Lead Fishing Weights and Other Fishing Tackle in Selected Waterbirds

J. CHRISTIAN FRANSON[1], SCOTT P. HANSEN[1], TERRY E. CREEKMORE[1,2], CHRISTOPHER J. BRAND[1], DAVID C. EVERS[3], ADAM E. DUERR[4,5] AND STEPHEN DESTEFANO[4,6]

[1]U.S. Geological Survey, National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711 USA
Internet: chris_franson@usgs.gov

[2]Current address: Department of Veterinary Sciences, University of Wyoming
1174 Snowy Range Road, Laramie, WY 82070 USA

[3]BioDiversity Research Institute, 411 Route 1, Suite 1, Falmouth, ME 04105 USA

[4]Arizona Cooperative Fish and Wildlife Research Unit, School of Renewable Natural Resources
University of Arizona, Tucson, AZ 85721 USA

[5]Current address: Vermont Cooperative Fish and Wildlife Research Unit, University of Vermont
328 Aiken Center, Burlington, VT 05401 USA

[6]Current address: Massachusetts Cooperative Fish and Wildlife Research Unit, University of Massachusetts
Box 34220, Amherst, MA 01003 USA

Abstract.—From 1995 through 1999, 2,240 individuals of 28 species of waterbirds were examined in the United States for ingested lead fishing weights. A combination of radiography and visual examination of stomachs was used to search for lead weights and blood and liver samples from live birds and carcasses, respectively, were collected for lead analysis. Ingested lead weights were found most frequently in the Common Loon (*Gavia immer*) (11 of 313 = 3.5%) and Brown Pelican (*Pelecanus occidentalis*) (10 of 365 = 2.7%), but also in one of 81 (1.2%) Double-crested Cormorants (*Phalacrocorax auritus*) and one of 11 (9.1%) Black-crowned Night Herons (*Nycticorax nycticorax*). Birds with ingested lead fishing weights (including split shot, jig heads, and egg, bell, and pyramid sinkers) were found in California, Florida, Maine, New Hampshire, North Carolina, and Wisconsin. The size and mass of ingested lead weights ranged from split shot of 7 mm in the longest dimension, weighing less than 2 g, to a 22 × 39 mm pyramid sinker that weighed 78.2 g. Six ingested lead weights were more than 25.4 mm in the longest dimension. Lead concentrations in the blood and liver of birds with lead fishing weights in their stomachs ranged up to 13.9 ppm and 26.0 ppm (wet weight basis), respectively. During the study, we also noted the presence of ingested or entangled fishing tackle, with no associated lead weights, in eight species. *Received 25 November 2002, accepted 11 March 2003.*

Key words.—Brown Pelican, Common Loon, Fishing weights, *Gavia immer*, ingestion, lead, *Pelecanus occidentalis*, stomach, waterbirds.

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Lead poisoning of swans (*Cygnus* spp.) from the ingestion of lead fishing weights has been reported in England, Ireland, and Scotland (Birkhead and Perrins 1985; O'Halloran *et al.* 1988; Spray and Milne 1988; Sears 1988). Lead split-shot have been found in up to 90% of Mute Swans (*Cygnus olor*) diagnosed with lead poisoning and efforts to reduce the problem resulted in a prohibition on the sale and importation of small (<28.4 g) lead fishing weights in England and Wales, effective in 1987 (Kirby *et al.* 1994). In Canada, lead sinker ingestion has been found most frequently in the Common Loon (*Gavia immer*), accounting for about 30% of adult mortality reported in areas of Ontario, Quebec, and the Maritime provinces where loon habitat and sport fishing overlap (Scheuhammer and Norris 1995). Canada prohibited the use of lead sinkers or jigs weighing less than 50 g in national parks and national wildlife areas in 1997 (Canadian Wildlife Service 1997).

In the United States, lead poisoning from ingested fishing weights has been reported in several species, including the Common Loon, Trumpeter Swan (*Cygnus buccinator*), Mute Swan, Tundra Swan (*Cygnus columbianus*), and Sandhill Crane (*Grus canadensis*) (Locke and Young 1973; Locke *et al.* 1982; Windingstad *et al.* 1984; Blus *et al.* 1989; USEPA 1994). Published reports indicate that, of all the species listed, the ingestion of lead fishing weights is a particular problem in the Common Loon. In New England, lead poisoning from the ingestion of fishing sink-

ers has been reported as a frequent cause of death in the Common Loon, accounting for about half of the mortality reported in breeding adults (Pokras and Chafel 1992; Sidor *et al.* 2003). Franson and Cliplef (1992) reviewed National Wildlife Health Center records of 222 Common Loon carcasses submitted for necropsy from throughout the U.S. from 1976-1991, and reported that lead fishing weights were found in eleven of 14 loons diagnosed with lead poisoning. Although reports of ingested lead fishing weights have been published for several other avian species in North America and Europe, including the Bald Eagle (*Haliaeetus leucocephalus*), Canada Goose (*Branta canadensis*), Common Merganser (*Mergus merganser*), Mallard (*Anas platyrhynchos*), Pochard (*Aythya ferina*), Greater Scaup (*Aythya marila*), and White-winged Scoter (*Melanitta fusca*), the frequencies of sinker ingestion in these species are often much lower than in swans and loons (Mudge 1983; Scheuhammer and Norris 1995; Anderson *et al.* 2000).

In 1994, the U.S. Environmental Protection Agency proposed a nationwide ban on the manufacture, importation, processing, and distribution of fishing sinkers containing lead or zinc and which are ≤25.4 mm in any dimension (USEPA 1994). Three states (Maine, New Hampshire, and New York) have passed legislation restricting the use of certain lead sinkers and jig heads statewide, and lead sinkers are prohibited at certain reservoirs used by loons in Massachusetts. Lead tackle is banned on some federal areas used by loons and swans, including Red Rock Lakes National Wildlife Refuge in Montana and Yellowstone National Park in Wyoming. Although the ingestion of lead weights has been identified as a problem in loons, swans, and cranes, additional information regarding the size range of ingested weights would be useful in light of the fact that enacted and proposed restrictions on sinkers and jig heads are often based on the longest dimension or mass. Furthermore, little has been published regarding the prevalence of sinker ingestion and resulting lead exposure in avian species other than loons and swans. Here, we report the results of a study of waterbirds from several areas of the U.S. for the presence of ingested lead fishing tackle, and lead concentrations in samples of blood and liver.

METHODS

During 1995-1999, a total of 2,240 individuals of 28 species (Table 1, Appendix 1) was examined from 25 states, although 47% of the samples were from Florida and California. Dead birds that were sampled included carcasses of a variety of species found by cooperators during disease mortality events, those that died at rehabilitation centers, and Sandhill Cranes and Tundra Swans shot by hunters. Stomachs were removed from carcasses, radiographed, and examined visually for the presence of fishing weights and other fishing tackle. Apparently healthy live birds were sampled in the field in conjunction with studies being conducted by cooperators, and sick or injured birds were examined and sampled at rehabilitation centers. Live birds were radiographed and objects observed on x-rays were evaluated on the basis of size, shape, and radiodensity to determine if they were consistent with fishing tackle. Blood samples and livers were collected from live birds and carcasses, respectively, and frozen at -20°C until analyzed for lead.

Blood samples were analyzed for lead by graphite furnace atomic absorption spectrophotometry (DeStefano *et al.* 1991). Liver samples were analyzed by flame atomic absorption, after microwave digestion as described by Franson and Smith (1999). Lower limits of detection were 0.25 parts per million (ppm; wet weight) for liver and 0.02 ppm (wet weight) for blood. Recoveries of lead from spiked samples were 99.5% (SD ± 4.4) for liver and 98.8% (SD ± 4.9) for blood. All lead residue results are expressed in ppm on wet weight basis.

Chi-square tests were used to compare frequency data for species with ingested lead fishing weights, or ingested and entangled tackle exclusive of lead, in two or more of the groups sampled (birds taken to rehabilitation centers, those that were apparently healthy, and those found dead in the field). Chi-square also was used to compare the frequency of ingested lead fishing weights between Common Loons sampled during the breeding season in New England versus those in other breeding areas in the U.S.

Data from NWHC files have been included in published reports of lead poisoning from ingested lead fishing weights in the Common Loon, Trumpeter Swan, and Sandhill Crane (Locke *et al.* 1982; Windingstad *et al.* 1984; Blus *et al.* 1989; Franson and Cliplef 1992). The NWHC necropsy files from 1975-2001 were reviewed for comparison to our findings in the current study, and for previously unpublished cases of lead exposure or poisoning resulting from the ingestion of lead fishing weights in species of the following orders: Anseriformes, Charadriiformes, Gruiformes, Pelecaniformes, Gaviiformes, Ciconiiformes, Coraciiformes, and Falconiformes.

RESULTS

Ingested lead fishing tackle was found in eleven Common Loons, ten Brown Pelicans (*Pelecanus occidentalis*), one Double-crested Cormorant (*Phalacrocorax auritus*), and one

Table 1. Waterbirds with ingested lead fishing weights, 1995-1999. Live birds, including those found sick or injured and taken to rehabilitation centers and apparently healthy birds captured in the field, were radiographed. Stomachs were removed from carcasses, radiographed, and examined visually.

Species	N	No. with ingested lead weights	Frequency (%)
Common Loon			
Rehabilitation centers	156	6	3.8
Apparently healthy	109	5	4.6
Found dead in field	48	0	0
Total	313	11	3.5
Brown Pelican			
Rehabilitation centers	308	10	3.2
Apparently healthy	4	0	0
Found dead in field	53	0	0
Total	365	10	2.7
Double-crested Cormorant			
Rehabilitation centers	68	0	0
Apparently healthy	8	0	0
Found dead in field	5	1	20
Total	81	1	1.2
Black-crowned Night Heron			
Rehabilitation centers	0	N/A[a]	N/A
Apparently healthy	1	0	0
Found dead in field	10	1	10
Total	11	1	9.1

[a]Not applicable.

Black-crowned Night Heron (*Nycticorax nycticorax*) (Table 1). Types of lead fishing tackle found included split shot, jig heads, and bell-shaped, egg-shaped, and pyramid-shaped sinkers (Table 2). The size of lead tackle ranged from split shot that was 7 mm in the longest dimension to pyramid and bell-shaped sinkers that were 39 mm long, and the mass of lead weights ranged from 0.6 g to 78.2 g (Table 2). Birds with ingested sinkers were found in California, Florida, Maine, New Hampshire, North Carolina, and Wisconsin (Table 2). Of waterbirds with ingested lead sinkers and for which tissue samples were analyzed for lead, 64% and 71%, respectively, had lead concentrations of ≥2.0 ppm wet weight in their livers or ≥0.2 ppm wet weight in blood. Maximum lead concentrations in liver and blood were 26.0 ppm and 13.9 ppm wet weight, respectively (Table 2). In birds without ingested lead in our study, liver lead concentrations were ≥2.0 ppm in 0.7% of those tested (N = 866) and blood lead concentrations were ≥0.2 ppm in 2.2% (N = 742).

The NWHC necropsy files contained records of lead exposure or poisoning from ingested lead fishing weights in five species of waterbirds that were not included in previously published NWHC reports (Table 3). Lead concentrations in liver ranged from 1.67 ppm to 104 ppm wet weight (Table 3).

Presence of fishing tackle, excluding lead sinkers, was found in 235 individuals of eight species (Table 4). These birds commonly had fishing line entangled around their bodies, had fishing hooks embedded in their skin or upper alimentary tract, or had ingested some type of fishing material other than sinkers. For birds with sample sizes of over 50, exposure to these materials occurred most frequently in the Brown Pelican (48%), Double-crested Cormorant (15%), and Common Loon (11%). The frequency of such tackle was greater in Brown Pelicans and Common Loons taken to rehabilitation centers than in those found dead in the field (Table 4).

DISCUSSION

In Common Loons, the overall lead tackle ingestion rate was 3.5%, the same frequency found in historic records of 340 Common

Table 2. Characteristics of ingested lead fishing weights and tissue lead concentrations in four species of waterbirds, 1995-1999.

Species County, state[a] (date)	Type of weight	Size (mm)	Mass (g)	Lead (ppm wet wt) Liver	Blood
Common Loon					
San Diego, CA (11/22/97)	unknown[b]	5 × 8	1.1	14.7	
Broward, FL (01/30/98)	split shot	6 × 8	1.8		
	split shot	7 × 7	1.8	16.9	
Aroostook, ME (08/16/98)	split shot	8 × 9	2.9	8.03	
Somerset, ME (07/23/97)	jig head[c]				0.30
Carteret, NC (01/02/98)	jig head	8 × 25	4.2	16.6	4.24[d]
Carteret, NC (12/05/97)	unknown[b]	5 × 8	0.6	12.8	6.02[d]
Carteret, NC (04/20/98)	pyramid sinker	22 × 39	78.2	16.9	
Carrol, NH (07/22/98)	jig head[c]				ND[e]
Carrol, NH (08/10/99)	jig head[c]				0.40
Oneida, WI (06/19/96)	split shot[c]				0.97
Oneida, WI (07/23/96)	split shot[c]				0.28
Brown Pelican					
Broward, FL (01/17/98)	egg sinker	13 × 16	16.2		0.35
Broward, FL (01/14/98)	jig head	10 × 27	6.4		1.14
Broward, FL (01/25/98)	bell sinker	10 × 32	12.8		1.32
	split shot	7 × 7	1.5		
	split shot	6 × 7	1.5		
Broward, FL (02/18/98)	bell sinker	7 × 11	3.3		0.14
Broward, FL (02/05/98)	egg sinker	14 × 16	15.0	0.82	
Broward, FL (02/17/98)	egg sinker	9 × 13	5.6		13.9
Broward, FL (04/02/98)	egg sinker[c]				0.04
Dade, FL (01/17/97)	egg sinker	19 × 25	48.1		0.06
Dade, FL (02/02/98)	egg sinker	13 × 17	14.9	1.45	
Palm Beach, FL (04/18/97)	jig head	11 × 28	6.2	ND	
Double-crested Cormorant					
Broward, FL (02/26/98)	bell sinker	12 × 39	21.1	ND	
Black-crowned Night Heron					
San Diego, CA (08/29/97)	jig head	14 × 32	15.1	26.0	

[a]CA = California, FL = Florida, ME = Maine, NC = North Carolina, NH = New Hampshire, WI = Wisconsin.
[b]Extensive wear and erosion prevented identification of type.
[c]Based on radiograph; the lead weight was not recovered.
[d]Birds from which a blood sample was collected and which subsequently died and a liver sample was collected.
[e]Not detected (<0.25 ppm wet weight for liver, <0.02 ppm wet weight for blood).

Loon carcasses necropsied at the National Wildlife Health Center during 1975-2001 (NWHC files). Previous reports from New England indicate that lead poisoning from ingested lead fishing sinkers accounts for about half of the mortality in Common Loon adults during the breeding season (Pokras and Chafel 1992; Sidor *et al.* 2003). In our study, ingested lead sinkers were found in four of 53 (7.5%) Common Loons during the breeding season in New England and two of 59 (3.4%) Common Loons in breeding areas elsewhere in the U.S., but the difference between these frequencies was not statistically significant. The fact that we found a lower frequency of ingested sinkers in Common Loons in New England than the previous two studies may have been because all but two of the loons we sampled in New England were live birds. On the other hand, Pokras and Chafel (1992) and Sidor *et al.* (2003) reported on dead and moribund loons submitted for necropsy. In an area where lead poisoning is an apparent problem and where active carcass searches are being carried out, it could be expected to find a higher frequency of ingested lead tackle in a sample of dead loons than the live, and ap-

Table 3. Records of ingested lead fishing weights from National Wildlife Health Center (NWHC) files, 1975-2001, from species not included in previously published NWHC reports.

Species County, state[a] (date)	Type of weight	Size (mm)	Mass (g)	Liver lead
Brown pelican				
Nueces, TX (01/01/95)	LS[b]	ND[c]	31	1.67[d]
Canada Goose				
Alexander, IL (02/05/79)	LS	4 × 12	ND	33.6[e]
Union, IL (12/18/78)	LS	3 × 10	ND	5.45[d]
Canvasback				
LaSalle, LA (1977)	Split shot	7 × 8	ND	107[e]
Great Blue Heron				
Skamania, WA (1978)	LS	15 × 20	ND	0.94[d]
	LS	8 × 11	ND	
Redhead				
Yates, NY (03/02/94)	Bell sinker	4 × 6	0.34	104[d]

[a]TX = Texas, IL = Illinois, LA = Louisiana, WA = Washington, NY = New York.
[b]Described only as lead sinker.
[c]Not determined.
[d]ppm wet weight.
[e]ppm dry weight.

parently healthy, loons that we sampled in New England. In addition, their sample of over 500 loons encompassed a broader area of New England than our sample of 53 from Maine and New Hampshire, and may thus reflect geographical differences in lead sinker availability or ingestion. Only one of the 48 Common Loons found dead in the field (Table 1) was from New England.

Unlike our findings in Common Loons, where ingested lead tackle was found both in birds sampled at rehabilitation centers and those in the wild, all of the Brown Pelicans with ingested lead tackle were from rehabilitation centers. Ingested lead sinkers were found in 2.7% of the Brown Pelicans, compared with a frequency of 0.4% in 279 Brown Pelican carcasses necropsied at NWHC that were picked up in the field during acute mortality events. Because ingested or entangled fishing tackle, exclusive of lead materials, was found with greater frequency in the Brown Pelicans and Common Loons taken to rehabilitation centers than in those found dead in the field, the prevalence of this type tackle exposure may be overestimated when data from rehabilitation centers are used.

We found no records of ingested lead sinkers in the Double-crested Cormorant or Black-crowned Night Heron in NWHC files and we are unaware of any published records for these two species. The fact that we found no ingested sinkers in the 334 swans examined differs from the findings of Blus *et al.* (1989), who reported ingested sinkers in four of 72 Trumpeter Swans found dead from 1976 to 1987 in Idaho, Nevada, and Washington.

Although similar threshold criteria have not been developed for the four species of waterbirds in which we found ingested lead sinkers, the concentrations of lead in blood and liver that are commonly used as indicators lead exposure in waterfowl and many other species of birds are 0.2 ppm and 2 ppm on wet weight basis, respectively (Franson 1996; Pain 1996; Eisler 2000). For the birds that were found with ingested sinkers, blood lead concentrations exceeded 0.2 ppm wet weight in ten of 14 and liver lead concentrations exceeded 2 ppm in seven of eleven (Table 2). Lead enters the environment from a variety of sources, including mining waste, smelter and vehicle emissions, and from lead-containing materials deposited in landfills but, in general, lead does not bioacummulate in the food chain (Eisler 2000). Lead poisoning has occurred in waterfowl ingesting contaminated

Table 4. Birds with ingested, embedded, or entangled fishing tackle with no associated lead fishing weights. Live birds, including those found sick or injured and taken to rehabilitation centers and apparently healthy birds captured in the field, were examined visually for external embedded and entangled tackle and radiographed. Carcasses were given an external visual examination and radiographed, after which stomachs were removed and examined visually.

Species	N	No. (%) with non-lead tackle
Brown Pelican		
Rehabilitation centers	308	170 (55)[a]
Apparently healthy, sampled in field	4	0
Found dead in field	53	4 (7.5)
Total	365	174 (48)
Common Loon		
Rehabilitation centers	156	25 (16)[a]
Apparently healthy, sampled in field	109	9 (8.3)
Found dead in field	48	1 (2.1)
Total	313	35 (11)
Brandt's Cormorant		
Rehabilitation centers	20	1 (5.0)
Apparently healthy, sampled in field	49	5 (10)
Found dead in field	14	0
Total	83	6 (7.2)
Double-crested Cormorant		
Rehabilitation centers	68	12 (18)
Apparently healthy, sampled in field	8	0
Found dead in field	5	0
Total	81	12 (15)
Great Blue Heron		
Rehabilitation centers	33	2 (6.1)
Apparently healthy, sampled in field	30	1 (3.3)
Found dead in field	8	0
Total	71	3 (4.2)
Pacific Loon		
Rehabilitation centers	11	3 (27)
Apparently healthy, sampled in field	0	N/A[b]
Found dead in field	0	N/A
Total	11	3 (27)
Black-crowned Night Heron		
Rehabilitation centers	0	N/A
Apparently healthy, sampled in field	1	0
Found dead in field	10	1 (10)
Total	11	1 (9.1)
Bald Eagle		
Rehabilitation centers	2	0
Apparently healthy, sampled in field	0	N/A
Found dead in field	3	1 (33)
Total	5	1 (20)

[a]Significantly different than frequency for birds found dead in the field (Brown Pelican: $\chi^2_1 = 41.1$, $P < 0.001$; Common Loon: $\chi^2_1 = 6.4$, $P < 0.02$).
[b]Not applicable.

sediment, and lead is known to accumulate in tissues of the feral Pigeon (*Columba livia*) in urban areas with high traffic densities (Hutton and Goodman 1980; Sileo *et al.* 2001). However, the ingestion of metallic lead is a well-known cause of high tissue concentrations and lead poisoning in birds, and we attribute the elevated tissue lead levels (up to 13.9 ppm wet weight in blood and 26.0 ppm wet weight in liver) in the waterbirds listed in Table 2 to the presence of the ingested lead weights (Eisler 2000). Birds with ingested lead

sinkers, but with low blood or liver lead concentrations, may have ingested the sinkers shortly before the samples were collected and before significant amounts of lead had been absorbed from the stomach. Species such as the Common Loon and Brown Pelican may also accumulate lead in their tissues at a slower rate than waterfowl, which have gizzards with greater grinding action.

Regional differences may exist in the frequency of lead sinker ingestion by waterbirds and, because lead poisoning is a chronic disease and affected birds can be expected to seek cover and die where they may not be found, surveys of lead tackle ingestion may underestimate the true rate of lead exposure from these materials. Of the waterbirds that we sampled, ingested lead fishing weights occurred most frequently in the Common Loon and Brown Pelican, but also in one Double-crested Cormorant and a Black-crowned Night Heron. In each of these species, we found one or more ingested lead weights for which the longest dimension was over 25.4 mm. Thus, the proposal to ban the use of lead fishing weights of one inch (25.4 mm) or less in any dimension (USEPA 1994) would not be expected to eliminate all cases of lead poisoning in waterbirds resulting from the ingestion of lead fishing weights.

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Appendix 1. Waterbirds examined (N = 1,470), but in which no ingested lead fishing weights were found, 1995-1999.[a]

Species	Number examined[b]
Sandhill Crane (*Grus canadensis*)	491
Tundra Swan (*Cygnus columbianus*)	190
Western Gull (*Larus occidentalis*)	136
American White Pelican (*Pelecanus erythrorhynchos*)	118
Trumpeter Swan (*Cygnus buccinator*)	113
California Gull (*Larus californicus*)	84
Brandt's Cormorant (*Phalacrocorax penicillatus*)	83
Ring-billed Gull (*Larus delawarensis*)	71
Great Blue Heron (*Ardea herodias*)	71
Mute Swan (*Cygnus olor*)	31
Herring Gull (*Larus argentatus*)	14
Great Egret (*Ardea alba*)	13
Pacific Loon (*Gavia pacifica*)	11
Laughing Gull (*Larus atricilla*)	10

[a]Ingested shotgun pellets, including lead and nontoxic shot, were found in six Sandhill Cranes, 28 Tundra Swans, 27 Trumpeter Swans, 15 Mute Swans, and one Bald Eagle.

[b]Samples from each of the following species totaled less than 10 (combined total = 34): Snowy Egret (*Egretta thula*), Neotropic Cormorant (*Phalacrocorax brasilianus*), Bald Eagle (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), White-faced Ibis (*Plegadis chihi*), Red-throated Loon (*Gavia stellata*), Glossy Ibis (*Plegadis falcinellus*), Northern Gannet (*Morus bassanus*), White Ibis (*Eudocimus albus*), Wood Stork (*Mycteria americana*).