Shot Ingestion by Dabbling Ducks Wintering in Coastal South Carolina

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Abstract: We determined the incidence of lead, steel, and total shot ingestion in 4 species of dabbling ducks on a major wintering area of the Atlantic Flyway. Gizzards (N = 1,771) were collected from hunter-harvested mallards (*Anas platyrhynchos*), northern pintails (*A. acuta*), blue-winged teal (*A. discors*), and American green-winged teal (*A. crecca*) during the 1985–86, 1986–87, and 1987–88 waterfowl hunting seasons on the Santee River Estuary (SRE), South Carolina. Total shot ingestion rates were high in northern pintails (15.9%) and mallards (8.4%), and low in American green-winged teal (1.3%) and blue-winged teal (0.8%). Because gizzard analysis can underestimate the extent of lead shot exposure in waterfowl, the SRE is implicated as a serious contributor to lead shot ingestion by wintering northern pintails and mallards.

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South Carolina is an important staging and wintering area for dabbling ducks in the Atlantic Flyway (Addy 1964, Bellrose 1980, Gordon et al. 1987, Prevost 1987, Strange 1987). U.S. Fish and Wildlife Service Midwinter Waterfowl Survey data for 1970–88 indicate South Carolina harbored 24% of all dabbling ducks wintering in the Atlantic Flyway during this period, including 55% of the American green-winged teal, 46% of the northern shovelers (*Anas clypeata*), 33% of the mallards, 33% of the northern pintails, 31% of the American wigeon (*A. americana*), and 30% of the gadwall (*A. strepera*). Managed coastal wetlands of South Carolina

are important to these species (Gordon et al. 1987, Prevost 1987, Strange 1987). From 1983 to 1988, 60% of the dabbling ducks wintering in South Carolina occurred in the coastal marshes, and 50% occurred in the Santee River Estuary (SRE) (T. Strange, unpubl. data).

Declines in South Carolina's wintering waterfowl populations from an estimated 417,000 ducks in 1970 to 133,000 ducks in 1988 (U.S. Dep. Int., Fish and Wildl. Serv. Mid-winter Inventory Reports, 1970–88) have caused concern among waterfowl professionals and stimulated interest to better understand all factors affecting regional waterfowl populations. Sanderson and Bellrose (1986) provided a comprehensive review of lead poisoning due to shot ingestion in North American waterfowl. Shot pellet ingestion rates derived from extensive studies have been published for 4 states in the Atlantic Flyway, but among states south of Maryland, only Florida has reported data (Sanderson and Bellrose 1986). The potential impact from lead poisoning is great in South Carolina because of the relatively large numbers of dabbling ducks wintering there.

Our objective was to quantify the frequency of occurrence of shot in gizzards of hunter-harvested northern pintails, mallards, blue-winged teal, and American green-winged teal on the SRE to 1) determine exposure to lead shot and the potential for lead poisoning in regional waterfowl populations, 2) compare shot ingestion rates of waterfowl harvested in the SRE to those observed in waterfowl populations in other geographic regions of the Atlantic Flyway, 3) establish baseline data to monitor the reduction of lead shot ingestion by waterfowl following implementation of nontoxic shot zones in South Carolina, and 4) facilitate hunter compliance in nontoxic zones by providing information on the extent of lead shot ingestion by waterfowl in the area.

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Methods

The SRE is located about 24 km south of Georgetown, South Carolina, and contains 19,269 ha of tidal wetlands including 7,935 ha of managed marsh, 1,586 ha of fresh marsh, 2,610 ha of brackish marsh, and 7,139 ha of salt marsh. See Tiner (1977) for a detailed description. Wetland management in the SRE is directed toward encouraging growth of certain naturally occurring plant communities to provide high quality waterfowl habitat (Morgan et al. 1975, Prevost et al. 1978, Prevost 1987).

Migratory dabbling ducks begin to arrive on the SRE in late September, increasing in number through early December. Few ducks move into the area after mid-December. Currently, dabbling duck habitat use in the SRE is restricted almost entirely to managed wetlands (Gordon et al. 1987). Hunting pressure in these wetlands has been light to moderate, and in recent years half-day hunts were conducted only 1–2 days each week during the waterfowl hunting season. Managed wetlands in the SRE are shallowly flooded during winter, generally hard bottomed, and are seldom ice covered as the winters are relatively mild. These factors make the area a potential high risk zone for lead shot ingestion by bottom-feeding waterfowl.

Lead shot was permitted for waterfowl hunting in the SRE during the 1985–86 and 1986–87 hunting seasons except at Annandale Plantation. Annandale Plantation required steel shot in 12 gauge and 20 gauge loads during the study and did not allow use of 10 gauge guns. Steel shot was required on the entire SRE during the 1987–88 waterfowl hunting season.

Gizzards from hunter-killed ducks were collected at the SCWMRD Santee Coastal Reserve (4,553 ha of managed wetlands), SCWMRD Santee Delta WMA (460 ha), Kinloch Plantation (897 ha), and Annandale Plantation (499 ha) throughout the waterfowl hunting season (mid-December through mid-January). These 4 areas accounted for >90% of the annual waterfowl harvest in the SRE. We did not begin gizzard collections until mid-December in order to reduce the probability of sampling ducks that may have ingested shot prior to arrival on the SRE. Gizzards were collected from mallards and northern pintails during the 1985–86 waterfowl hunting season and from mallards, northern pintails, blue-winged teal, and American green-winged teal during the 1986–87 and 1987–88 seasons. Gizzards were placed in separate plastic bags, labeled, and frozen until examination.

Each gizzard was opened and contents were washed thoroughly into a 0.25-mm sieve. Particles held by the sieve were placed into a labeled aluminum weighing dish to air dry. Gizzard linings were examined for shot pellet holes and the number recorded. Dried gizzard contents were placed in pre-labeled plastic ziplock bags. Bags were mounted on 35 x 43 cm sheets of poster board (equal to the size of 1 X-ray film exposure). X-ray exposures of each poster board sheet were made using a Dunlee, Inc., X-ray tube connected to a Picker International generator. Each X-ray exposure was inspected for signatures resembling shot. Gizzard contents suspected of containing shot were then examined manually with a 10x-20x dissecting scope to verify the number and type (lead or steel) of shot present.

The physical appearance of shot found in gizzards and presence or absence of holes in the gizzard lining determined whether the shot had been ingested or "shot-in" (Montalbano and Hines 1978, Anderson and Havera 1985). Failure to find a hole in the gizzard lining did not prevent classifying a shot as "shot-in" (Anderson and Havera 1985). When difficulty was encountered in differentiating between ingested and penetrating shot, the presence of pellet holes in the gizzard lining was considered indicative of shot-in pellets (Montalbano and Hines 1978). Lead pellets were verified by nicking the soft metal with a dental probe; steel pellets were detected with a magnet.

Data analysis consisted of calculating percent occurrence of shot ($\geq$1 pellet/gizzard) in the gizzards by number and type for each duck species in each year. We assumed that ducks ingested steel shot as readily as lead shot. Two-sample chi-square tests (Siegel 1956) determined differences in frequencies of lead, steel, and total shot ingestion among years and species. One-sample chi-square tests determined differences between the frequencies of shot ingestion observed in this study and other geographic regions. We used U.S. and Atlantic Flyway estimates for each species reported by Sanderson and Bellrose (1986) to calculate expected frequencies.

Results

We examined a total of 1,771 gizzards from 479 mallards, 454 northern pintails, 472 American green-winged teal, and 366 blue-winged teal (Table 1). This sample of gizzards represents populations of the 4 species wintering within the SRE rather than distinct populations associated with specific management areas. Visual observations and limited radio-telemetry information indicated a regular exchange of ducks among management areas on the SRE.

Ingested total shot (lead and steel combined), lead shot, and steel shot were significantly higher ($P < 0.05$) in northern pintails than mallards. Pintails and mallards had significantly higher ($P < 0.05$) shot ingestion frequencies than American green-winged teal and blue-winged teal, but there were no differences ($P > 0.05$) between the 2 teal species.

Total, lead, and steel shot ingestion frequencies did not differ ($P > 0.05$) among years for northern pintails, American green-winged teal, or blue-winged teal. Total shot ingestion frequencies did not differ ($P > 0.05$) among years for mallards, but the occurrence of lead shot decreased 6% whereas steel shot increased 6% between the 1986–87 and 1987–88 seasons ($P < 0.05$).

Discussion

Northern pintails typically have higher shot ingestion rates than mallards (Sanderson and Bellrose 1986). However, Bellrose (1959) reported similar ingestion rates for 77 mallards (9.1%) and 56 northern pintails (10.7%) collected in South Carolina and Georgia between 1938 and 1954. Northern pintails wintering in

Table 1. Incidence of ingested shot in waterfowl gizzards collected from Santee River Estuary, South Carolina, 1985–87 hunting seasons.

Year	N[a] gizzards	No. with shot (%)	No. lead shot (%)	No. steel shot (%)
		Northern pintail		
1985–86	216	33 (15.3)	23 (10.6)	12 (5.6)
1986–87	97	15 (15.4)	11 (11.3)	5 (5.2)
1987–88	141	24 (17.0)	16 (11.3)	10 (7.1)
Combined	454	72 (15.9)	50 (11.0)	27 (5.9)
		Mallard		
1985–86	185	19 (10.2)	17 (9.1)	2 (1.1)
1986–87	90	7 (7.8)	6 (6.7)	1 (1.1)
1987–88	204	14 (6.9)	2 (1.0)	14 (6.9)
Combined	479	40 (8.4)	25 (5.2)	17 (3.5)
		American green-winged teal		
1986–87	271	5 (1.8)	3 (1.1)	2 (0.7)
1987–88	201	1 (0.5)	0	1 (0.5)
Combined	472	6 (1.3)	3 (0.6)	3 (0.6)
		Blue-winged teal		
1986–87	133	0	0	0
1987–88	233	3 (1.3)	1 (0.4)	2 (0.9)
Combined	366	3 (0.8)	1 (0.3)	2 (0.6)

[a]Because some gizzards contained both ingested lead and steel shot, the sum of gizzards containing ingested lead shot and gizzards containing ingested steel shot may be greater than the total number of gizzards containing ingested shot.

the SRE had a significantly higher ($P < 0.05$) incidence of ingested shot than the U.S. estimate (11.7%), but significantly lower ($P < 0.05$) than the Atlantic Flyway estimate (21.1%) (Sanderson and Bellrose 1986). However, the Atlantic Flyway estimate may be biased upward by a disproportionately large sample of northern pintail gizzards from Florida in which the percent occurrence of ingested shot was high. Whereas ingestion rates of northern pintails wintering in the SRE were lower than the Atlantic Flyway estimate, they were second only to the 25.6% ingestion rate reported in Florida (Baker and Thompson 1979). This implicates the SRE as a problem area for shot ingestion by this species.

Mallards wintering in the SRE had shot ingestion rates similar ($P > 0.05$) to the U.S. estimate (8.1%) but significantly lower ($P < 0.05$) than the Atlantic Flyway estimate (12.3%) (Sanderson and Bellrose 1986) further implicating the SRE as a problem area for lead shot exposure to waterfowl. Only the estimate of ingested shot in mallards collected in Maine (3.0%) was lower within the flyway (Longcore et al. 1982). Shot ingestion rates of American green-winged teal wintering on the SRE were similar ($P > 0.05$) to the U.S. (1.3%) and Atlantic Flyway estimates (1.9%). Only ingestion rates of American green-winged teal collected in Florida (3.3%) were higher within the flyway (Thul, upubl. rep., *in* Sanderson and Bellrose 1986). Shot ingestion by blue-winged teal wintering in the SRE was significantly

less ($P < 0.05$) than the Atlantic Flyway and U.S. estimates of 2.3% and 3.2%, respectively (Sanderson and Bellrose 1986).

The high incidence of shot ingestion in northern pintails (15.9%) and mallards (8.4%) harvested in the SRE may greatly underestimate exposure to lead shot and the potential for lead poisoning in populations wintering there. Sanderson and Bellrose (1986) estimated that a much larger percentage of all ducks in a given population consume lead pellets (≤40%) than the proportion of ducks (gizzards) found with ingested shot in any given sample. Their estimate is based on the following logic. Leads shot disappears from waterfowl gizzards within 20 days of ingestion either because of erosion or passage through the gastrointestinal tract. This implies that ingested lead pellets present at any particular time were consumed within the preceding 20 days. Because waterfowl spend about 150 days on migration and wintering grounds and this period is equal to 7.5 intervals of 20 days, Sanderson and Bellrose (1986) suggest 7.5 times the percentage of waterfowl in a sample found with ingested shot probably consume lead pellets. Applying these calculations to waterfowl populations on our study area, we calculate that during a 90-day period of winter residency on the SRE (DEC - FEB) there are 4.5 intervals of 20 days. Using the percentages of ingested lead shot derived from our gizzard samples, we estimate 50% of the northern pintails (4.5 × 11.0%) and 23% of the mallards (4.5 × 5.2%) on the SRE ingested lead shot. These higher estimates of lead shot exposure are supported by Anderson and Havera (1985) who reported that the presence of ingested pellets is the least sensitive indicator of lead exposure and lead poisoning in wild waterfowl populations.

A more accurate and more sensitive indicator of lead shot exposure is blood lead level (Anderson and Havera 1985). A blood lead level ≥0.2 ppm, a criterion used by the U.S. Fish and Wildlife Service to identify lead poisoning problem areas (Friend 1985), can occur in 3 to 5 times the number of waterfowl that have ingested lead shot (W. L. Anderson, pers. commun.). Conservatively, this method of estimation suggests 3 times the number of SRE northern pintails and mallards containing ingested lead shot could have had a blood lead level of at least 0.2 ppm.

South Carolina required the use of steel shot in 12 gauge shotguns on the SRE beginning with the 1979–80 waterfowl hunting season and gradually broadened the regulations to include 10 and 20 gauge shotguns during the 1982–83 hunting season. After the 1982–83 hunting season, steel shot restrictions on the SRE, and other areas in South Carolina, were lifted. Annandale Plantation, however, has required the use of steel shot in 12 gauge guns every year since the 1979–80 waterfowl hunting season, with the majority of hunters there shooting 12 gauge guns. We believe northern pintails wintering in the SRE had relatively high rates of steel shot ingestion in hunting seasons prior to 1987–88 because of the steel shot policy practiced at Annandale Plantation. Annandale Plantation has traditionally been an important feeding area for northern pintail populations in the SRE. However, Annandale Plantation receives infrequent use by mallards as they typically avoid the structurally open habitats found there such as extensive submersed stands of wigeongrass (*Ruppia maritima*) and dwarf spikerush (*Eleocharis parvula*). Conse-

quently, mallards wintering on the SRE before the 1987–88 hunting season did not benefit to the extent northern pintails did from Annandale Plantation's steel shot policy.

We are uncertain why lead shot ingestion rates of mallards wintering in the SRE decreased during the 1987–88 hunting season while northern pintail lead shot ingestion rates remained the same as the previous 2 years. Because there was no significant change in total shot ingestion in mallards between 1986–87 and 1987–88, the 6% decrease in lead shot ingestion was apparently offset by an equal increase in steel shot ingestion. The difference between the 2 species may be related to different habitat use patterns (Gordon et al. 1987, Gray et al. 1987) or differences in feeding behavior thereby possibly exposing mallards to relatively higher concentrations of steel shot.

We concur with Sanderson and Bellrose (1986) and Anderson et al. (1987) that waterfowl mortality from lead shot ingestion can be eliminated by regulation. The mandatory use of steel shot for waterfowl hunting in the SRE and other areas throughout the region during the 1987–88 hunting season reduced lead shot exposure in the mallard population wintering there. Continual monitoring should be conducted as steel shot replaces lead shot in the gizzards of mallards and northern pintails wintering in the SRE.

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