3198 Lead Poisoning

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AN ABBREVIATED REVIEW OF LEAD POISONING IN WATERFOWL

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Lead poisoning in wild waterfowl has been recognized for more than 100 years (Grinnell 1894, 1901; Hough 1894; Phillips and Lincoln 1930). Bellrose (1959) conducted one of the earliest studies on the extent of lead poisoning in wild waterfowl and the first experimental study of the effects of ingested lead shot. Little or no controversy regarding Bellrose's study arose at the time it was published. Much controversy developed approximately 20 years later when the U.S. Fish and Wildlife Service (1974) proposed to require the use of steel shot for hunting waterfowl on selected areas.

In his 1959 study Bellrose stated, "At the present time, lead poisoning losses do not appear to be of sufficient magnitude to warrant such drastic regulations as, for example, prohibition of the use of lead shot in waterfowl hunting. Should lead poisoning become a more serious menace to waterfowl populations, iron shot provides a possible means of overcoming it. Because of the increasing numbers of waterfowl hunters and the increasing incidence of lead poisoning, as well as because of the suffering that results among waterfowl seriously afflicted with the malady, the search for the best possible solution to the lead poisoning problem should be continued" (p. 286). Twenty years later Bellrose (1975:167) commented, "Why has my view on this problem changed? The principal reason is that our waterfowl populations have declined. Like all of our disappearing natural resources they are relatively more valuable today than they were then."

With the continuing decline of the waterfowl population, many biologists and managers believe that all reasonable steps to benefit waterfowl should be taken. As a result, the U.S. Fish and Wildlife Service (1974) proposed to require the use of steel shot for hunting waterfowl in selected areas of the U.S. Most biologists and wildlife managers, the professional society representing wildlife biologists, managers, administrators, and law enforcement personnel (The Wildlife Society, 1984), and the National Wildlife Federation (1978, 1985), among other organizations, supported the use of steel shot for hunting waterfowl; however, well-organized and widespread opposition surfaced immediately (e.g., National Rifle Association 1978, Arnett 1985:7). Recently the National Wildlife Federation (1985) has provided an excellent summary of the misunderstandings on which most of the opposition to steel shot was based.

The purpose of the present paper is to summarize and briefly discuss the main issues that have led to differences of opinion regarding the magnitude of the problem of lead poisoning in wild waterfowl and to review the benefits to be derived from the use of steel instead of lead shot.

SOURCES OF LEAD AND INCIDENCE OF LEAD SHOT

The incidence of lead shot in gizzards of wild waterfowl is generally acknowledged. Nearly 200,000 gizzards from more than 16 species of waterfowl have been examined for species and regional shot incidence during the fall and early winter hunting seasons. Bellrose (1959:262-263) analyzed 39,610 gizzards from waterfowl in the U.S. and British Columbia. He found that although the incidence of ingested lead varied by region and by species, lead occurred in gizzards from all regions. An average of 6.6

percent of the 39,610 gizzards contained one or more lead shot. More recent studies in which intact gizzards and gizzard contents were x-rayed indicate that Bellrose's rates were low. A summary of shot ingestion rates from 1973 through 1984 showed that 8.9 percent of 171,697 gizzards contained one or more shot (Sanderson and Bellrose, in press). Differences of opinion regarding incidence of shot on a species and regional basis exist; however, the major disagreement has concerned the percentage of the population, by species and region, that suffers from lead poisoning as a result of ingested shot.

Bellrose (1959) found that ducks dosed with lead pellets were 1.65 times more likely to be bagged by hunters than were healthy ducks. Thus, he reported that at any given time about 5.4 percent of the wild duck population, instead of 6.6 percent, had lead in their gizzards. Many ducks do not die after ingesting lead shot, and the pellets either pass through or completely erode in about 20 days. Since ducks are on staging or wintering grounds for about 150 days, the 20-day cycle is repeated about 7.5 times. Thus, Bellrose calculated that as much as 40 percent of the game duck population ingests lead shot during the course of an entire season.

Because food habits and habitats vary, waterfowl species differ greatly in their rates of shot ingestion. The bay diving ducks--canvasback, lesser scaup, redhead, and ring-necked duck--generally have the highest rate (12-14 percent); mallard, black, and pintail have an intermediate rate (7-9 percent); and gadwall, wigeon, blue-winged teal, green-winged teal, shoveler, and wood duck have the lowest rate (1-3 percent). With few exceptions, states with extensive wintering waterfowl populations have high rates of shot ingestion: Florida, Louisiana, and

Texas. Some localities in the flyways have a low rate; others have a high rate. Except for the Great Plains region of the U.S., shot ingestion by waterfowl is appreciable.

Although most investigators agree that spent shot from guns of waterfowl hunters is the main source of lead that poisons wild waterfowl, the Winchester Group (1974) argued that lead in the wing bones of ducks as reported by the U.S. Fish and Wildlife Service (1974) could have come from low-level exposure to environmental lead and not from ingested lead pellets. Many incidental sources of lead for waterfowl and other wild animals exist--lead in mine wastes (Phillips and Lincoln 1930; MacLennan 1954; Chupp and Dalke 1964), in paint, and in the atmosphere (Bazell 1971). Nevertheless, Sanderson and Bellrose (in press) state, "We are concerned about the levels of lead pollution in the atmosphere, soils, water, and plants of the world. However, there is no evidence of extensive mortality from lead poisoning in any wild animals other than lead poisoning in wild waterfowl as a result of ingesting lead pellets."

SUSCEPTIBILITY TO LEAD POISONING

The susceptibility of a waterfowl species to lead poisoning depends on its tendency to ingest lead shot and its food habits relating to the intake of protein, calcium, and phosphorus. Jordan and Bellrose (1951) concluded that type of food is probably the single most important factor controlling the level of toxicity of ingested lead. The highest levels of lead toxicity occurred with a diet of corn and the lowest with commercial duck pellets with a high protein content. The green foliage of aquatic plants also suppressed the toxic effects of lead.

On the basis of shot ingestion, lead present in wing bones, and food habits, Sanderson and Bellrose (in press) rated the susceptibility of several species to lead toxicosis. Because of its moderately high rate of shot ingestion and its tendency to feed on cereal grains, the mallard is highly vulnerable to lead. The shot ingestion rate for the black duck was about the same (higher in some areas) as the rate for mallards; however, black ducks have a high protein food intake in the Northeast, and the proportion of wing bones of black ducks with over 20 ppm lead was lower than that found in mallards (Stendell et al. 1979). Mottled ducks have the highest rate of shot ingestion of any species, but the high protein level of their diet probably mitigates against the catastrophic losses that might otherwise occur. Pintails have a shot ingestion rate slightly higher than that of mallards, but because of a more favorable protein diet, especially in California, their losses from lead poisoning probably are not proportionally as large as those of mallards. Only about half as many pintails from the Pacific Flyway as mallards had lead concentrations in their wing bones higher than 20 ppm. However, the large losses of pintails from lead poisoning at Catahoula Lake, Louisiana, confirms that this species can be highly susceptible to lead poisoning. The remaining dabbling ducks (wood duck, gadwall, wigeon, green-winged teal, blue-winged teal, and shoveler) have relatively few losses from lead poisoning, but these losses are difficult to estimate.

The rates of lead ingestion of the bay diving ducks are appreciably higher than those of mallards and pintails. A high proportion of wing bones from canvasbacks and redheads had lead levels over 20 ppm, but the lesser scaup, which has a high rate of shot ingestion, had fewer than 1 percent of its wing bones with lead levels over 20 ppm. Its extensive diet of mollusks may inhibit the absorption of lead into the blood. The high percentage of animals and aquatic plants in the diets of canvasbacks and redheads would reduce toxicity to levels below those suffered by mallards. Thus, the large proportion of their wing bones with over 20 ppm lead suggests that the beneficial aspects of their diet are overwhelmed by the large amounts of lead ingested. On the basis of levels of lead in wing bones and rates of ingestion of lead shot, we estimate that losses of canvasbacks, redheads, and ring-necked ducks are on the same order of magnitude as losses in mallards.

The amount of lead ingested by geese seldom leads to death because of a diet, which is high in green forage. When green forage is in short supply or unavailable, perhaps because it is covered with snow, lead poisoning may be severe in geese.

Dozens of studies with penned ducks have shown that many variables affect toxicity of ingested lead: type and amount of food consumed, amount of soil ingested, age, sex, and size of bird, amount of lead shot ingested, and season. The type of food consumed is believed to be the single most important factor, and the foods most successful in alleviating lead toxicity are those high in protein. Lead storage in animal tissues is decreased by a high calcium diet and increased by a low calcium diet. Ingestion of at least some types of soil also alleviates lead poisoning in waterfowl. Lead shot has a greater toxic effect on females than on males except in the spring. The increased resistance of females to lead poisoning in spring appears to be related to the high metabolic rate and mobilization of energy resources for egg-laying. Lead has less effect on birds up to about 7 months of age, but after late December little difference between age groups has been observed. Because lead salts follow the same pathways in the blood stream as calcium, a high proportion of lead is probably deposited in the skeletons of young birds. This deposition no doubt removes circulating lead from the blood stream and helps to reduce lead toxicosis. The larger the bird, the less effect an identical amount of ingested lead has.

LEAD POISONING MORTALITY

Although hunters and the general public seldom notice dead ducks in the marsh, banding data indicate that at least a fourth of all ducks alive in September die from natural causes within the year--slightly more than are killed by hunters. Why does the death of so many ducks go largely unnoticed? When a duck becomes seriously ill, it leaves its flock and seeks dense cover out of water in marshes and along the shores of lakes. There, a host of predators rapidly remove all traces of most dead ducks. Zwank et al. (1985) removed 1,072 sick, dead, and dying lead-poisoned waterfowl from Catahoula Lake, Louisiana, from 13 October 1980 through 31 January 1981. No reports of waterfowl die-offs were received during the time collections were made. Neither was a die-off reported in this area during the 1979-80 season when Smith (1980) found levels of ingested lead similar to those reported by Zwank et al. These studies prompted Zwank et al. (1985:23) to conclude, "This magnitude of mortality without a corresponding reported die-off supports Bellrose's (1976) contention that the most important aspect of lead toxicosis mortality may not be the recorded massive die-offs, but the day-to-day losses." As long as ducks sick and dead from lead poisoning do not exceed the ability of predators and scavengers to eat them, little evidence of mortality is left.

Estimates based on the mortality rates (58.5% of the ducks with lead shot in their gizzards at any one time will die of lead poisoning, Bellrose 1959) of ducks with ingested lead and the ability of intensive searches to find dead ducks in the marsh show the following: If a winter migration area contained 50,000 mallards, if 6.8% had one or more lead pellets in their gizzards at any given time, if the area were searched each day for 150 days (the calculated time ducks spend on wintering areas), searchers should find an average of only 1.3 sick or dead lead poisoned mallards per day. However, nearly 2,000 mallards would have died of lead poisoning during the 150-day period. Thus, it is not surprising that "routine" losses from lead poisoning go largely unnoticed.

Most large-scale losses of waterfowl from lead poisoning are noted in winter and early spring, after the hunting season and at a time when few people are in marshes and swamps. Losses at this season occur most frequently for several reasons, but perhaps the most important is that hunting deters waterfowl from feeding in many areas until the close of the hunting season. Hunters place their blinds on or near the best feeding sites and spent lead is deposited most densely in the vicinity of the blinds. After the close of the hunting season and if freezeup has not occurred, waterfowl are attracted to the abundant food still available near the blinds.

Bellrose (1959) dosed free-flying wild mallards with lead pellets and found a higher rate of band recoveries from dosed wild mallards during the first 10 months after banding and a reduced band recovery rate among dosed ducks during the hunting season 1 year after banding. A similar dosing experiment was conducted with pintails in California between 22 January and 23 March 1979 by the U.S. Fish and Wildlife Service and the California

Department of Fish and Game (Deuel 1985). Subsequent band recoveries did not reveal significant difference in survival between dosed and undosed ducks. To understand the difference in results between experiments with free-flying wild mallards in Illinois and free-flying wild pintails in California is to understand the difference in food habits between the two species in the respective regions. Many laboratory experiments have shown the importance of diets high in protein, calcium, and phosphorus as a means of alleviating lead toxicosis. Diets of pintails in three regions of California show a high protein level, especially in late winter and early spring, the period of the experimental dosing study. Pintails were found to consume appreciable quantities of invertebrates; midge larvae were especially important and most prevalent in late winter and early spring diets. The crude protein of the most important invertebrates ranged from 46 to 76 percent. Swamp timothy, an important food for pintails in the Central Valley of California, has a crude protein content of 13.9%, high for a plant species. We believe that the high protein diet of pintails in late winter and early spring in California mitigated against mortality from lead at the shot level tested (2 No. 5 pellets). Had the experiments been conducted during the fall when the pintails feed more extensively on rice, barley, and weed seeds, the results might have been different. Stendell et al. (1979) reported that 12.5% of adult and 8.9% of juvenile pintail wing bones from California had over 20.0 ppm lead, thus establishing that significant amounts of lead enter the bodies of pintails during the hunting season, the time the wing bones were collected. There are several reports of waterfowl, including pintails, dying of lead poisoning in California.

MANAGEMENT PRACTICES TO REDUCE LEAD TOXICOSIS IN WATERFOWL

Several ways of manipulating the habitat to reduce lead poisoning in waterfowl have been considered. Osmer (1940) suggested distributing gravel to be used as grit by waterfowl. Several individuals have suggested, without supporting evidence, that lead pellets remain in the gizzard longer when grit is limited. Sanderson and Irwin (1976) reported a higher expulsion rate of lead pellets when ducks had access to soil; however, balanced against the expulsion rate was the increased erosion rate of lead pellets when ducks had access to soil. Thus, the total effect of readily available grit and soil on mortality from ingested lead is unclear.

Scare devices to drive waterfowl from heavily shot areas have generally proved unsuccessful. Losses of waterfowl to lead poisoning have been reduced in some cases by lowering water levels in feeding grounds after the hunting season so that ducks will leave. However, when ducks are discouraged from using waterfowl habitat--by any means--except during the hunting season, the value of that habitat is lost to waterfowl for all other times of the year. On areas that can be cultivated, lead pellets can be made less available to feeding waterfowl by plowing or disking, but after a few years, cultivation turns up as many lead pellets as it buries.

Others have suggested that managers encourage the growth of submerged, leafy aquatic plants for duck food because these foods provide the most protection against lead poisoning of any natural plant food. This practice, however, is not feasible for much of the waterfowl habitat because siltation has decreased water depth in some cases and decreased penetration of sunlight in others so that only limited areas support submerged aquatic plants. Most large-scale impoundments do not provide suitable habitats for aquatic plants. As long as lead shot is used for hunting waterfowl, it seems only reasonable that the boundaries of refuge areas remain the same year after year so that rest areas will remain free of lead shot. On many state and federal waterfowl refuges, however, areas open and closed to hunting are rotated, a practice that spreads the shot to feeding waterfowl. The only management practice, other than closing the waterfowl hunting season, that will eliminate mortality from ingested shot in waterfowl is the substitution of nontoxic shot for lead shot. Presently the only proven nontoxic shot available is steel.

Roster (1978:26) stated, "Although steel shot can bag ducks as well as lead shot can, the belief persists that steel shot will cripple more waterfowl and damage shotguns. This belief stems from ignorance of the results of tests to investigate gunbarrel damage as well as from ignorance of the ballistic properties of steel shot. Ballistically, steel shot can be loaded to perform as well as lead shot in bagging waterfowl out to seventy yards. Steel shot retains its shape better than lead shot does, and compensations can be made for its lighter weight, enabling it to retain energy as well as lead shot."

Hunters have voiced several objections to steel shot. A primary objection is that steel shot will cripple (mortally wound) more unretrieved waterfowl than are poisoned and crippled by lead shot. Sanderson and Bellrose (in press) cite the results of three intensive field shooting experiments that compare the effectiveness of various lead and steel loads. No statistically significant differences in cripples per shot fired were found for steel and lead pellets. They also cite two studies comparing lead and steel loads for bagging Canada geese; neither study reported significant differences in crippling rates for lead and steel shot.

Although early shooting experiments with soft steel and lead loads indicated that steel shot was deficient in killing power at ranges of 50 yards or more (Bellrose 1959; Andrews and Longcore 1969), more recent field tests with lead and improved steel shot have shown little difference between the two loads at long ranges (Anderson and Sanderson 1979; Smith and Roster 1979; Mikula et al. 1977; Humburg et al. 1982).

Although the danger of excessive gun barrel damage was dispelled long ago, the myth lingers on. The three major arms and ammunition companies have stated (U.S. Fish and Wildlife Service 1976) that steel shot would cause no significant reduction in the life of most modern full-choke shotguns.

The increased cost of steel shells is a deterrent to the use of steel shot shells by many hunters (National Wildlife Federation 1985). Components for reloading steel shot are now routinely available from many sources. As steel shot becomes more widely available, the spread in price is getting smaller, and shotshells make up a minor part of the overall expense of waterfowl hunting. Sanderson and Bellrose (in press) show that at prices prevailing in 1985, the average duck hunter would, at most, spend an additional $4.50 per hunting season. If a 10-gauge gun were used, a saving of $4.86 would result.

Ballistically, lead and steel loads are different, but surprising to many ballisticians steel shot possesses a quality of form retention that makes for a better pattern and a shorter shot string than soft lead (Brister 1976). Because of the impact among pellets passing down the gun barrel, lead shot pellets become more deformed than steel pellets, which resist deformation from pellet impact and leave the barrel in a more nearly spherical form. Steel pellets are also more nearly round and more uniform than lead pellets before they are fired. As a result, the steel charge is more compact with fewer holes in its pattern than the softer lead shot.

Although steel is lighter than lead, downrange energy loss can be compensated for by using a steel shot pellet two sizes larger than would be used for lead and by an increase in muzzle velocity. Because of the greater velocity and greater form retention, however, many hunters have learned that steel shot in the same sizes as their favorite lead loads performs satisfactorily.

More steel pellets are found in a given weight and shot size than is true for lead. Both the shorter shot string and the tighter patterns of steel contribute to more hits on a target or to a "clean" miss. Also, because of the tighter pattern with both steel and buffered lead loads (A Missouri study showed that No. 4 lead performed better than No. 4 buffered lead.), evidence suggests that ability to aim in relation to choke has a bearing on bag/cripple results. These factors may explain the generally superior performance of steel shot over lead for hunting Canada geese. Because of the tighter patterns of steel loads, a modified or improved cylinder choke is recommended rather than a full choke.

CONCLUSIONS

An examination of the population dynamics of waterfowl reveals that losses due to lead poisoning during late winter early spring have a more important influence on potential production than do the earlier losses due to crippling. Losses in one area, such as from hunting, are replaced by birds that survive natural losses because more habitat niches have become available to them. The earlier in the fall season that mortality occurs, the better the opportunity for the remaining birds to survive as breeders.

Hence, the closer to the breeding season that a bird survives, the more likely it will achieve breeding status. Because most losses from lead poisoning occur just prior to the breeding season, they affect the potential breeding population more severely than an equal number of losses due to crippling during the previous fall.

The potential impact of lead poisoning on the fall duck population is related to the comparative abundance of the species most vulnerable to this disease. The species we deem the most vulnerable are mallard, black duck, mottled duck, pintail, canvasback, redhead, and ring-necked duck. These species make up 42% of the continental game duck population.

Waterfowl management may well have more to gain by the judicious use of steel shot than by the continued use of lead shot. Although there are habitats and species of waterfowl where the use of lead shot would have a limited impact, there are also many habitats and several species of waterfowl where the use of steel shot would be of benefit. In addition, in some areas botulism, fowl cholera, and DVE cause extensive waterfowl mortality. Some individuals seem to be saying that because on some areas as many or more ducks die from other diseases as die of lead toxicosis, lead poisoning should be ignored. If the other diseases could be eliminated by regulations, such regulations should be implemented.

Although the use of steel shot has been limited in time and place, a surprisingly large proportion of recently analyzed gizzards show steel shot ingestion. Thus, the use of nontoxic shot appears to have a prompt effect in reducing the potential for lead poisoning in waterfowl.

Although disagreement continues regarding the extent of lead poisoning in waterfowl, most biologists, wildlife managers, administrators, and waterfowl hunters agree that appreciable waterfowl mortality results from lead poisoning. With the continuing decline in quality and quantity of nest habitat for waterfowl and the consequent declines in continental waterfowl populations, a conservative approach to the problem of lead poisoning in waterfowl seems prudent. It sometimes seems that advocates of the use of steel shot for hunting waterfowl are being asked to demonstrate that steel is "better" than lead before its use is acceptable. Instead, we should focus on the effects of the use of lead and steel shot on ducks and geese--the mortality rate from lead poisoning and crippling by lead shot versus the mortality rate from crippling by steel shot in waterfowl hunting.

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