Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 89-94
received 4/21/98
accepted 6/9/98

Food Contents of Mallard Gizzards With and Without Ingested Lead or Steel Shot

Stephen P. Havera
Illinois Natural History Survey
Forbes Biological Station
P.O. Box 590
Havana, IL 62644

William L. Anderson
Department of Natural Resources
Natural Resources Studies Annex
1910 Griffith Dr.
Champaign, IL 61820

ABSTRACT

The diets of hunter-harvested mallards (*Anas platyrhynchos*) taken throughout Illinois from 1979 to 1981 and containing ingested lead shot, ingested steel shot, or no shot were compared. This is the first known study to investigate whether free-ranging mallards mitigate the effects of lead exposure by adjusting their diets. Mallards containing ingested lead shot consumed significantly more plant matter ($P < 0.001$) and a higher number of plant species ($P < 0.001$) than controls. In addition, our results indicate ($P = 0.07$) that mallards with ingested lead shot were more likely to consume animal matter than controls. These findings agree with numerous dosing studies that have demonstrated the role of diet in alleviating the symptoms of lead poisoning in waterfowl.

INTRODUCTION

The ameliorating effects of diet and the rate of food consumption on the toxicity of ingested lead in waterfowl are well documented. Several investigations have reported the effects of diets on lead poisoning in waterfowl (Jordan and Bellrose 1951, Sanderson and Irwin 1976, Forbes and Sanderson 1978, Sanderson and Bellrose 1986). These investigations concluded that the amount of food, protein, calcium, and soil consumed may have some mitigating effects on the symptoms of lead poisoning in ducks dosed with lead shot. Jordan (1968) noted that when given a choice of food items, lead-poisoned birds shifted to items more easily digested. He suggested that lead-poisoned birds in the wild may select foods that tend to alleviate the effects of lead and thereby enhance their probability of surviving. Jordan and Bellrose (1951) concluded that diet rather than the level of shot dose was the more important variable in lead poisoning. Diet also had a major influence on the retention and erosion of lead pellets in the gizzards and the amount of lead retained in body tissues of mourning doves (*Zenaida macroura*) (Marn et al. 1988). However, to our knowledge, the diets of free-ranging wild ducks containing ingested lead or steel

pellets have not been examined. This study investigated whether wild mallards with ingested lead shot attempt to ameliorate the symptoms of lead exposure by modifying their diets.

METHODS

From 1979 to 1981, 9,300 hunter-harvested mallard gizzards were collected at 29 public and private sites throughout Illinois to document shot ingestion rates (Anderson and Havera 1989) and food habits (Havera 1998). Examination of gizzard contents by X ray (grit) and fluoroscopy (food) with visual verification, as described by Anderson and Havera (1989), revealed that 404 of the gizzards containing ingested lead shot pellets and 92 of those with ingested steel shot pellets also contained food. Steel (nontoxic) shot has been required for use in sport hunting of waterfowl in at least some areas of Illinois since 1977 (Anderson and Havera 1989). To investigate whether gizzard contents of mallards with ingested lead pellets or steel pellets differed from those without ingested pellets, an equal number of controls (404 for lead and 92 for steel) was selected randomly from those gizzards of harvested mallards taken on the same date and at the same location. This approach allowed for similar availability of food resources, which varied among weeks, years, and locations. Food contents of gizzards with lead shot were not directly compared with those that had steel shot because sample sizes from the same dates and areas were not sufficient.

The food contents were identified, measured by the use of the dry volumetric method (Rogers and Korschgen 1966; L.J. Korschgen, Mo. Dept. of Conserv., pers. commun.), and recorded to the nearest 0.01 ml; grit was measured to the nearest 0.1 ml (Havera 1998). The percent calcium content of grit from 75 randomly selected gizzards that contained ingested lead shot and their respective controls was determined by methods modified from Harper (1964) and Harper and Labisky (1964); the grit was dissolved in acid and a gravimetric procedure was used with inductively coupled argon-plasma emission spectroscopy.

Comparisons of food and grit contents (Table 1) between gizzards with ingested lead shot and their controls and gizzards that contained ingested steel shot and their controls were evaluated with Wilcoxon Signed Ranks Test. The percent calcium in grit in gizzards with ingested lead shot and their controls was compared by the use of the paired t-test (Wilkinson 1996). The aggregate volume of plant food and the percentage with animal food were compared for gizzards that contained ingested shot and their controls by use of the percent test (Sokal and Rohlf 1981:735). The level of statistical significance used was $P \leq 0.05$.

RESULTS AND DISCUSSION

There is evidence that the diet and body condition of hunter-harvested ducks may differ from those collected by researchers (Greenwood et al. 1986, Reinecke and Shaiffer 1988, Sheeley and Smith 1989, Dufour et al. 1993, Heitmeyer et al. 1993). Biases may also occur when contents from gizzards rather than from gullets (esophagi and proventriculi) are used to determine foods consumed by waterfowl (Perret 1962, Bartonek and Hickey 1969, Dirschl 1969, Swanson and Bartonek 1970). Although these shortcomings are of

major concern for food habits studies *per se*, we believe that gizzard contents from hunter-harvested birds are useable for our study objective of comparing relative food habits of mallards with and without ingested shot.

Of the various grit, plant, animal, and corn (*Zea mays*) variables compared, mallards with ingested lead shot consumed more plant matter ($P < 0.001$) and a higher number of plant species ($P < 0.001$) than their counterparts without ingested shot (Table 1). In addition, there was an indication ($P = 0.07$) that a higher percentage of them had eaten animal matter than their controls. There was no difference in the average volume of grit in gizzards with ingested lead shot and their controls. Although the average calcium content of grit in gizzards containing lead shot (0.183%) was higher than that for the control group (0.157%), the difference was not significant ($P = 0.25$). No difference in the amount of corn consumed was noted for mallards containing ingested lead shot.

The only significant difference between the diets of mallards with ingested steel shot and their controls was that the controls consumed more corn ($P = 0.03$). We can not explain the statistical or biological significance of this result other than speculating that either these control birds fed in cornfields with minimal hunting pressure and lower shot availability or perhaps that ducks with elevated iron levels from ingested steel shot for some reason chose more non-corn food.

A larger volume of plant matter (higher food intake) and a greater number of plant species in gizzards of mallards with ingested lead shot, in conjunction with an indication that more of these birds ingested animal matter (high in protein), suggest that wild mallards modify their diets to alleviate the symptoms of lead exposure and are consistent with the following findings from dosing studies.

The type of food consumed is probably the single most important factor affecting the toxicity level of ingested lead in waterfowl (Jordan and Bellrose 1951). Forbes and Sanderson (1978) remarked that the food consumed by waterfowl influenced the degree of lead poisoning through its nutritive content, binding capacity for lead, hardness and size, effect on acid secretion, and probably other factors. Sanderson and Irwin (1976) found that the diet of mallards apparently not only provided protection from lead after it was absorbed from the digestive tract, but diet also may have enhanced the excretion rate of lead. Stendell et al. (1979) concluded that diet had an important effect on the rate of uptake of lead in wing bones of mallards. Finley et al. (1976) reported that mallards dosed with one lead shot and maintained on a balanced diet may not accumulate extremely high lead levels in the kidney and liver. Jordan and Bellrose (1951) reported that birds maintaining a normal rate of food intake failed to show symptoms of lead poisoning and they suggested that the volume of food intake may be important in alleviating lead poisoning.

In several experiments with various kinds of foods, Jordan and Bellrose (1951) found that foods high in protein were most successful in alleviating lead toxicity. Natural food items mitigating lead poisoning included green foliage of aquatic plants, followed by small seeds, such as those of millets and smartweeds. Animal food was also beneficial whereas corn was the least beneficial. Sanderson and Irwin (1976), Finley et al. (1976), and Finley and Dieter (1978) noted increased toxicity of ingested lead in mallards fed a

corn diet. Chasko et al. (1984) determined that black ducks (*A. rubripes*) and mallards feeding on a variety of plant and animal foods were less susceptible to lead poisoning than those feeding on cereal grains. Koranda et al. (1979) noted that a high protein-calcium diet was important in mitigating the effects of lead in dosed mallards and that some aquatic plants were high in calcium content. Other studies have demonstrated the beneficial effects of protein or calcium in alleviating lead toxicosis in mallards (Godin 1967, Longcore et al. 1974, Clemens et al. 1975, Carlson and Nielsen 1985).

The use of lead shot for sport hunting of waterfowl was banned throughout the United States beginning in 1991. Unfortunately, spent lead shot will remain available in many wetlands into the foreseeable future. The encouragement of diverse and abundant plant and animal food resources on refuges, public hunting areas, and private clubs will help alleviate the impacts of lead exposure in waterfowl that ingest lead pellets. It is ironic that waterfowl may ultimately be the instruments that remove the last vestiges of lead shot from our nation's wetlands.

ACKNOWLEDGMENTS

Numerous Illinois Department of Natural Resources (IDNR) personnel, members and employees of duck hunting clubs, and private citizens collected gizzards. P.A. Brewer and G.E. Potts (IDNR) processed gizzards for ingested shot. R.L. Keen, Department of Veterinary Clinical Medicine, University of Illinois at Urbana-Champaign, performed the radiological work. G.A. Perkins, Illinois Natural History Survey (INHS), performed the food habit analyses and S.G. Wood and M.M. Georgi (INHS) determined the calcium content of grit samples. D.L. Swofford, J.D. Brawn, and A.P. Yetter (INHS) assisted with the statistical analyses. K.E. Roat (INHS) performed the word processing. F.C. Bellrose, J.M. Levengood, and G.C. Sanderson (INHS) reviewed the manuscript and C.E. Warwick (INHS) provided editorial assistance. The study was funded in part by Federal Aid in Wildlife Restoration Projects, W-43-R and W-88-R, with cooperation from IDNR—Division of Wildlife Resources, INHS, and the U.S. Fish and Wildlife Service, cooperating.

LITERATURE CITED

Anderson, W.L. and S.P. Havera. 1989. Lead poisoning in Illinois waterfowl (1977–1988) and the implementation of nontoxic shot regulations. Ill. Nat. Hist. Surv. Biol. Notes No. 133. 37 pp.

Bartonek, J.C. and J.J. Hickey. 1969. Food habits of canvasbacks, redheads, and lesser scaup in Manitoba. Condor 71(3):280–290.

Carlson, B.L. and S.W. Nielsen. 1985. The influence of dietary calcium on lead poisoning in mallard ducks (*Anas platyrynchos* [sic]). Amer. J. Vet. Res. 46(1):276–282.

Chasko, G.G., T.R. Hoehn, and P. Howell-Heller. 1984. Toxicity of lead shot to wild black ducks and mallards fed natural foods. Bull. Environ. Contam. Toxicol. 32:417–428.

Clemens, E.T., L. Krook, A.L. Aronson, and C.E. Stevens. 1975. Pathogenesis of lead shot poisoning in the mallard duck. Cornell Vet. 65:248–285.

Dirschl, H.J. 1969. Foods of lesser scaup and blue-winged teal in the Saskatchewan River delta. J. Wildl. Manage. 33(1):77–87.

Dufour, K.W., C.D. Ankney, and P.J. Weatherhead. 1993. Condition and vulnerability to hunting among mallards staging at Lake St. Clair, Ontario. J. Wildl. Manage. 57(2):209–215.

Finley, M.T. and M.P. Dieter. 1978. Toxicity of experimental lead-iron shot versus commercial lead shot in mallards. J. Wildl. Manage. 42(1):32–39.

Finley, M.T., M.P. Dieter, and L.N. Locke. 1976. Lead in tissues of mallard ducks dosed with two types of lead shot. Bull. Environ. Contamin. Toxicol. 16(3):261–269.

Forbes, R.M. and G.C. Sanderson. 1978. Lead toxicity in domestic animals and wildlife. Pp. 255–277 *in* J.O. Nriagu, ed. The biogeochemistry of lead in the environment. Part B: biological effects. Elsevier/ North Holland Biomedical Press, New York, NY. 397 pp.

Godin, A.J. 1967. Test of grit types in alleviating lead poisoning in mallards. Special Scientific Rep., Wildl. No. 107. U.S. Fish and Wildl. Serv., Washington, DC. 9 pp.

Greenwood, H., R.G. Clark, and P.J. Weatherhead. 1986. Condition bias of hunter-shot mallards (*Anas platyrhynchos*). Can. J. Zool. 64:599–601.

Harper, J.A. 1964. Calcium in grit consumed by hen pheasants in east-central Illinois. J. Wildl. Manage. 28(2):264–270.

Harper, J.A. and R.F. Labisky. 1964. The influence of calcium on the distribution of pheasants in Illinois. J. Wildl. Manage. 28(4):722–731.

Havera, S.P. 1998. Waterfowl of Illinois: status and management. Ill. Nat. Hist. Surv. Spec. Publ. No. 21. (Forthcoming).

Heitmeyer, M.E., L.H. Fredrickson, and D.D. Humburg. 1993. Further evidence of biases associated with hunter-killed mallards. J. Wildl. Manage. 57(4):733–740.

Jordan, J.S. 1968. Influence of diet in lead poisoning in waterfowl. Trans. NE Fish and Wildl. Conf. 25:143–170.

Jordan, J.S. and F.C. Bellrose. 1951. Lead poisoning in wild waterfowl. Ill. Nat. Hist. Surv. Biol. Notes No. 26. 27 pp.

Koranda, J.J., K. Moore, M. Stuart, and C. Conrado. 1979. Dietary effects of lead uptake and trace element distribution in mallard ducks dosed with lead shot. Wildl. Investigations Lab., Calif. Fish and Game Dep., Sacramento. 40 pp.

Longcore, J.R., R. Andrews, L.N. Locke, G.E. Bagley, and L.T. Young. 1974. Toxicity of lead and proposed substitute shot to mallards. Special Scientific Rep., Wildl. No. 183, U.S. Fish and Wildl. Serv., Washington, DC. 23 pp.

Marn, C.M., R.E. Mirarchi, and M.E. Lisano. 1988. Effects of diet and cold exposure on captive female mourning doves dosed with lead shot. Arch. Environ. Contam. Toxicol. 17:589–594.

Perret, N.G. 1962. The spring and summer foods of the common mallard (*Anas platyrhynchos platyrhynchos* Linn.) in south central Manitoba. M.S. Thesis, University British Columbia, Vancouver. 82 pp.

Reinecke, K.J. and C.W. Shaiffer. 1988. A field test for differences in condition among trapped and shot mallards. J. Wildl. Manage. 52(2):227–232.

Rogers, J.P. and L.K. Korschgen. 1966. Foods of lesser scaups on breeding, migration, and wintering areas. J. Wildl. Manage. 30(2):258–264.

Sanderson, G.C. and F.C. Bellrose. 1986. A review of the problem of lead poisoning in waterfowl. Spec. Pub. 4, Ill. Nat. Hist. Surv. 34 pp.

Sanderson, G.C. and J.C. Irwin. 1976. Effects of various combinations and numbers of lead:iron pellets dosed in wild-type captive mallards. Final Report. Contract No. 14–16–0008–914. U.S. Fish and Wildl. Serv. and Ill. Nat. Hist. Surv. 67 pp.

Sheeley, D.G. and L.M. Smith. 1989. Tests of diet and condition bias in hunter-killed northern pintails. J. Wildl. Manage. 53(3):765–769.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Second ed. W.H. Freeman and Co. New York, NY. 859 pp.

Stendell, R.C., R.I. Smith, K.P. Burnham, and R.E. Christensen. 1979. Exposure of waterfowl to lead: a nationwide survey of residues in wing bones of seven species, 1972–73. Special Scientific Rep., Wildl. No. 223., U.S. Fish and Wildl. Serv., Washington, DC. 12 pp.

Swanson, G.A. and J.C. Bartonek. 1970. Bias associated with food analysis in gizzards of blue-winged teal. J. Wildl. Manage. 34(4):739–746.

Wilkinson, L. 1996. Statistics: SYSTAT 7.0 for Windows. SPSS Inc. Chicago, IL. 751 pp.

Table 1. Characteristics of gizzard contents ($\bar{x}$ ± SD) of mallards with ingested lead shot, with ingested steel shot, or with no shot (controls). The gizzards were collected throughout Illinois during the hunting seasons, 1979–1981.

	Gizzards			
Characteristic	With lead shot (n=404)	Control (n=404)	With steel shot (n=92)	Control (n=92)
Volume of grit (ml)	2.16 ± 1.03	2.24 ± 0.83	2.21 ± 0.84	2.27 ± 1.03
Volume of plant matter (ml)	3.01 ± 2.22[A]	2.43 ± 1.83[A]	2.56 ± 2.19	2.84 ± 2.65
Volume of animal matter (ml)	0.04 ± 0.27	0.02 ± 0.19	<0.01	<0.01
Volume of corn (ml)	0.62 ± 1.52	0.75 ± 1.55	0.64 ± 1.51[B]	1.15 ± 2.55[B]
Aggregate volume of plant food in gizzards (%)	98.78	99.12	99.89	99.72
Percentage of plant food (%)	98.48 ± 9.12	98.94 ± 7.84	99.81 ± 0.73	98.63 ± 10.51
Number of plant species	4.3 ± 2.4[A]	3.7 ± 2.1[A]	3.6 ± 1.9	3.7 ± 2.3
Number of animal species	0.1± 0.5	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.3
Percentage of gizzards with animal food (%)	11.14[C]	7.43[C]	10.87	8.70

[A] $P < 0.001$
[B] $P = 0.03$
[C] $P = 0.07$