MINI REVIEW

The ecotoxicology of lead shot and lead fishing weights

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Lead shot ingestion is the primary source of elevated lead exposure and poisoning in waterfowl and most other bird species. For some species (e.g. Common Loons, Gavia immer), lead sinker ingestion is a more frequent cause of lead poisoning. In freshwater environments where recreational angling activity and loon populations co-occur, lead poisoning from ingestion of small (<50 gram) lead sinkers or jigs accounts for 10–50% of recorded adult loon mortality, depending on the locations studied. Lead shot ingestion occurs in waterfowl, and in a wide variety of non-waterfowl species, including upland game birds, shorebirds, raptors, and scavengers. Where it has been explicitly studied in Canada and the US, lead poisoning mortality of bald (Haliacetus leucocephalus) and golden eagles (Aquila chrysactos) from eating prey animals with lead shot embedded in their tissues accounts for an estimated 10–15% of the recorded post-fledging mortality in these raptorial species. In addition to environments that experience hunting with lead shot, clay target shooting ranges, especially those in which the shotfall zones include ponds, marshes, lakes, rivers, beaches, or other aquatic-type environments, create a significant risk of shot ingestion and poisoning for waterbirds. Metallic lead pellets deposited onto soils and aquatic sediments are not chemically or environmentally inert, although tens or hundreds of years may be required for total breakdown and dissolution of pellets. Functional, affordable non-toxic alternatives to lead shot and sinkers are being currently produced, and additional such products are being developed. Several countries have successfully banned the use of small lead sinkers, and of lead shot for waterfowl and other hunting, also for clay target shooting, using a phasing-out process that gives manufacturers, sellers, and users adequate time to adjust to the regulations.

Keywords: lead shot; lead sinkers; lead poisoning; birds; toxicity; environmental fate.

Introduction

Lead (Pb) is a soft, bluish, metallic element found naturally in all environmental media. It has been mined and used in society for many hundreds of years. Pb’s low melting point, malleability, ease of processing, and low cost have resulted in its use in a wide range of products, including Pb shotshell (and other) ammunition, and Pb fishing weights

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(sinkers and jigs). However, due to Pb’s relatively high intrinsic toxicity, and the continual refinement of the science of Pb toxicology, which has resulted in the recognition of adverse effects of Pb at lower and lower levels of exposure, many of the traditional uses of Pb have been phased out in recent decades. Its uses in solder, plumbing pipes, paints, pottery glazes, crystal ware, and gasoline have been banned or severely reduced.

World production of Pb metal is about 4–6 million tonnes annually (OECD, 1993). Battery and pigment manufacturing together account for about 76% of the current world production of Pb. The manufacture of Pb shot and sinkers represents a relatively minor use of Pb (<1% of world Pb production).

The ingestion of Pb shot by waterfowl and other avian species, and the toxic effects of this ingestion, have been extensively studied and reviewed (e.g. Bellrose, 1959; Mudge, 1983; Sanderson and Bellrose, 1986; USFWS, 1986; Pain, 1992). Here, we briefly review the major toxic effects of Pb in birds from shot or sinker ingestion; the environmental chemistry and fate of metallic Pb pellets in the environment; and the approaches taken by different nations to deal with the problems caused by Pb shot and sinker use.

**Lead shot ingestion**

It has been known since the late 1800s (Grinell, 1894; Hough, 1894) that waterfowl ingest spent Pb shotgun pellets that have been deposited on the bottoms of lakes and marshes, mistaking these pellets for food items or grit. These Pb pellets often become lodged in the gizzard where ionic Pb is released due to the grinding action of the gizzard combined with its acidic environment. Acute or chronic Pb poisoning can result. If there has been ingestion of a large number (>10) of shot, acute Pb poisoning rapidly ensues, and birds usually die within a few days. Victims of acute poisoning can appear to be in good condition, without pronounced weight loss. More commonly, birds die of chronic Pb poisoning following ingestion of a smaller number of shot pellets. In these instances, signs of Pb poisoning (distention of the proventriculus, green watery faeces, drooping wings, anaemia, weight loss) appear gradually, and affected birds die approximately 2–3 weeks post ingestion, often in a very emaciated condition (Sanderson and Bellrose, 1986; USFWS, 1986). In addition, many sublethally-exposed birds probably die even though mortality cannot be attributed directly to Pb poisoning. Pb exerts sublethal toxic effects on many tissues, primarily the central and peripheral nervous systems, the kidneys, and the circulatory/haematopoietic systems (Scheuhammer, 1987). The lesions caused in these tissues by Pb exposure result in biochemical, physiological, and behavioural impairments. These impairments contribute to an increased risk of starvation, predation, and disease in affected birds. Sublethal exposure to Pb results in an impaired ability to cope with other potential sources of mortality.

Pb shot ingestion by waterfowl has been documented in many countries including Australia (Kingsford et al., 1989), Britain (Mudge, 1983), Canada (Kennedy and Nadeau, 1993; Scheuhammer and Norris, 1995), France (Pain, 1990), Spain (Guitart et al., 1994), the Netherlands (Lumeij and Scholten, 1989), Japan (Honda et al., 1990; Ochiai et al., 1993), and the US (Sanderson and Bellrose, 1986; USFWS, 1986). Pb shot ingestion has been judged to be the primary source of elevated Pb exposure and Pb poisoning in waterfowl (Sanderson and Bellrose, 1986; Scheuhammer and Dickson,