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[Management Brief]

Estimates of Tackle Loss for Five Minnesota Walleye Fisheries

Paul Radomski,* Tom Heinrich, Thomas S. Jones, Pat Rivers, and Phil Talmage
Minnesota Department of Natural Resources, 500 LaFayette Road, St. Paul, Minnesota 55155, USA

Abstract.—Lead poisoning in waterbirds from ingestion of lead fishing items may be a growing problem. There are few studies that quantify tackle loss for recreational fisheries. Tackle loss from large recreational lake fisheries in Minnesota is unknown. The objectives of this study were to determine tackle loss for five large lake fisheries targeting walleye *Sander vitreus* in Minnesota by means of creel surveys and to estimate recent cumulative losses. Mean rates of tackle loss were low: 0.0127/h for lures, 0.0081/h for large sinkers, 0.0057/h for small sinkers, 0.0247/h for jigs, and 0.0257/h for hooks. Many anglers lost no fishing tackle on a fishing trip. The estimated total loss of tackle for the five water bodies in the summer of 2004 was 214,811 items. Over 100,000 lead-based items were estimated to have been lost, representing about 1 metric ton of lead. Assuming 2004 lead tackle loss rates, estimates of cumulative lead item loss for Lake of the Woods and Mille Lacs and Rainy lakes from 1983 to 2004 were 285,000 (SE = 8,800), 1,033,000 (SE = 39,700), and 211,000 (SE = 8,400) items, respectively. In critical wildlife areas with high angling effort or high tackle loss rates, determining the impacts of lead tackle on wildlife would be prudent, and prohibiting the use of lead tackle may be necessary.

There is now greater awareness of the direct and indirect effects of fishing on fish and wildlife and their habitat. Recent studies on the physical disturbances from commercial fish trawlers and trappers on benthic habitat have found substantial reductions in habitat complexity (Auster and Langton 1999). Recreational anglers also diminish natural resources through the loss and inappropriate disposal of fishing tackle or gear. Wildlife have been injured or killed as the result of entanglement or ingestion of fishing tackle. Entanglement with fishing line is known to have killed brown pelicans *Pelicanus occidentalis*, mute swans *Cygnus olor*, and bald eagles *Haliaeetus leucocephalus* (Zimmerman 1976; Birkhead 1982; Schreiber and Mock 1988). In Minnesota, entanglement accounted for 19% and lead poisoning from lead sinker ingestion for 17% of adult mortalities of common loons *Gavia immer* (Ensor et al. 1992). Higher rates of mortality for common loons as a result of lead poisoning have been found elsewhere (Pokras et al. 1993; Scheuhammer and Norris 1995; Daoust et al. 1998).

Lead poisoning from ingestion of lead fishing items may be a growing problem. Common loons, mute swans, and trumpeter swans *Cygnus buccinator* appear to be susceptible to lead poisoning (Blus et al. 1989; Environmental Protection Agency 1994). Lead poisoning from lead sinker ingestion was first reported in the United Kingdom for mute swans (Simpson et al. 1979). These findings resulted in a ban on lead sinkers in England and Wales in 1987 (Kirby et al. 1994). The incidence of lead poisoning cases in mute swans then fell and the population increased, yet blood lead levels in mute swans remain high, probably from long-lost lead fishing sinkers and weights (Perrins et al. 2003). In North America, Locke et al. (1982) was among the earliest to report lead poisoning in common loons from fishing sinkers. Perry (1994) compiled over 300 incidences of sinker ingestion in over 20 wildlife species. In Canada, Scheuhammer and Norris (1995) found 46 incidences of lead poisoning from lead sinker ingestion in 8 bird species and later revised those numbers and noted 381 incidences of ingested lead fishing sinkers in North America in 28 wildlife species (Scheuhammer et al. 2003). Pokras et al. (1993) state that ingestion of a single lead sinker or lead-headed jig is a lethal dose for a loon. Franson et al. (2003) examined loons that died in rehabilitation centers or were found dead in the wild and noted that ingested lead sinkers were found in 11 of 313 birds (3.5%).

There are few studies that quantify tackle loss for recreational fisheries. We are aware of only one unpublished study in North America on estimates of tackle loss and abundance of lead sinkers in sediment. Duerr (1999) interviewed 859 anglers from 14 sites in the United States and found that anglers, on average, lost 0.18 sinkers per hour, 0.14 pieces of fishing line per hour, and 0.23 hooks and lures per hour. Tackle loss in large recreational lake fisheries in Minnesota is unknown. The objective of this study was to determine tackle loss for five large lake fisheries that target walleye *Sander vitreus* in Minnesota and to estimate recent cumulative losses. These lakes are also important waterbird lakes; therefore, estimated lead densities

* Corresponding author: paul.radomski@dnr.state.mn.us

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in lake sediments may be useful information for wildlife managers.

Methods

Creel surveys were conducted on Rainy Lake, Namakan Reservoir, Leech Lake, Mille Lacs Lake, and Lake of the Woods (Figure 1). Rainy Lake and Namakan Reservoir are located on the border of Minnesota and Ontario, Canada. These waters are infertile with little aquatic vegetation, and much of the shoreline is rocky and irregular. Walleye is the primary species of interest for anglers, although northern pike *Esox lucius*, sauger *S. canadensis*, smallmouth bass *Micropterus dolomieu*, and black crappie *Pomoxis nigromaculatus* are also sought and harvested. Leech Lake is in north-central Minnesota. Although the maximum depth is 48 m, about 80% of the lake is less than 11 m deep. Most anglers seek walleye, yellow perch *Perca flavescens*, northern pike, or muskellunge *E. masquinongy*. Mille Lacs Lake is the second largest lake entirely within Minnesota. The saucer-shaped basin of Mille Lacs Lake has a maximum depth of 13 m and averages 9 m. Offshore habitats include sand and mud flats, rock reefs, and a few small, exposed islands. Rocky areas, where tackle may be more likely to be lost, comprise less than 10% of the total lake surface area. The fish community is primarily composed of walleye, yellow perch, northern pike, and muskellunge, and these are also the principal species targeted by anglers (in decreasing order of effort). Lake of the Woods' surface area is 384,997 ha, of which 128,287 ha are managed by the State of Minnesota, including Muskeg, Big Traverse, and Little Traverse bays. Big Traverse and Muskeg bays are largely devoid of structure and islands, while Little Traverse Bay is more characteristic of the Ontario water of Lake of the Woods, along with numerous islands and reefs. Average depth of Big Traverse Bay is 7 m. The summer fishery is dominated by anglers seeking walleye (>80% of the anglers).

Nonuniform-probability creel survey designs were used, where each creel survey began on May 15, 2004, the opening of the fishing season, and extended to September or October (Table 1). Creel strata included time periods (usually half-month periods). Each time strata was also split into weekdays and the weekend or holidays. Sampling days were split into two nonoverlapping time periods such that the bulk of the fishing day was sampled. Angling effort was determined from aerial boat counts (Rainy Lake, Namakan Reservoir, Leech Lake) or number of boats landing within a designated stretch of shoreline (Mille Lacs Lake and Lake of the Woods). Most angling on these fisheries in the summer was from a boat.

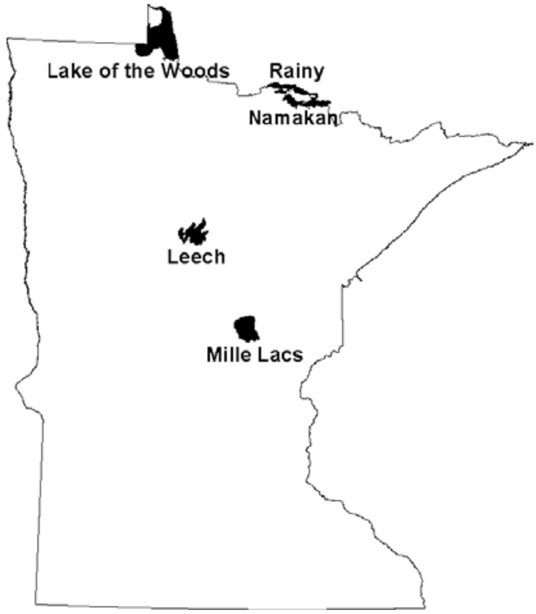

FIGURE 1.—Location of five lakes in Minnesota where estimates of tackle loss were determined during walleye recreational fisheries, summer 2004.

Completed-trip interviews were obtained by interviewing anglers returning to shore. In addition to the standard questions posed to anglers, creel clerks asked anglers whether they lost any fishing tackle. If anglers lost tackle, the creel clerk followed up with questions to determine what and how much tackle they lost that day. Anglers were asked how many lures, jigs, hooks, split shot sinkers (all sinkers less than 11 g), or large sinkers were lost. Lead tackle items included lead-headed jigs, split shot sinkers, and large sinkers. Estimates of angler effort and tackle loss were calculated following the methods described by Bindman and Mach (1997), which incorporate standard creel survey calculation procedures (Pollack et al. 1994). Tackle loss calculations followed the same procedures as estimates of fish harvest. For lead items, the estimated loss in weight was calculated by multiplying the estimate of loss by the prevailing weight of the item used for the given fishery.

For Lake of the Woods, Mille Lacs, and Rainy lakes, the cumulative loss of lead tackle items from 1983 to 2004 was estimated from summer estimates of angler effort from past creel surveys multiplied by the 2004 estimate of lead item loss per angler effort for the lake (Table 2). The 1983–2004 time period was selected because annual summer creel surveys were conducted on these lakes during this time period. Namakan Reservoir and Leech Lake did not have annual

TABLE 1.—Measures and creel survey statistics for five Minnesota lakes for which estimates of tackle loss were determined during walleye recreational fisheries, summer 2004. Standard errors are in parentheses.

Measure or statistic	Lake of the Woods	Leech	Mille Lacs	Namakan	Rainy
Lake size (ha)	128,287	45,134	53,626	18,976	21,910
Sample period	May 15–Sep 30, 2004	May 15–Sep 30, 2004	May 15–Oct 31, 2004	May 15–Sep 26, 2004	May 15–Sep 26, 2004
Interviews for tackle loss	2,092	2,049	1,735	356	257
Total interviews	2,092	2,049	1,783	1,276	868
Angler counts	1,152	94	2,637	51	51
Fishing effort (h)	811,341 (69,422)	696,153 (45,033)	978,000 (36,000)	495,715 (34,333)	236,944 (8,815)
Fishing effort (h/ha)	6.32 (0.54)	15.42 (1.00)	18.24 (0.67)	26.12 (1.81)	10.81 (0.40)
Trips	151,144 (10,690)	188,150 (NA)	222,000 (8,000)	113,732 (8,111)	50,845 (2,325)
Mean party size	2.73 (0.03)	2.52 (0.12)	2.54 (0.05)	2.60 (0.06)	2.49 (0.05)
Mean trip length (h)	5.0 (0.06)	3.7 (0.26)	4.4 (0.2)	4.30 (0.07)	4.66 (0.07)

estimates of angler effort, so cumulative estimates of loss could not be estimated. Estimated summer total lead item loss for each lake (J) was calculated as the product of angling effort for the lake (E) and the 2004 lead item loss per hour for the lake (R). The SE was estimated as the SE of a product (Goodman 1960) as follows:

$$\mathrm{SE}(J) = [E^2 \cdot \mathrm{SE}(R)^2 + R^2 \cdot \mathrm{SE}(E)^2 - \mathrm{SE}(R)^2 \cdot \mathrm{SE}(E)^2]^{1/2}.$$

In years when the angling effort SE was not reported, the SE was assumed to be similar to reported SEs by multiplying summer angling effort by the lake-specific average coefficient of variation (7% for Lake of the Woods and Mille Lacs Lake and 5% for Rainy Lake). The accumulated estimate of summer lead tackle item loss was the sum of estimated summer losses, and the SE was estimated as the SE of a sum (Pollack et al. 1994).

Results and Discussion

Of the 8,068 angler interviews from the five creel surveys conducted in 2004, 6,489 angling parties were interviewed for tackle loss (Table 1). Rates of tackle loss were low; mean loss rates were 0.0127/h for lures, 0.0081/h for large sinkers, 0.0057/h for split shot sinkers, 0.0247/h for jigs, and 0.0257/h for hooks (Table 3). Many anglers lost no fishing tackle on a fishing trip (Table 4). On average for the five fisheries, 93% of the angler parties interviewed lost no lures, 94% lost no large sinkers, 97% lost no split shot sinkers, 88% lost no jigs, and 87% lost no hooks.

TABLE 2.—Estimates of summer fishing effort (h) for Lake of the Woods, Mille Lacs Lake, and Rainy Lake from 1983 to 2004.

	Lake of the Woods		Mille Lacs Lake		Rainy Lake	
Year	Angler effort	SE	Angler effort	SE	Angler effort	SE
1983	421,974		945,080		117,786	
1984	504,477		1,104,993		115,982	
1985	846,989		949,479	105,353	153,618	
1986	796,705		1,259,828	140,311	112,073	
1987	721,944		1,524,464	88,554	165,297	
1988	564,789		1,987,526	108,879	84,662	
1989	628,230		1,673,018	86,448	137,655	
1990	986,044		1,667,618	109,092	158,069	
1991	904,081		1,650,544	114,415	132,014[a]	
1992	660,436	33,210	2,314,115	124,591	120,834	7,263
1993	787,416		1,942,424	148,308	111,498	7,243
1994	757,847		1,326,534	79,839	137,449	8,336
1995	662,934	45,770	1,430,657	76,378	167,964	9,132
1996	657,534	36,055	1,903,488	145,345	171,038	9,057
1997	846,370	81,849	1,337,429	80,907	185,943	7,981
1998	789,385	42,682	1,278,635	90,383	243,838	12,040
1999	638,634	49,240	1,531,181	68,020	271,578	14,115
2000	916,541	89,512	1,284,719	54,361	275,268	13,105
2001	745,983	49,728	1,543,737	165,050	246,504	13,926
2002	675,129	50,793	1,697,442	180,720	225,662	12,912
2003	809,994	53,829	1,149,577	41,774	270,513	9,662
2004	811,341	69,422	977,789	37,594	236,944	8,815

[a]No estimate was made. This value is an average of the four surrounding years.

TABLE 3.—Tackle loss statistics for five lakes in Minnesota for the summer of 2004. Standard errors are in parentheses.

Statistic	Lake of the Woods		Leech		Mille Lacs		Namakan		Rainy	
Loss per angler hour (*N*/h)										
Lures	0.0023	(0.0005)	0.0097	(0.0013)	0.0038	(0.0006)	0.0307	(0.0061)	0.0168	(0.0055)
Large sinkers	0.0122	(0.0018)	0.0066	(0.0013)	0.0144	(0.0018)	0.0049	(0.0017)	0.0021	(0.0011)
Split shot sinkers	0.0001	(0.0001)	0.0033	(0.0003)	0.0024	(0.0012)	0.0097	(0.0030)	0.0130	(0.0045)
Jigs	0.0054	(0.0012)	0.0240	(0.0031)	0.0149	(0.0046)	0.0393	(0.0070)	0.0397	(0.0081)
Hooks	0.0276	(0.0043)	0.0121	(0.0013)	0.0231	(0.0027)	0.0219	(0.0050)	0.0438	(0.0099)
Total Loss (*N*)										
Lures	1,844	(399)	6,776	(799)	3,700	(570)	14,905	(1,814)	3,965	(1,365)
Large sinkers	9,922	(1,187)	4,570	(855)	14,100	(1,700)	2,278	(814)	499	(261)
Split shot sinkers	59	(42)	2,284	(485)	2,390	(1,170)	4,849	(1,532)	3,476	(1,242)
Jigs	4,362	(905)	16,717	(2,099)	14,600	(4,500)	18,638	(3,688)	9,387	(1,875)
Hooks	22,428	(2,934)	8,412	(1,009)	22,600	(2,500)	10,498	(2,498)	11,552	(2,794)
Total Loss (kg)										
Large sinkers	281	(34)	52	(10)	160	(19)	26	(9)	6	(3)
Split shot sinkers	0.3	(0.2)	26	(6)	14	(7)	27	(8)	20	(7)
Jigs	31	(6)	99	(13)	83	(25)	106	(21)	53	(11)
Loss per ha (*N*/ha)										
Lures	0.014	(0.003)	0.150	(0.018)	0.069	(0.011)	0.785	(0.096)	0.181	(0.062)
Large sinkers	0.077	(0.009)	0.101	(0.019)	0.263	(0.032)	0.120	(0.043)	0.023	(0.012)
Split shot sinkers	0.000	(0.000)	0.051	(0.011)	0.045	(0.022)	0.256	(0.081)	0.159	(0.057)
Jigs	0.034	(0.007)	0.370	(0.047)	0.272	(0.084)	0.982	(0.194)	0.428	(0.086)
Hooks	0.175	(0.023)	0.186	(0.022)	0.421	(0.047)	0.553	(0.132)	0.527	(0.128)

Tackle loss rates reported by Duerr (1999) were considerably higher than those found in this study. For 14 sites across the United States, Duerr (1999) reported average loss rates of 0.18/h for sinkers, 0.23/h for hooks or lures, and 0.04/h for other tackle items. It appears that Duerr (1999) interviewed mostly anglers fishing from shore, and it is conceivable that shore anglers have greater opportunity for tackle loss because of the presence of rocks, trees, and aquatic vegetation along the shore and, in many cases, the inability to move close to the snagged location. We interviewed primarily boat anglers (>98% of the interviews), and it is hypothesized that angling from a boat on a lake (primarily for walleye) may reduce the likelihood of tackle loss.

The estimated total loss of tackle for the summer of 2004 for the five water bodies was 214,811 items (Table 3). Hooks accounted for 35% of the loss with a total of 75,490 estimated lost, and jigs accounted for 30% of the items lost with an estimated total of 63,704 lost. Large sinker losses were highest for Mille Lacs Lake and Lake of the Woods, and split shot sinker losses were highest for Namakan Reservoir and Rainy Lake. Over 100,000 lead-based items were estimated to have been lost, representing about 1 metric ton of lead. Total jig loss was highest in the Namakan Reservoir at 18,638 (SE = 3,688) jigs, which had the second highest jig loss rate. Rainy Lake and Namakan Reservoir have rocky shorelines and had the highest jig loss rate.

Assuming 2004 lead tackle loss rates, estimates of cumulative lead item losses in Lake of the Woods and Mille Lacs and Rainy lakes from 1983 to 2004 were 285,000 (SE = 8,800), 1,033,000 (SE = 39,700), and 211,000 (SE = 8,400) items, respectively, representing over 16 metric tons of lead (Figure 2). Given the size of these lakes, the average density of recently lost lead tackle items on the lake bottom would be low (<0.002/m^2). However, the occurrence of lead tackle in sediments is likely to be clustered or aggregated, given that anglers often concentrate near shores and inlets or above reefs and shoals. Assuming that lead tackle losses only occurred in rocky areas of Mille Lacs Lake, the density of recently lost lead items on these lake bottoms would be approximately 10 times higher. In

TABLE 4.—Distribution of tackle items (number and percent) lost per interviewed angler party per trip during the summer of 2004 for five Minnesota lakes.

		Number of tackle items lost										
Item	Lake	0	1	2	3	4	5	6	7	8	9	≥10
Lure	Lake of the Woods	2,032 97.1%	46 2.0%	10 0.5%	2 0.1%	0 0.0%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Leech	1,901 92.8%	119 5.8%	19 0.9%	7 0.3%	1 0.1%	1 0.1%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Mille Lacs	1,670 96.3%	55 3.2%	5 0.3%	4 0.2%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	0 0.0%
	Namakan	306 86.0%	22 6.2%	15 4.2%	5 1.4%	5 1.4%	0 0.0%	1 0.3%	1 0.3%	0 0.0%	0 0.0%	1 0.3%
	Rainy	234 91.1%	13 5.1%	7 2.7%	1 0.4%	0 0.0%	0 0.0%	1 0.4%	0 0.0%	0 0.0%	0 0.0%	1 0.4%
Large sinker	Lake of the Woods	1,873 89.5%	113 5.4%	44 2.1%	46 2.2%	4 0.2%	0 0.0%	8 0.4%	0 0.0%	0 0.0%	2 0.1%	2 0.1%
	Leech	1,911 93.3%	42 2.1%	16 0.8%	5 0.2%	3 0.2%	1 0.1%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	70 3.4%
	Mille Lacs	1,582 91.2%	99 5.7%	34 2.0%	5 0.3%	7 0.4%	3 0.2%	3 0.2%	0 0.0%	0 0.0%	0 0.0%	2 0.1%
	Namakan	346 97.2%	2 0.6%	6 1.7%	2 0.6%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Rainy	253 98.4%	1 0.4%	2 0.8%	1 0.4%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Split shot sinker	Lake of the Woods	2,090 99.9%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Leech	1,969 96.1%	27 1.3%	8 0.4%	2 0.1%	1 0.1%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	40 2.0%
	Mille Lacs	1,722 99.3%	6 0.3%	2 0.1%	3 0.2%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	1 0.1%
	Namakan	340 95.5%	6 1.7%	7 2.0%	0 0.0%	1 0.3%	0 0.0%	1 0.3%	0 0.0%	0 0.0%	0 0.0%	1 0.3%
	Rainy	242 94.2%	5 1.9%	5 1.9%	1 0.4%	2 0.8%	0 0.0%	2 0.8%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Jig	Lake of the Woods	2,003 95.7%	46 2.2%	21 1.0%	6 0.3%	8 0.4%	0 0.0%	6 0.3%	0 0.0%	0 0.0%	0 0.0%	2 0.1%
	Leech	1,846 90.1%	103 5.0%	58 2.8%	11 0.5%	13 0.6%	2 0.1%	5 0.2%	2 0.1%	0 0.0%	0 0.0%	9 0.4%
	Mille Lacs	1,648 95.0%	49 2.8%	22 1.3%	8 0.5%	3 0.2%	3 0.2%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Namakan	292 82.0%	28 7.9%	20 5.6%	5 1.4%	3 0.8%	3 0.8%	3 0.8%	0 0.0%	1 0.3%	0 0.0%	1 0.3%
	Rainy	204 79.4%	19 7.4%	20 7.8%	3 1.2%	6 2.3%	3 1.2%	1 0.4%	0 0.0%	0 0.0%	0 0.0%	1 0.4%
Hook	Lake of the Woods	1,823 87.1%	100 4.8%	65 3.1%	40 1.9%	29 1.4%	8 0.4%	8 0.4%	0 0.0%	4 0.2%	0 0.0%	15 0.7%
	Leech	1,906 93.0%	96 4.7%	24 1.2%	9 0.4%	8 0.4%	5 0.2%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
	Mille Lacs	1,496 86.2%	152 8.8%	56 3.2%	13 0.7%	4 0.2%	4 0.2%	7 0.4%	0 0.0%	0 0.0%	0 0.0%	3 0.2%
	Namakan	316 88.8%	18 5.1%	12 3.4%	4 1.1%	3 0.8%	0 0.0%	2 0.6%	0 0.0%	0 0.0%	0 0.0%	1 0.3%
	Rainy	202 78.6%	26 10.1%	10 3.9%	9 3.5%	4 1.6%	2 0.8%	3 1.2%	0 0.0%	0 0.0%	0 0.0%	1 0.4%

addition, lead tackle lost before 1983 would also be present. Using metal detectors and a logistic detection model (Duerr and DeStefano 1999), Duerr (1999) found lower densities of tackle in offshore lake sediments and higher densities in lake sediments along the shore. Higher tackle densities in sediments have been reported elsewhere; for example, lead tackle densities in river sediment in the United Kingdom ranged from 0.9 to 6.2 items/m^2 (Sears 1988).

Lead tackle in the environment poses environmental

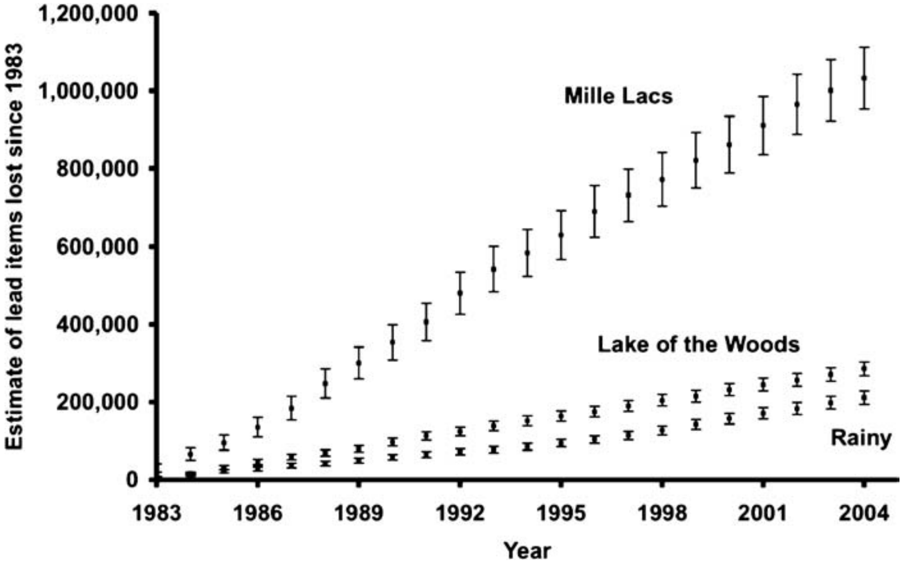

FIGURE 2.—Estimates of cumulative lead tackle lost in Lake of the Woods, Mille Lacs, and Rainy lakes from 1983 to 2004 assuming lake-specific 2004 lead item loss rates. Error bars represent approximately two times the SE.

concerns and risks. Even with low loss rates, the cumulative impact over many years of use will increase the risk of lead ingestion for waterbirds. Of the five lakes in this study, dead loons from lead tackle ingestion have been found on Leech and Mille Lacs lakes (Ensor et al. 1992). The risks of lead toxicosis for fish that ingest lead are unknown. Scheuhammer et al. (2003) estimated that lost or discarded fishing sinkers and jigs annually introduce about 500 metric tons of lead into the Canadian environment, which represented up to 14% of all lead releases. Recently, the Minnesota Department of Natural Resources, in cooperation with fishing tackle retailers, has begun educating anglers about the concerns of lead tackle and the availability of alternative materials for sinkers and jigs (e.g., tin, steel, tungsten, ceramic, clay, and bismuth). Lead tackle densities in North American rivers and lakes should be assessed and the risks of this unintended deposition quantified. In critical wildlife areas with high angling effort or high tackle loss rates, lead tackle could pose a significant risk to waterbirds. This situation, therefore, warrants further consideration and evaluation.

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