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Lead Concentrations in Tissues of Marsh Birds: Relationship of Feeding Habits and Grit Preference to Spent Shot Ingestion

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The toxic effects of lead shot ingestion on waterfowl are well documented (Bellrose 1959). Incidences of ingested shot in other species have also been reported. For example, Lewis and Legler (1968) found up to 24 lead pellets in gizzards of mourning doves. Stendell et. al. (1980) reported 7.4% incidence of ingested shot in Sora rails, and the detrimental effect of lead exposure on kestrels was shown by Stendell (1980). Lead shot is even toxic to bald eagles that have preyed upon affected waterfowl, perhaps accounting for up to 7% of dead specimens collected. And recently the death of a whooping crane with more than 75 ingested lead shot was reported (US Fish and Wildlife Service, NM).

During the summer of 1982, a random sample of marsh birds from the upper Texas coast indicated a relatively high incidence of shot ingestion in several species. In addition, lead and arsenic levels in bones of these species were correlated with the presence of ingested shot. This paper addresses possible reasons why some species are affected and others are not, in particular the relationship between feeding habits and size of grit which is found in the gizzards of each species.

MATERIALS AND METHODS

Specimens were collected during July and August, 1982 from brackish marshes on the H & G Ranch, Chambers County, Texas. Gizzard were thoroughly washed out and the contents placed in small vials. The presence of ingested shot was determined by x-ray analysis of the vials (Torrex 150 x-ray inspection system, Torr X-ray Corp., 65-75 KV, 3 ma, 30 sec exposure). Visual inspection of the contents provided positive identification of shot fragments, and a magnet was used to separate lead from steel shot. The gizzard lining was inspected during dissection to eliminate the possibility that pellets in the lumen were shot in during collection.

Soil samples were collected from representative ponds to estimate the number and depth of available shot. Six PVC cores (5 cm diameter and 30.5 cm deep) were collected at 50 m intervals along 3 to 9 transects radiating outward from established duck blinds on three ponds. The cores were x-rayed (80 KV, 3 ma, 1 min) and the depth of shot was determined.

The size distribution of the grit in each gizzard was determined after oxidizing any remaining organic material with 30% hydrogen peroxide. The oxidized, dry sample was sieved into various size classes using standard testing sieves (2.0 mm, 1.0 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm) and a Bico sieve shaker. Each fraction was weighed to determine the relative proportions of each size class.

Bone, feather and liver samples were prepared for inductively coupled plasma emission spectrometric analysis (ICP) following EPA guidelines (1979). Ten ml of glass distilled water and 3 ml of concentrated nitric acid (Baker analyzed reagent grade) were added to weighed tissue samples in 100 ml beakers. These were evaporated to near dryness on hot plates at 180 C. Another 3 ml of acid was added and the samples were refluxed until digestion was complete. After filtering through a Buchner fritted glass funnel, the sample volume was adjusted to 25 ml. Concentrations of 17 elements (Al,As,Ba,Cd,Co,Cr,Cu,Fe,Mn,Ni,Pb,Sb,Se,Sn,Ti, V,Zn) were determined in each digested sample using a Jarrell-Ash inductively coupled plasma emission spectrophotometer (atomic series 855). Data for bones and livers are expressed a mg per kg wet weight while feather concentrations are on a dry weight basis.

RESULTS AND DISCUSSION

Twenty-one species of marsh birds were collected, however it was not always possible to collect more than one individual of a particular species. Species represented by only one specimen included a semipalmated sandpiper, Louisiana heron, American avocet, meadowlark, olivaceous cormorant, and Wilson's phalarope. Since none of these individuals contained ingested shot, they were not included in further analyses. A marbled godwit was collected which contained two ingested lead shot; it was also omitted from further analyses due to lack of additional specimens.

The remaining species were divided into two groups on the basis of their feeding habits: those which probe into the sediment searching for food, and those which do not probe, but feed on fish, insects, or vegetation. The probing species were divided into two groups on the basis of presence of ingested shot. Table 1 summarizes the species included in each group along with the sample size collected and the average bill length of probers as reported in Pough (1951).

Table 1. Summary of species collected.

COMMON NAME	SCIENTIFIC NAME	TOT N	PB N	$\bar{X}$ BILL LENGTH
	PROBERS WITH PB SHOT			
Black-necked stilt	Himantopus mexicanus	14	3	6.0
White-faced ibis	Plegadis chihi	4	1	13.6
Long-billed dowitcher	Limnodromus scolopaceus	8	1	6.4
	PROBERS WITHOUT PB SHOT			
Yellowlegs	Totanus flavipes	3	0	3.5
Least sandpiper	Erolia minutilla	5	0	1.9
Pectoral sandpiper	Erolia melanotos	4	0	2.9
Western sandpiper	Ereunetes mauri	7	0	2.5
Stilt sandpiper	Chlidonias niger	7	0	3.5
Willet	Catoptrophorus semipalmatus	2	0	5.4
	NON-PROBERS			
King rail	Rallus elegans	2	0	
Gallinule	Gallinula chloropus	3	0	
Black-crown night heron	Nycticorax nycticorax	2	0	
Black tern	Chlidonias niger	2	0	
Cattle egret	Bubulcus ibis	2	0	

Grit size distributions are presented in Table 2 for probing species. Those species which were prone to ingesting spent shot had a larger proportion of grit that was greater than 2 mm in diameter. In contrast, finner particles predominated in the grit from species which did not have ingested shot in their gizzards. This difference in grit size distribution is also reflected in the average grit diameter.

Table 2. Comparison of grit size distributions and mean grit diameter for seven species of probing marsh birds.

	SPECIES+						
	BNS	WFI	DOW	PSP	SSP	WSP	LSP
N	12	4	5	4	7	7	5
% WITH SHOT	21.4	25.0	12.5	0	0	0	0
$\bar{X}$ GRIT DIAM (SE)	1.23 a* (0.17)	0.98 ab (0.29)	1.23 ab (0.11)	1.11 ab (0.08)	0.91 ab (0.04)	0.71 b (0.05)	0.69 b (0.09)
GRIT SIZE							
%>2	47.7 a*	30.9 ab	26.3 ab	14.2 b	7.3 b	0.0 b	0.0 b
% 1.0	17.0	21.4	71.2	80.6	65.8	46.4	50.8
% 0.5	13.5	22.2	2.5	3.6	17.1	46.4	28.0
% 0.25	12.0	21.6	0.6	1.0	5.2	5.7	13.8
% 0.125	6.5	5.0	0.0	0.4	4.4	1.6	3.8
% 0.063	3.4	0.0	1.4	0.3	0.0	0.0	3.8

+ Species abbreviations: BNS = black-necked stilt, WFI = white-faced ibis, DOW = long-billed dowitcher, PSP = pectoral sandpiper, SSP = stilt sandpiper, WSP = western sandpiper, LSP = least sandpiper.

* Means within rows with same letter are not significantly different ($p < 0.05$, Duncan's multiple range test).

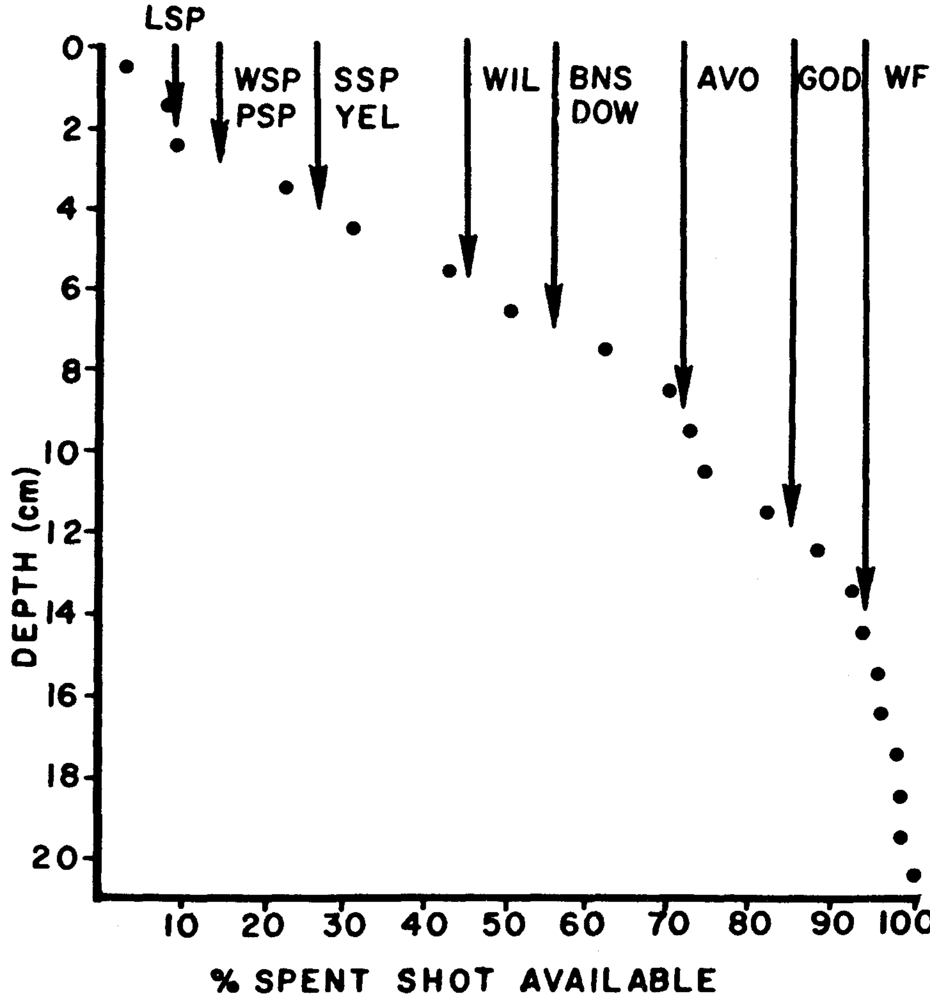

Figure 1. Depth of spent shot in relation to bill length (AVO = avocet, GOD = godwit, YEL = yellowlegs, WIL = willet, remaining abbreviations as in Table 2),

The estimated shot density in ponds within the collection area varied greatly, from a minimum of 296,000 to a maximum estimate of 930,000 shot per acre. The mean depth of shot was more uniform, ranging from 6.9 to 8.3 cm. The overall range of shot depth was 0.5 to 20 cm. Figure 1 illustrates the depth of shot in relation to bill length of the probing species investigated. Those species with bills less than 4 cm long would only be exposed to 23.5% of available spent shot. This is in contrast to those with bills over 6 cm which would be exposed to a minimum of 62.7% of estimated shot, and the white-faced ibis (bill length 13.6 cm) which would be exposed to over 94% of the deposited shot.

Probing species with lead shot present in their gizzard had significantly higher levels of lead and arsenic in their bones (Table 3). There was no difference in the mean lead or arsenic concentrations in livers of these three groups, nor in the concentrations of the other elements in any tissue. Unexplainably, probing species without lead shot had significantly lower arsenic in their feathers than the other two groups.

Table 3. Summary of means (and standard errors) of Pb and As concentrations (mg per kg) in bones, feathers, and liver samples of 14 species of marsh birds.

ELE	TIS	PROBERS WITH PB IN GIZZARD N = 50	PROBERS WITHOUT PB IN GIZZARD N = 46	NON-PROBERS N = 22
	B	11.28 (0.96) a+	5.47 (0.48) b	6.22 (0.68) b
Pb	F	3.87 (0.44) ab	5.20 (1.26) b	2.03 (0.39) a
	L	0.34 (0.33) a	0.03 (0.02) a	0.00 (0.00) a
	B	12.80 (0.80) a	8.75 (1.43) b	5.35 (0.76) b
As	F	8.87 (0.73) a	4.84 (0.70) b	12.09 (3.33) a
	L	4.48 (0.76) a	5.09 (0.45) a	3.63 (0.37) a

+ Means within rows with same letter are not significantly different ($p < 0.05$, Duncan's multiple range test).

Much of the variation in the occurrence of ingested spent shot can be explained solely on the basis of feeding habits of the species investigated. Obviously, one would expect little or no ingestion of shot in those species which do not come in contact with it. Thus it is not surprising that we did not observe shot in the terns, egrets, night herons, gallinules, or rails. On the other hand, species which probe into the sediment in search of food are likely to come in contact with spent shot, especially those which frequent ponds and other hunted marsh habitats. Within this group, two factors appear to be important in judging the tendency to ingest spent shot. In marshes along the northern Texas gulf coast, suitable grit material is often limiting and those species which prefer larger material may pick up shot as a consequence. Thus the percent of grit material sized greater than 2 mm may be an indicator of the susceptibility of a particular species to ingestion of shot. In addition, bill length in relation to depth of available shot seems to be a good predictor of whether or not a species will ingest shot. In our study area, most of the spent shot is deeper than those species with bills shorter than 6 cm can reach. Of the species we collected which did not contain shot, only the willet and the American avocet (8.9 cm) had bill lengths which approached that limit. However, habitat preference may be more significant in this case since willets tend to frequent mud flats and shallows along the shoreline rather than heavily hunted inland ponds. Unfortunately we were only able to collect one avocet. Since avocets skim the surface of ponds for insects and larvae rather than probing into the sediment they too would not be expected to come into contact with high densities of spent shot.

While those species with ingested shot had higher lead levels than those without shot, the levels did not approach toxic levels reported for other waterfowl. Especially in liver tissue, lead concentrations were quite low, usually below our detection limits. However, arsenic levels in liver tissue were higher than those reported by White et. al. (1980). They measured arsenic concentrations from 0.05 to 0.23 ppm which they felt reflected background contamination and were not harmful. Thus the concentrations we measured may be an indication of higher than normal environmental levels or due to the trace levels of arsenic that are present in lead shot.

In conclusion, continued deposition of lead shot into the environment is a problem for many bird species in wetland habitats. Not only do economically important species of ducks and geese suffer, but other species are also exposed to these potentially toxic levels of lead. Especially during dry periods individuals are concentrated in areas that have high spent shot densities. Under these circumstances species which probe for food deep into the sediment are especially susceptible. As water levels drop, more and more species are capable of reaching depths at which shot is deposited. However, even if ponds become completely dry, it is unlikely some species such as the small sandpipers will come in contact with high densities of spent shot.

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