction

Maine Audubon has helped coordinate the collection of common loon carcasses from lakes and ponds across the state since 1987. Dozens of Maine Audubon volunteers, as well as wardens and biologists from the Department of Inland Fisheries and Wildlife (DIFW), field staff from Biodiversity Research Institute and Acadia National Park, and many others have collected 450 loon carcasses from Maine in that time. These have been brought to the Wildlife Clinic at the Cummings School of Veterinary Medicine at Tufts University, where Dr. Mark Pokras, leading a team of staff and students, has conducted detailed necropsies, collected tissue samples, and taken radiographs (Figure 1) to try to determine the cause of death for each loon. The results of those necropsies are presented here, with a focus on assessing the impact from lead fishing tackle over the last 25 years.

Figure 1. Radiograph of Common Loon TV10-138, showing an ingested lead jighead (circled). Recovered from Toddy Pond in Orland, ME on Sept. 7, 2010. (Source: Mark Pokras, Tufts Veterinary School)

Background

Lead is a highly toxic metal, and exposure leads to a variety of serious health problems in people, especially in children, who are susceptible to very low levels of lead exposure. Wildlife exposed to lead, both long- and short-term, can suffer severe health consequences, as well as death. Ingested lead has been a leading culprit in raptor mortality, and most recently has had a major impact on the sustainability of the endangered California condor population in the western U.S. (Finkelstein et al, 2012). Ingestion of lead sinkers has been documented in 27 species of birds in North America (Perry 1994). The highest rates of mortality from the ingestion of lead occurs in common loons in the United States (for example, Franson et al. 2003, Sidor et al. 2003, Pokras et al, 2009, Grade 2011) and mute swans in Great Britain (Kirby et al. 1994).

The unique physical properties of lead, as well as its low cost and relative natural abundance, resulted in its incorporation into a wide variety of consumer products during the last century, including paint, batteries, pipes, cosmetics and gasoline. Since 1980, federal and state regulations have eliminated much of the lead in consumer products, most notably in gasoline, paint, and ammunition for waterfowl hunting.

Despite these efforts to “get the lead out”, lead remains a prominent component in fishing tackle. National efforts to ban lead fishing tackle have not been successful, but six states have enacted some kind of lead tackle ban (Table 1), in large part over concern about loon mortality. Loons are particularly susceptible to ingesting lead fishing tackle. As fish-eaters, loons likely catch injured or maimed fish that are hooked with lead tackle and broken line. Loons also need to ingest gravel that will sit in their gizzard and grind up their food. They pick this up from lake bottoms, where lead tackle lost by anglers may be found among similarly sized rocks and gravel (Figure 2).

Table 1. Current state lead bans, as of January 2013

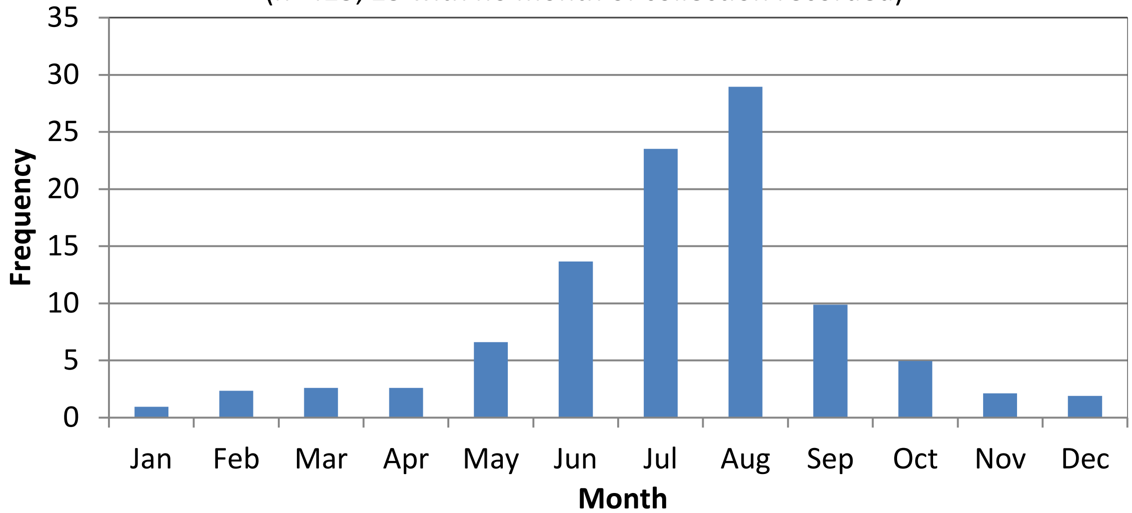
State	Sale or Use?	Type of Regulation
NH	Sale & Use	Lead Sinkers 1 oz. or less Lead jigs less than 1” (incl. hook)
NY	Sale	Lead sinkers ½ oz. or less
MA	Use	Lead sinkers or lead jigs less than 1 oz.
ME	Sale	Lead sinkers ½ oz. or less
VT	Sale & Use	Lead sinkers ½ oz. or less
WA	Use	Lead fishing weights and jigs measuring 1 ½ “ or less , limited to 13 lakes

Figure 2. Gravel taken from the gizzard of Common Loon TV05-298, including one lead jighead (circled)**.** Recovered from Barker Pond in Lyman, ME on Sept. 17, 2005.

Overview of Maine Loon Mortality Data

Of the 450 loon carcasses collected since 1987 from Maine, most (352) were adults, and most (345) were found on freshwater lakes and ponds. Sixty percent were male and 40% were female. Collection of carcasses peaks in the summer (Figure 3), likely a combination of when highest mortality rates occur and when the most people are out on Maine's lakes and ponds. On average, there were 18 carcasses collected each year. Because the collection relies primarily on unpaid volunteers, or agency and organization staff who pick up carcasses incidental to their primary duties, there is no standard sampling technique. Efforts have varied over the years, from a low sample of 1 in 1987 to a high of 22 loons collected in 2005. Overall, we are likely collecting a relatively small percentage of the loons that die each year in Maine.

Figure 3. Distribution of Timing of Loon Carcass Collection in Maine
(n=425, 25 with no month of collection recorded)



Causes of Mortality

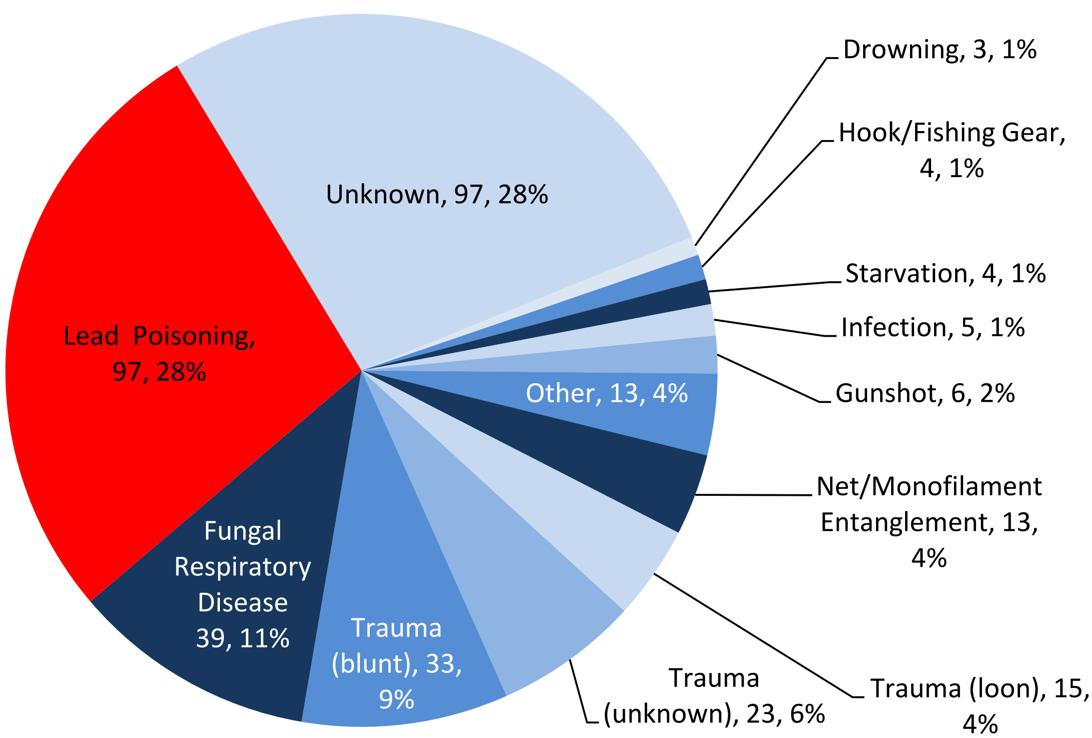
There were 13 categories of cause of death determined for the 450 loons assessed in this study (Table 2). Lead poisoning from lead sinkers and lead-headed jigs was the leading cause of death for adult loons, responsible for 28% of deaths (97 out of 352 adult mortalities) between 1987 and 2012 (Figure 4). Lead poisoning was disproportionately higher in male loons. Male loons made up 60% of the total adult loons collected in the 25 years of this study but made up 72% of the lead-poisoned loons. Only six of 97 lead-poisoned loons were found on saltwater, the rest were found on fresh water bodies.

Table 2. Determined causes of death for Maine common loons.

Cause of Death	Adult	Chick	Immature	Unknown Age	Total
Lead Poisoning[1]	97		1	3	101
Unknown[2]	97	9	11	1	121
Fungal Respiratory Disease[3]	39	2	3		44
Trauma (blunt)[4]	33	14	11	1	59
Trauma (unknown)[5]	23	12	4		39
Trauma (loon)[6]	15	4			19
Net/Monofilament Entanglement	13		2		15
Other	13	8	3		24
Gunshot	6				6
Infection	5	2	1		8
Hook/Fishing Gear	4		1		5
Starvation	4		1		5
Drowning	3	1			4
Grand Total	**352**	**52**	**38**	**8**	**450**

1 Lead poisoning confirmed with the recovery of a piece of lead from the gizzard and/or with tests of lead levels in blood or tissue.
2 Cause of death could not be determined due to deteriorated carcass condition; 3 Most was Aspergillosis, a fungus present in the air sacs of healthy loons at low levels, but growing to high levels and causing mortality when loons are under stress; 4 Likely collision with a large object like a boat; 5 Cause of trauma could not be determined; 6 Likely the result of a puncture wound inflicted by another loon.

Figure 4. All Causes of Adult Common Loon Mortality in Maine, 1987-2012, n=352
(Cause of death followed by number of cases and percentage of total)



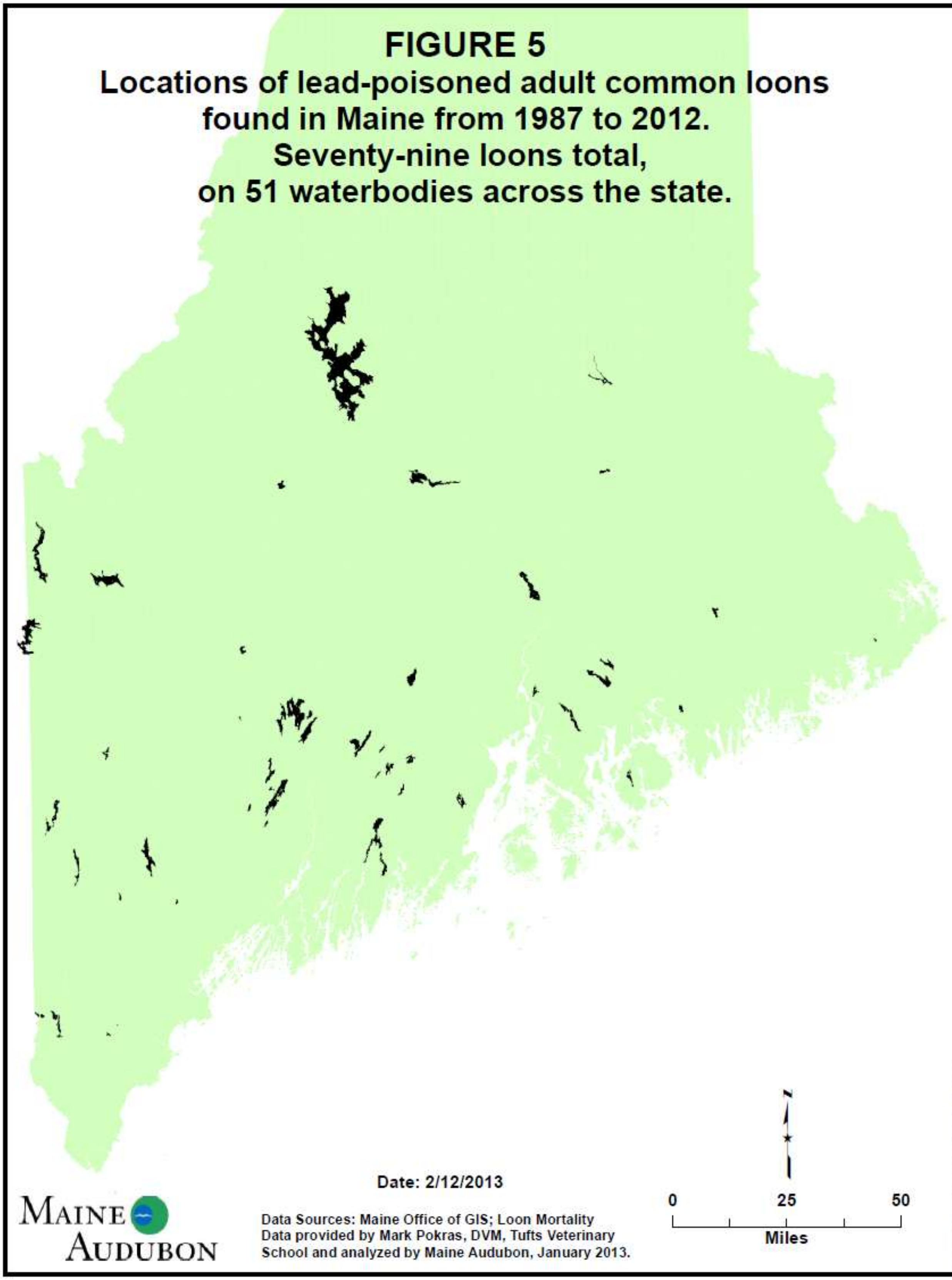
Analysis of adult loon mortality in New Hampshire has found a higher rate of lead poisoning in adult loons (50%) (Grade 2011, Vogel 2012), perhaps due to higher fishing pressure or to more systematic collection efforts. The Loon Preservation Committee in New Hampshire has 8-10 seasonal staff that closely monitor nesting loons and actively watch for and collect loon carcasses. Other studies have had comparable results to those found in Maine, including a 22% lead mortality rate for common loons in New England (Pokras et al. 2009), though for breeding adults only, that percentage jumps to 44% lead mortality (T. Grade, pers. comm.). In Canada, Scheuhammer and Norris (1995) found a lead mortality rate of 33% for loons, and that rate was estimated to be 36% in New York (Stone and Okoniewski, 2001). Only one study showed a very low rate of lead ingestion of 7.5% in common loons (Franson et al. 2003), but this was based on a study where more than a third of the loons were live and apparently healthy birds, and the majority of dead birds were collected on salt water during the winter.

The distribution of lakes with lead-poisoned loons (Figure 5) shows lead mortality is widespread through the state and not localized in any particular region. Most lakes had only one lead-poisoned loon collected over the last 25 years, but five lakes had two loons collected, four lakes had three loons collected, and five lakes had four loons collected, the highest number any lake (See Appendix A for complete list of lakes and recoveries). The distribution of where loons were collected, as well as the number collected per lake, may be an artifact of where we have active volunteers on lakes willing to collect and store dead loons, but it also may be related to levels of fishing pressure. The lack of lead-poisoned loons recovered north of Moosehead Lake is almost certainly due to the very small volunteer base in that region, compared to southern and central Maine.

The remaining analysis in this paper focuses on the adult common loons that died from lead poisoning since 1987.

FIGURE 5

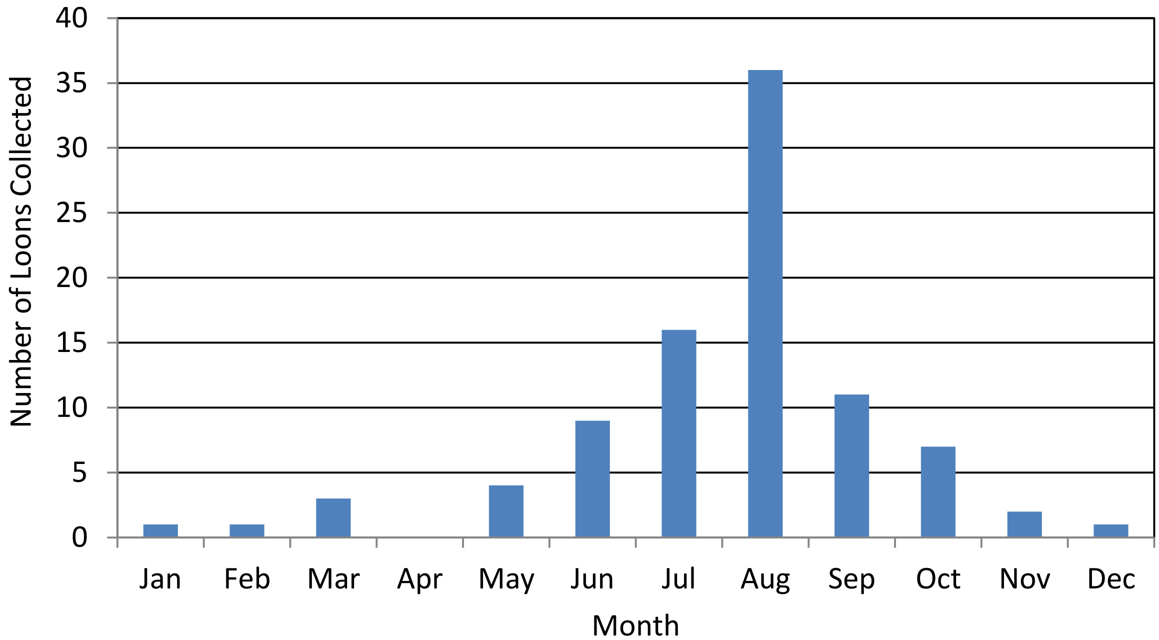
Locations of lead-poisoned adult common loons found in Maine from 1987 to 2012. Seventy-nine loons total, on 51 waterbodies across the state.



Lead Poisoning Over Time

Like overall collection rates (Figure 3), the collection of lead-poisoned loons peaked in August, when nearly 40% of these birds were collected (Figure 6). July and August collections combined accounted for about 60% of the total lead-poisoned loons recovered in Maine. This likely relates in part to the peak of volunteers out on lakes willing to collect dead loons but also in part to the frequency and intensity of fishing.

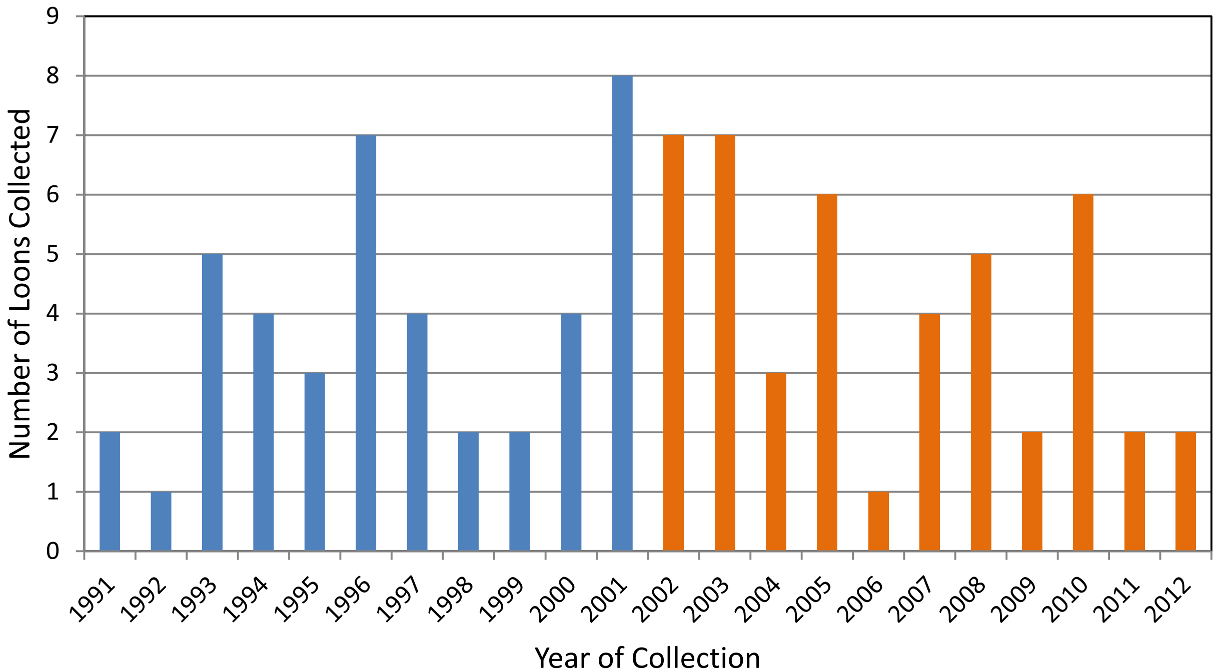
Figure 6. Timing of lead-poisoned adult loons collected in Maine from 1987-2012 (n=91, 6 loons with no date of collection noted).



Mortality from lead poisoning over the last 22 years has varied dramatically from year to year, from just one lead-poisoned loon collected 1992 and 2006, to a high of 8 collected in 2001 (Figure 7). At least one lead-poisoned loon was found each year since 1989. On average, 3.9 adult common loons recovered each year in Maine died from lead poisoning.

<u>More common loons in this analysis died from lead poisoning in the 11 years *after* the ban on the sale of lead sinkers ½ oz. or less went into effect (January 1, 2002), compared to the 11 years before the ban.</u> During the pre-ban period, 42 adult loons died from lead poisoning compared to 45 loons in the post-ban period. Although more loons were collected in recent years, making the percentage of lead poisoned adults decrease slightly from 31% of total loon mortalities pre-ban to 24% post-ban, the continued presence of sometimes high levels of lead mortality continue to be a concern for long-term conservation of common loons in Maine.

Figure 7. Number of lead poisoned adult loons recovered in the 11 years before the lead sinker ban (blue) compared to the 11 years since (orange) (n=87)



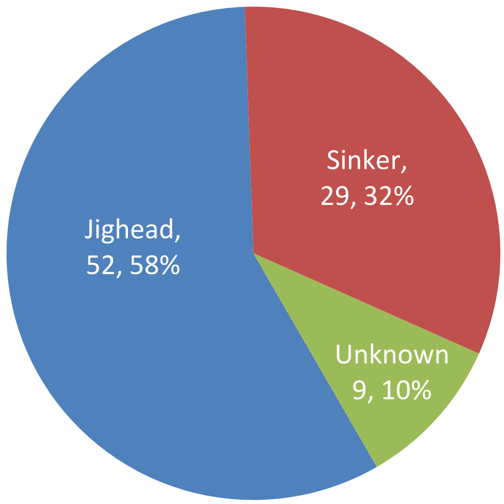
Types of Lead Objects Recovered in Loons

The gizzard contents of necropsied common loons were saved for the majority of birds in this study, and radiographs showing lead objects were also archived. For common loons where lead poisoning was found to be the primary cause of death, the gizzard contents were checked to see if a lead object was present, and if so, the type of object, its size (length in longest dimension) and and/or mass were recorded by researchers at either the Loon Preservation Committee in New Hampshire or at the Tufts Wildlife Clinic. If vials containing gizzard contents could not be found, radiographs or pathology report notes were checked to find any pertinent records of lead objects documented at the time of necropsy.

Vials and/or radiographs were missing for 16 birds that died from lead poisoning. Of the remaining 81 adults, most (91%) had some type of lead object present in their gizzard at the time of death. Only seven common loons that died from lead poisoning had no lead objects identified in their gizzard contents, probably because the object had passed through the loon's system. The gizzard contents of 74 lead-poisoned loons contained a total of 90 lead objects, with almost all the objects identified as some kind of fishing tackle, either sinkers (32%) or jigs

(58%) (Figure 8). The nine remaining lead objects were too eroded to make a determination, or were suspected to be internal weights associated with larger lures. Most loons (80%) had only one lead object in their gizzard. Nineteen percent of the loons had two objects in their gizzard, and only one loon had three lead objects (all unknown types).

Figure 8. Types of lead objects recovered from adult Common Loons in Maine, 1987-2012 (90 objects recovered from 74 common loons, type of object followed by number and percent of total)



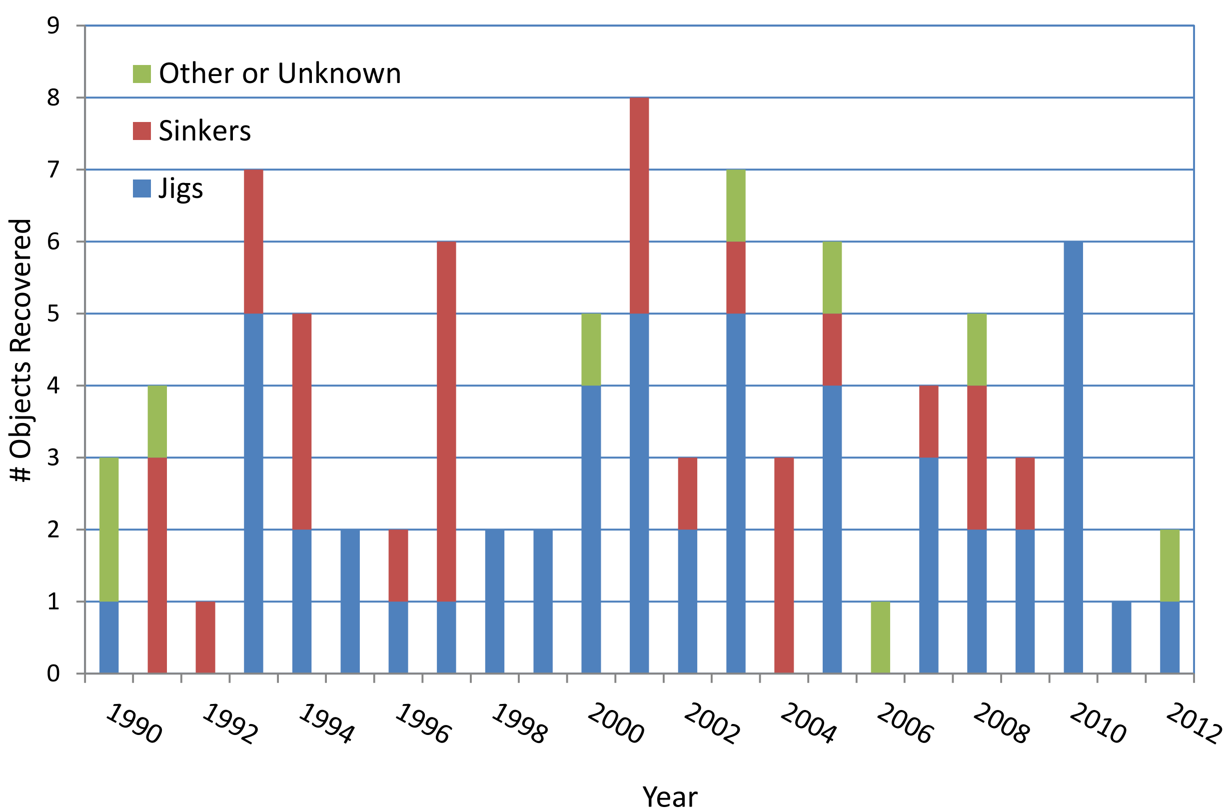
The high percentage of lead-headed jigs is of concern, as there are no existing regulations around the sale or use of lead-headed jigs in Maine. Analysis of New Hampshire loon necropsy results has found a similar predominance of lead-headed jigs (Vogel, 2012, Grade 2011), with lead-headed jigs accounting for 50% of the lead tackle recovered from dead adult loons, most of these thought to be longer than the one inch legal limit for jig length in that state at the time of ingestion. Jigs were found to make up only 19% of the lead objects sampled in an earlier study of regional loon mortality (Pokras et al., 2009). The higher percentages in more recent studies may be the result of a more thorough examination of the objects by Grade (2011), who has standardized methods for distinguishing eroded jigs from sinkers.

Almost 40% of adult loons that died from lead poisoning (38 out of 97) had some type of additional tackle in their digestive system at the time of necropsy, including monofilament, swivels, and/or hooks, indicating the likely ingestion of fish impaired by tackle cut loose or broken from anglers' lines. This is lower than similar measures in New Hampshire, where Grade (2011) found at least 66% of lead-poisoned loons had associated tackle in their systems.

Types of Fishing Tackle Over Time

The number of lead objects recovered from dead loons each year varied, with jigs found in 19 of the last 23 years, and sinkers found in 14 of the last 23 years (Figure 9). Eighteen sinkers were recovered from 13 loons that died in the 11 years before 2002 (when the ban on the sale of lead sinkers ½ ounce or less was put in place) compared to 10 sinkers recovered from 9 loons that died in the 11 years since, indicating some reduction in mortality from this source. The incidence of jig ingestion in lead-poisoned loons varied by year. The number of jigs recovered from loons pre- and post-ban was about equal (24 jigs recovered from 22 loons before vs. 26 jigs recovered from 23 loons after).

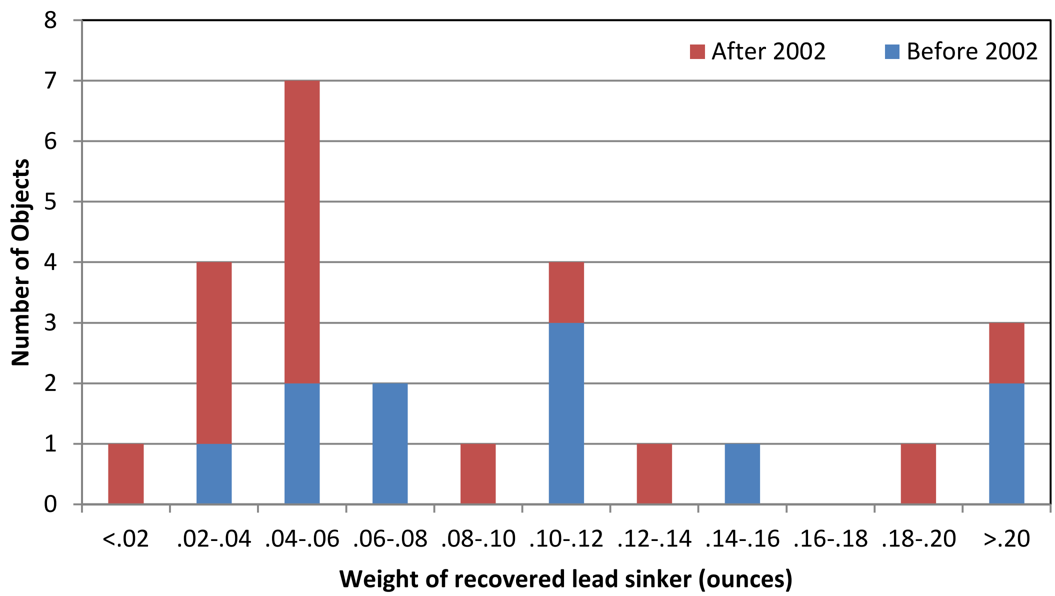
Figure 9. Types of lead objects recovered over time from Maine Common Loons, 1990-2012 (88 objects from 71 loons, no objects identified in 1987-1989)



Size and Weight of Fishing Tackle in Loons

Measurements were taken for 79 of the lead tackle objects recovered from adult loon carcasses, including measurements for 54 jigs and 25 sinkers. Sinker weights ranged from 0.02 to 0.85 ounces, with an average weight of 0.13 (Figure 10). The distribution of sinker sizes in Maine is similar to findings by others (Pokras et al, 2009) though slightly larger than the distribution of lead sinker sizes recovered from loons in New Hampshire (Grade 2011). It is important to note that loons can ingest larger lead sinkers, with records in New Hampshire of an ingested sinker greater than one ounce (T. Grade, pers. comm.), and the largest sinker ever recovered a 2.76 oz. pyramid sinker off the North Carolina coast (Franson et al, 2003).

Figure 10. Weight distribution of 25 lead sinkers recovered from adult Maine loons (1990-2012)



Over time, there has been no obvious trend in the sizes of sinkers recovered from loon gizzards. The 11 sinkers recovered before the ban (blue in Figure 10) range from the second smallest to the largest size category, very much like the 14 sinkers recovered after the ban (red in Figure 10). It appears the same range of sizes in sinkers have been ingested by loons over the past 23 years.

The sinkers recovered from loons in Maine were significantly eroded from their original size, since they had been in the gizzard for some length of time, subject to both the acidic environment and the grinding action of gravel. The objects have also leached enough lead into the loon's system to kill it. No reliable measures of how much a lead sinker will erode in a loon's gizzard in a given period of time have been taken. Regulations based on the weight of sinkers recovered from loons will not accurately capture the sizes that are actually being ingested.

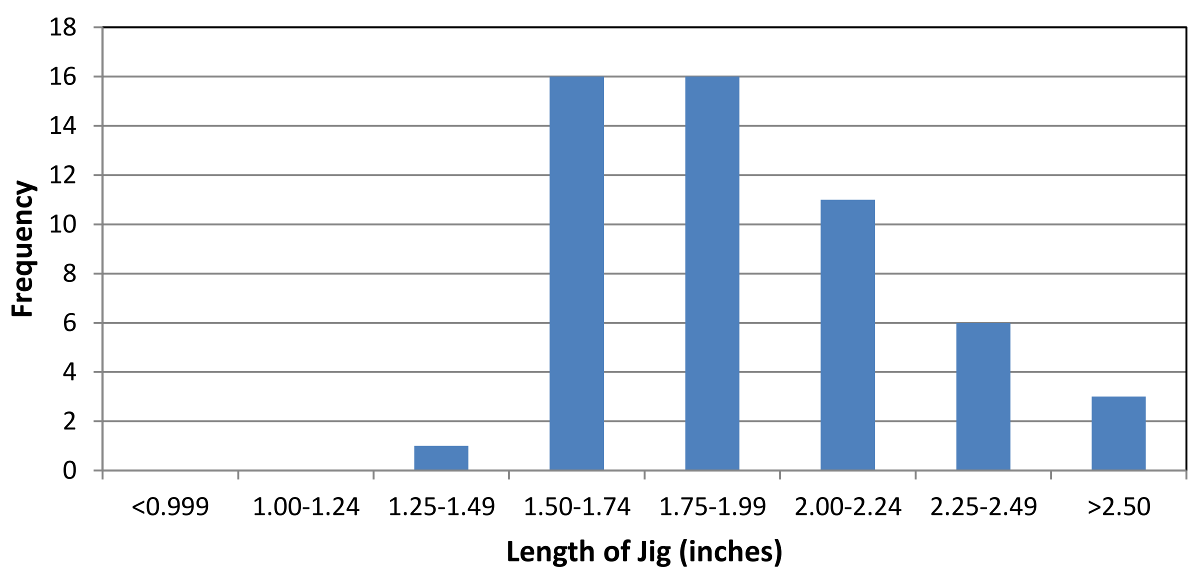
Pokras et al. (2009) measured the size of gravel recovered from gizzards of loons that had died from lead poisoning. He found that gravel ranged in size from 6 mm to 23 mm along its longest axis, with a mean gravel size of 12.4 mm (+/- 2.96 mm). A rough estimate of the weight of lead sinkers that would be similar in size to the sample gravel shows that they would weigh between 0.21 and 0.71 ounces (Table 3). Although only a hypothetical example, based on diameter of a spherical lead weight, this weight range may more accurately reflect the sizes of those sinkers likely to be ingested by loons from lake bottoms than those recovered from loon gizzards.

Table 3. Estimated weight of different diameter lead sinker spheres

Diameter of hypothetical round lead sinker	Estimated Weight (based on lead density of 11.34 g/mL)
10 mm	0.21 oz
11 mm	0.28 oz
12 mm	0.36 oz
13mm	0.46 oz
14 mm	0.57 oz
15 mm	0.71 oz

Jigs found in dead loons are similarly eroded, but in the case of jigs, Grade (2011) has developed estimates of hook length, based on new purchased jigs, to add on to the measured lengths of jigs recovered from dead loons (for full methods see Appendix B). Applying these corrections to the lengths of jigs recovered from dead loons illustrates that no jigs less than 1.25 inches were ingested by loons, and that most jigs were in the 1.5 to 2.0 inch category (Figure 9). This is similar to the findings in New Hampshire (Vogel 2012, Grade 2011). Restrictions on jigs less than 2.5 inches in length would have prevented 94% of the loon mortality from lead jigheads found over the last 25 years in Maine loons.

Figure 11. Total Length of Jigs ingested by ME loons 1987-2012, n=53



Summary:

The loon carcasses collected in Maine are a sample of the total number of loons dying in Maine each summer. Loon carcass collection in Maine depends in large part on resilient volunteers willing to go through many, often unpleasant, steps to collect and store loon bodies. There is no doubt that many more loons are dying in the state than we are able to collect through our volunteer network, so the numbers presented in this report are minimums of the actual mortality occurring on Maine's lakes and ponds.

Lead poisoning is the leading cause of death for adult loons in Maine. In the last 25 years, volunteers have collected 450 loon carcasses from Maine. Most (352) were adults, and 97 of those (28%) died from lead poisoning, more than any other documented cause of death. Lead poisoning was limited almost exclusively to adult loons, on fresh water, with the highest rates of mortality in July and August. These are probably breeding birds, otherwise in good health who likely would have survived otherwise to produce offspring.

Lead-headed jigs make up the majority (58%) of the lead objects recovered from dead adult loons, followed by lead sinkers (32%). The lead that is poisoning loons in Maine is almost exclusively fishing tackle. The high number of jigs recovered from dead loons is of concern, as there are no limits on the use or sale of lead-headed jigs in Maine.

Both lead-headed jigs and lead-sinkers are documented consistently over the last 25 years. Lead mortality has varied from 1 to 8adult loons each year (5-60% of total adult mortality), with no years free from lead-caused loon deaths.

There was a slight decrease in the number of loons recovered with lead sinkers in their gizzards, from 13 in the 11 years preceding the ban on the sale of small lead sinkers (2002) to 9 in the 11 years since. This may represent some success of the ban, though the sizes of recovered sinkers have not seemed to change in that time. Give that the results analyzed here represent only a sample of the actual number of loons dying in Maine each summer, there are likely substantially more sinker-related loon deaths occurring despite the ban on lead sinker sales.

There has been virtually no change in the incidence of jig-related deaths since 1991, with on average a minimum of two loons dying from jigs each year. The role of jigs in loon mortality in Maine is a major concern over the long-term, given our small sample size, the lack of a downward trend over time, and the absence of any regulations.

The sizes of sinkers recovered from adult loons were substantially smaller than the legal sale limit of ½ ounce, but there is no good way to document the amount of erosion, over time, in a loon gizzard. Hypothetical weights of lead spheres roughly equivalent to the size of gravel recovered from dead loons indicate that weights up to .82 ounces might be likely to be ingested by loons foraging on lake bottoms for gravel.

Most of the jigs recovered from Maine's loons were estimated to be between 1.25 and 2.5 inches long at the time of ingestion. A ban on jigs less than 2.5 inches long might have prevented 94% of jig-related mortalities, or roughly half of the lead-poisoned loons over the last 25 years.

Acknowledgements: Thanks to Chris Kittridge for GIS help and creating Figure 5; to Tiffany Grade at the Loon Preservation Committee in New Hampshire for her analysis of gizzard contents for Maine common loons and for her helpful comments and reviews; and to Dr. Mark Pokras at the Tufts Wildlife Clinic for conducting necropsies over many years and for providing necropsy data for this analysis.

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Appendix A. List of lakes where loons with lead poisoning from the ingestion of lead fishing tackle have been recovered, n=79, 1987-2012.

Waterbody	# Loons Recovered	Acres	Town
Aziscohos Lake	1	6,916	Lincoln Plant./Parkertown TWP/Lychtown TWP
Beech Hill Pond	1	1,422	Otis
Branch Pond	1	310	China/Palermo
China Lake	2	3,939	China/Vassalboro
Clearwater Lake	1	796	Industry/Farmington
Cobbosseecontee Lake	4	5,540	Manchester/W. Gard./Litchfield/Monm./Winth.
Cochnewagon Pond	1	394	Monmouth
Crystal Lake	1	185	Gray
Damariscotta Lake	4	4,664	Nobleboro/Newcastle/Jefferson
Flanders Pond	1	535	Sullivan
Great Pond	4	8,533	Belgrade/Rome
Green Lake	1	3,132	Ellsworth/Dedham
Horn Pond	1	227	Acton
Indian Lake	1	126	Whiting
Kennebunk Pond	1	199	Lyman
Kezar Lake	4	2,665	Lovell/Stow
Long Pond	1	939	Mount Desert/Southwest Harbor
Long Pond	3	2,557	Belgrade/Mount Vernon/Rome
Lower Narrows Pond	1	223	Winthrop
Maranacook Lake	1	1,818	Winthrop/Readfield
Megunticook Lake	1	1,328	Camden/Hope/Lincolnville
Messalonskee Lake	1	3,489	Belgrade/Oakland/Sidney
Moose Pond	1	1,697	Denmark/Bridgton/Sweden
Moosehead Lake	2	75,469	Greenville et al.
Mousam Lake	1	1,010	Shapleigh/Acton
Norcross Pond	1	113	Chesterville
North Pond	1	307	Greenwood/Woodstock
Parker Pond	1	25	Lyman
Pemaquid Pond	4	1,537	Damariscotta/Nobleboro/Waldoboro/Bremen
Penobscot River	1	1,153	Medway
Pleasant Pond	1	1,037	Caratunk/The Forks Plantation
Pleasant River Lake	1	909	Beddington/Devereaux TWP
Pushaw Lake	1	4,680	Hudson/Old Town/Orono/Glenburn
Rangeley Lake	2	6,302	Rangeley/Rangeley Plantation
Salmon Pond	1	695	Belgrade/Oakland
Sand Pond	1	279	Litchfield/Monmouth
Sebec Lake	1	6,362	Sebec/Dover-Foxcroft/Willimantic/Bowerbank

Appendix A. (cont'd)

Waterbody	# Loons Recovered	Acres	Town
Sheepscot Pond	2	1,215	Palermo
Silver Lake	1	681	Bucksport
South Pond	1	463	Greenwood/Woodstock
Square Pond	3	877	Shapleigh/Aton
St George Lake	2	1,109	Liberty
Thompson Lake	3	4,415	Casco/Otisfield/Oxford/Poland
Toddy Pond	3	2,408	Surry/Blue Hill/Orland
Tricky Pond	1	315	Naples
Turner Pond	1	199	Somerville/Palermo
Umbagog lake	1	7,767	Upton/Magalloway Plantation/Cambridge
Unity Pond	1	2,569	Unity/Burnham/Troy
Upper Cold Stream Pond	1	648	Lincoln/Burlington
Washington Pond	1	565	Washington
Wilson Lake	1	307	Acton

Appendix B.

Methods for the calculation of jig lengths, from Tiffany Grade, LPC, 2013.

Methods for determining values for Figure 3 from LPC's report, "Effects of lead fishing tackle on loons in New Hampshire, 1989-2010"

-- Loon Preservation Committee --

When Common Loons ingest lead-headed jigs, a combination of acids and the grinding action of the gizzard causes the hook to break off from the lead jighead. This hook is rarely present at the time of necropsy, having either dissolved or passed from the loon before death. Thus, the original total length of the jig is unable to be directly measured from the objects remaining inside the loons.

Common Loon carcasses collected in New Hampshire by the Loon Preservation Committee between 1989 and 2010 were necropsied at the Tufts University Cummings School of Veterinary Medicine. Stomach contents were archived for many of these loons; and, among these archived contents, 57 lead jigheads were preserved. The hooks were broken off from all of these jigheads. We weighed each jighead on a digital scale to the nearest 1/100 of a gram and measured the length of the remaining lead jighead (i.e., excluding the hook) along the longest axis with a calipers to the nearest 1/100 of a millimeter. Due to erosion from acids and the grinding action of the gizzard while the jigheads were inside the loons, the lengths and weights of these jigheads (i.e., excluding the hook) have been reduced from their original sizes.

To establish the length of the hooks on the jigheads removed from the loons, we purchased 45 jigs of various sizes and styles from tackle shops and sporting goods stores. The majority were purchased in New Hampshire, while the remainder were purchased in Wisconsin. Of jigs purchased in Wisconsin, there is no difference from the sizes, types, styles, or materials of jigs purchased in New Hampshire. We categorized the jigs according to the weight printed on the packages. The length of the hook for each jig was measured along the longest axis with a calipers to the nearest 1/100 of a millimeter. We then averaged the hook lengths within each weight category. A small random sample of purchased jigs was also weighed to determine if there is a consistent bias from the weight standard printed on the packages within or between manufacturers. No consistent bias was found.

To determine the original lengths of the ingested jigs, we compared the mass of each jighead removed from a loon to the weight categories of purchased jigs. The objects removed from the loons were placed by weight in the nearest standard jig weight category (e.g., 1/8 oz, 1/16 oz). We then added the average length of the hooks of purchased jigs from that weight category to the length of the ingested jighead. These are the numbers which appear in Figure 3 of LPC's report.

On average for all ingested objects, the removed object varied from a standard weight category by 11.2%. The majority of the objects were below the standard jig weight category, thus accounting for erosion from the original tackle item. In a few cases, particularly among larger objects, the removed object weighed slightly higher than the nearest standard jig weight category. Allowing for variation in manufactured weights, the object was still categorized to the nearest jig weight class, thus resulting in a conservative measure of the length of the original jig.

The largest variation from the standard jig weight occurred in the smallest objects removed. Two objects removed from loons weighed 0.04 oz--36% smaller than the package weight of a 1/16 oz jig (0.0625 oz). Cook and Trainer (1966) found erosion of 66% of volume of lead shot in the gizzard of Canada geese after 3 days. Given this, it seemed more reasonable to assume erosion of 36% of these small lead tackle pieces from a loon's gizzard after several weeks than that a manufacturer would increase the size of a 1/32 oz jig by ~28%. The rate of erosion of small lead objects in avian gizzards suggests our average of 11.2% is a conservative value.