Spent Lead Shot and the Environment: A Topical Environmental Education Issue for Schoolchildren, Especially Rural Canadians and Native North Americans

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Abstract

On August 19, 1997, the Canadian Wildlife Service announced that the use of lead shot will be prohibited for the harvesting of migratory game birds, nation-wide, beginning on September 1, 1999. This paper presents some useful information with respect to the spent lead shot issue, as well as its most common replacement steel, and takes a holistic viewpoint. Hands-on activities are introduced that can be used at the elementary or secondary school level. The spent lead shot issue is a topical environmental education issue of particular interest to rural Canadians and Native North Americans for social, cultural, and economic reasons. The non-toxic shotshell issue will remain topical because concerns have been raised about the safety of substitutes, other than steel, with respect to the environment and human health.

Résumé

Le 19 août 1997, le Service canadien de la faune a annoncé qu'à partir du premier septembre 1999, l'usage des carabines à plomb serait défendu pour la chasse aux oiseaux migratoires, dans les réserves, à travers tout le pays. Cet article présente une information pertinente quant à la controverse des carabines à plomb ainsi qu'à son outil de remplacement, à savoir l'acier. Des activités expérientielles pour le primaire et le secondaire sont proposées. La controverse des carabines à plomb est un sujet d'intérêt en éducation relative à l'environnement, plus particulièrement pour les canadiens des régions rurales et pour les autochtones nord-américains et ce, pour des raisons sociales, culturelles et économiques. Des préoccupations ont été émises à propos de la sécurité de substituts autres que l'acier, en regard de l'environnement et de la santé humaine.

Lead is a toxin that adversely affects living organisms exposed to it, even at low levels (United States Centers for Disease Control [USCDC], 1991; Fleming, 1994). Moreover, there may be no safe level of lead exposure for living organisms (Rice & Silbergeld, 1996). In the past, lead had been documented to be present in a variety of environmental media (e.g., drinking water, air, soil, dust, consumer products); however, within the last two decades in North America, lead levels in the different environmental media have either been drastically reduced or eliminated. Examples include: the virtual elimination of leaded gasoline; lead-free solder being used in the canning industry; and a decrease in lead content in new paint products (USCDC, 1991; Fleming, 1994). Nevertheless, other sources of lead still exist, as has been highlighted in the mass media. These include: lead contained in plastic blinds (e.g., Flynn, 1996; Anon., 1996); lead contained in glazes used in bathtubs (e.g., Refinisher's News, 1995); and lead sinkers used in fishing (e.g., Scheuhammer & Norris, 1995). One significant source of environmental lead exposure that is very topical and important to rural Canadians and Native North Americans, in particular, is the use of lead shot for the harvesting of wild game (Tsuji & Nieboer, 1997; Tsuji, Nieboer, Karagatzides, & Kozlovic, 1997; Tsuji, Young, & Kozlovic, 1998).

In the United States prior to 1991, an estimated 6,000 tonnes of lead pellets were annually deposited into the environment (Humberg & Babcock, 1982). In Canada, approximately 2,000 tonnes of lead pellets are discharged annually into the environment (Scheuhammer & Norris, 1995). This spent shot may be ingested by birds and can cause numerous health effects, such as a decrease in reproductive capacity, immune suppression, and even death (United States Fish and Wildlife Service [USFWS], 1988; Scheuhammer & Norris, 1995). Two routes of lead exposure that may result in lead poisoning in birds have been identified:

- The primary route of lead exposure in birds is through the ingestion of lead pellets mistaken as grit. Grit typically consists of small stones stored in the gizzard (muscular organ of the birds stomach). Since birds do not possess teeth, grit is swallowed, stored, and used to grind the bird's food. The grinding action of the muscular gizzard erodes the lead pellets, and when coupled with the action of the gastric acids, breakdown of the lead pellet occurs. When soluble lead salts are formed, lead becomes bioavailable and may enter the body via the intestines. When toxic levels of lead enter into the body, lead poisoning occurs (Fisher, Hall, Wilder, Robinson, & Lobpries, 1986; Friend, 1987). A single ingested lead pellet is enough to cause mortality in birds (Longcore, Locke, Bagley, & Andrews, 1974.
- The ingestion of lead pellets embedded in tissue is a secondary source of lead exposure in birds. However, this is the primary route of lead exposure for predatory birds and scavengers (Eisler, 1988; Scheuhammer & Norris, 1995). Lead poisoning in birds has been recorded worldwide (e.g., Australia, Czechoslovakia, Denmark, Japan, the United Kingdom, Pain, 1992).

In the 1990s, the use of lead shot for waterfowl hunting was banned nation-wide in the United States and several other countries (e.g., Netherlands), due to the deleterious effects of lead on birds (USFWS, 1988; Annema, Booij, & Ros, 1993). In Canada, there are only a limited number of non-toxic zones where the use of lead shot is prohibited (Scheuhammer & Norris, 1995). In addition, as of September 1, 1997, hunters are now required "to use only non-toxic shot for hunting waterfowl and most other migratory game birds in areas within 200 metres of any water course or water body" (Canadian Wildlife Service [CWS], 1997). These new regulations are very ambiguous (Tsuji, 1997), thus, lead shot will still be widely used in Canada by Native Canadians as well as sport hunters until September 1, 1999, when a nation-wide ban on the use of lead shot for hunting migratory game birds is scheduled. It should also be mentioned that there are no regulations proposed (in Canada or the United States) restricting the use of lead shot for the harvesting of upland game birds (e.g., grouse, partridges) or small mammals.

In this paper, we present background information on the spent lead shot issue and subsequently discuss a frequently recommended non-toxic alternative, steel shot (soft iron). We also introduce several hands-on activities that can be incorporated into the curriculum at either the elementary or secondary school level. Hands-on activities have been shown to be effective educational tools with respect to the lead shot issue. In a study by Tsuji, Nieboer, & Karagatzides (1998), 47 randomly selected First Nation residents of the western James Bay region were asked an open-ended question: "Do you think lead shot used in hunting is bad for the animals, environment, and/or people of the James Bay region? Why?" Individuals were placed into one of two groups based on their answer: those who believed lead shot was a problem and those who did not. Forty participants believed that lead shot was not a problem or did not know whether it was a problem. On follow-up (after being involved in the adult spent lead shot environmental education program), all participants that were available (N=28) stated that they now believed that spent lead shot was detrimental to the environment, wildlife and/or human health. It appears that hands-on activities can be an important part of the learning process. The activities that will be described in this paper are primarily directed towards rural and Native schoolchildren, because harvesting of wild game with lead shotshell typically has more significance (social, cultural, and/or economic) to these groups compared to their urban counterparts (Tsuji, 1997). Other activities and programs for rural, urban, and Native North American schoolchildren, with respect to the environmental lead issue, in general, have been described in other articles (Kendler & Pirone, 1994; Marlowe & Trathen, 1996).

Background

Die-offs

Bellrose (1959; p. 236) suggests that the "most dramatic expression of lead poisoning in waterfowl are die-offs in which large numbers of birds in relatively small areas perish in short periods of time." However, larger waterfowl losses from lead poisoning probably are related to the "dispersed, day-to-day mortality that usually goes unnoticed" (Jordan & Bellrose 1951; p. 12).

Over the last two decades, known waterfowl losses in Canada due to die-offs have been limited (Scheuhammer & Norris, 1995). Only major die-offs are reported because low density waterfowl die-offs are difficult to document (Stutzenbaker, Brown, & Lobpries, 1986). In a study by Stutzenbaker et al. (1986), an 8 person search team found only 6 of 100 bird carcasses deposited 30 minutes prior even though 50 birds had been lying fully exposed atop vegetation. Moreover, Stutzenbaker et al. (1986) showed that of 47 duck carcasses used in a carcass longevity test, all carcasses were eventually consumed by predators and scavengers and a large portion were gone after the first day. Similarly, Humberg & Babcock (1982) found that within 5 days, approximately 90% of the carcasses put out were scavenged. These studies show that a large number of birds have to die before scavengers are unable to keep up and carcasses become visible in the field (Humberg & Babcock 1982). For these reasons, hunters (and your students) may not ever see a lead-poisoned bird in the wild even if they have hunted extensively for years (Stutzenbaker et al. 1986).

Signs And Symptoms Of Lead Poisoning In Birds

Birds that die of acute lead poisoning often do not show the signs and symptoms now described. Also, none of these signs or symptoms alone are diagnostic of lead poisoning. Pathological (microscopic tissue examination) and toxicological (tissue lead levels) data are also needed to make definitive (positive) diagnoses (Jordan & Bellrose, 1951; Friend, 1987).

Changes in behaviour that have been reported for lead poisoned birds include: birds that remain behind when others have taken flight; individuals that fly erratically for short distances; and birds that often seek cover and isolation when unprovoked. Changes in appearance of lead-poisoned birds include: wings assuming a characteristic "roof-shaped" position; birds chronically affected becoming emaciated, exhibiting a "hatchet-breast" with a prominent keel (breast) bone; loss of subcutaneous fat (no fat underneath the skin); bright green droppings sometimes staining the vent area (underside of the bird); and impaction (blockage) of the oesophagus and proventriculus (the soft part of the birds' stomach - Jordan & Bellrose, 1951; Friend, 1987).

Diagnosis Of Lead Poisoning In Birds

Three criteria commonly used to assess whether waterfowl have been exposed to lead are:

- presence of lead shot in the gizzards,
- lead residues in body tissues, and
- disruption of biochemical pathways (Friend, 1985).

The risk of exposure to lead pellets has been related to the amount of hunting in an area and the amount of lead found in the soil (Friend, 1985). An average of 500 person days or more annually in approximately a 200 km^2 area has been designated an area of intensive hunting (Dickson & Scheuhammer, 1993). The number of lead pellets in soil thought to constitute a hazard for waterfowl has been arbitrarily stated as 1 pellet per 0.2 m^2 of soil (Anderson, 1986; Anderson & Havera, 1985). These are measures of potential problem areas.

Actual measurement of lead shot ingestion can be done by manually examining the grit and/or by using radiography. Radiographs (X-rays) of gizzard contents (grit) are the most accurate way to assess the number of birds that actually ingest lead pellets (Montalbano & Hines, 1986). The Canadian Wildlife Service suggests two arbitrary levels of concern with regards to lead shot ingestion rates in birds: greater than 5%, more data required; greater than 10%, the establishment of a non-toxic zone is warranted (CWS, 1990). In the United States, the 5% level was considered the level of concern prior to the nation-wide ban in 1991 (United States Department of the Interior, 1986).

Liver and blood samples are usually examined to determine if lead levels are above background (normal) levels. Lead levels above 2 micrograms of lead per gram of tissue (wet weight) for liver and levels greater than 20 micrograms/dL for blood are considered elevated (Friend, 1985). Also, biochemical changes in blood caused by lead exposure have been measured, being used to infer lead poisoning in animals. In severe cases, these biochemical changes can result in brain damage in the organism (Anderson & Havera, 1985).

Steel Shot: A Nontoxic Alternative To Lead

The only readily available non-toxic shot in a variety of types is steel. Steel shot (or another "non-toxic" shotshell substitute) is already required in a limited number of non-toxic zones and other circumscribed areas in Canada (Scheuhammer & Norris, 1995; CWS, 1997). It is clear that once more supportive information is available, a nation-wide ban is probable for all migratory bird hunting. Before non-toxic regulations are imposed, it is important to educate the public to dispel misconceptions about steel shot and to win public support (Ronholt, 1992).

Physical Characteristics Of Lead Shot Compared To Steel Shot

Lead is much more dense than steel; thus, steel pellets are 30% lighter than lead pellets of the same size (Brister, 1992; Kruper, 1992). Lead is also approximately 44% softer than steel. Differences in the physical characteristics of the two metals used in making the pellets result in differences in the ballistic characteristics of the shot.

Cartridge Design And Ballistics

Since steel shot is approximately 30% lighter than lead shot, more space (volume) is required in the shell to load an equivalent weight of steel pellets compared to lead (Coburn, 1992; Kruper, 1992). Thus, the steel shotshell is a non-compressible shot wad (Coburn, 1992; Kruper, 1992). To compensate for the decrease in weight of lead pellets and to improve long range performance, steel pellets are launched at higher velocities than lead and require greater chamber pressures, at the permissible limit (Brister, 1992; Kruper, 1992). Slower burning propellants have been developed to offset the increase in chamber pressure (Coburn, 1992).

Upon being fired, the hard steel pellets do not deform like the soft lead pellets, there is no "setback deformation" (Brister, 1992). The hard steel pellets may damage (scratch) the interior of the barrel during passage through the gun, therefore, a special tough plastic shot cup was developed to encase the steel shot (Brister, 1992; Coburn, 1992; Kruper, 1992). The non-compressible shot wad can damage the choke constriction at the end of the gun barrel causing a basically cosmetic "ring bulge" (choke expansion) that reaches a maximum and expands no further (Brister, 1992; Kruper, 1992). About 4% of all North American shotguns have the potential for choke expansion; most North American single barrelled, pumpaction, and semi-automatic shotguns can handle steel shot without modification (Smith & Townsend, 1981; Brister, 1992; Shedden, 1992). However, the use of steel shot in thin-barrelled and soft-steel barrelled shotguns such as the double-barrelled (side-by-side and over-under) shotguns favoured by British hunters and older models of shotguns in North America, may result in significant choke expansion and even rib or barrel separation (Humberg & Babcock, 1982; Brister, 1992; Shedden, 1992).

After exiting the gun barrel, since steel pellets deform less, fewer pellets stray from the main swarm compared to lead (Brister, 1992; Kruper, 1992). This surface area and frictional effect can clearly be demonstrated in the class. All that is needed is a tub of water to demonstrate this effect. Have a student move a closed hand slowly through a tub of water (simulating a round steel pellet) and compare this movement to the movement experienced when the hand is fully opened (simulating a deformed pellet). The closed fist will move relatively straight in the water, while the opened hand will deviate from a straight path. The result of this surface area and friction effect is that steel pellets pattern tightly (smaller diameter), when impacting a target, with a greater number of pellets (increase in density) near the centre of the pattern, compared to lead (Brister, 1992; Kruper, 1992; Morehouse, 1992). Since steel pellets are also lighter, they do not retain comparable down-field velocity compared to lead shot, resulting in a decrease in target penetration (Brister, 1992; Coburn, 1992; Kruper, 1992; Morehouse, 1992). Further, steel shot does not deform as much as lead shot upon impact, resulting in a clean wound (that is, no feather balls like with lead - Morehouse, 1992). These characteristics have been perceived by the hunting public as a decrease in "knock-down" power when steel shot is used (Mikula, Martz, & Ryel, 1977). Therefore, it is recommended when using steel shot to use 2 sizes larger than normally used with lead shot to obtain ballistic characteristics similar to lead (e.g., steel # 4 replaces lead # 6 - Brister, 1992; Coburn, 1992; Kruper, 1992). It is also recommended when using steel shot to decrease the range at which waterfowl are shot to decrease crippling rates (Brister, 1992; Coburn, 1992).

Crippling Rates

Hunters have often claimed that steel shot is ballistically inferior to lead shot and that the use of steel shot increases crippling of waterfowl and offsets the benefit of decreased mortality due to lead poisoning (Morehouse, 1992). Although crippling rates did increase in the United States when steel shot was introduced, once hunters adjusted to the ballistic characteristics of steel shot, crippling rates for waterfowl have fallen, approaching earlier levels when lead shot was used (Morehouse, 1992). When comparing mortality figures for steel versus lead, one must compare steel shot crippling rates to lead shot crippling rates *plus* mortality rates from lead poisoning (Pain, 1992). Moreover, Morehouse (1992; p. 33), summarizing all available information on the performance of lead and steel shot in the field, found "no clear advantage to either lead or steel."

Safety Factors And Side Effects

Steel shot should be kept dry and checked occasionally by cutting a shell open to examine whether rusting together of steel pellets has occurred (Brister, 1992; Kruper, 1992). Moisture may also cause ignition problems resulting in a misfire, thus, if a hunter experiences a light recoil, the barrel should be checked for obstruction (Brister, 1992). Although steel pellets ricocheting off objects is not a major problem, one must be aware of this potential problem to avert accidents (Brister, 1992; Kruper, 1992).

Since steel shot is significantly harder than lead shot, there is a chance that human teeth may be damaged by tissue embedded steel shot (Kruper, 1992). Similarly, steel pellets embedded in trees can break the teeth on expensive blades used at saw-mills (Kruper, 1992).

Hands-On Activities

Class Preparation

Prior to the proposed field trip, students should know why lead exposure is an important environmental issue. Much of the material presented earlier in this article would be appropriate. Moreover, an expert (e.g., provincial/territorial wildlife worker or Canadian Wildlife Service representative) could be asked to give a classroom presentation. Students must be properly prepared, having a clear idea of the questions they are asking, related to the specific class and field activities.

Students should have the opportunity to see and manually examine different sizes and types of shot so they can readily identify them later, in the field and/or classroom. Pellets of different composition and size can either be purchased or obtained from local hunters. Plastic shotshells are easily cut with a knife to expose the pellets inside. Physical characteristics of the different types of pellets should be distinguished at this time. Activities could include: assessing the colour of the different shot types; weighing same size lead and steel pellets to ascertain relative density; determining relative hardness of the materials used to make the different types of shot, by squeezing pellets with a pair of pliers; and testing the magnetic properties of the pellets using a heavy-duty magnet. Actual size of the pellets (cf. manufacturer size designations such as #2, #4, #6, etc) can be determined for each material type, through direct linear measurement using a ruler or calipers (if available). This baseline information is important for future reference by students while in the field and after samples are collected. It should be stressed that the empty shotshells should be handled and disposed of with care because the propellant is still contained within the shell. Also, thorough washing of hands should be exercised after manipulation of the lead pellets to decrease the chance of lead exposure.

Examining Soil/Sediments For Pellets

If possible, two field trips to a heavily hunted area should be conducted; one prior to and one immediately after the hunting season is recommended. Hunting pressure can be estimated by comparing shot numbers before and after the hunting season. If only one field trip can be scheduled, it should be after the hunting season. Material required in the field includes: sieves, pails, shovels, quadrats, tape measure, large plastic bags, small plastic zip-lock bags, magnets, pliers, notebook, and pencil. A sieve can easily be constructed using a wooden frame, mesh/screening, and nails.

The community should also be involved at this point with students collecting information from experienced hunters about suitable areas to examine. That is, local hunters can identify areas of interest such as heavily hunted areas (e.g., well-used hunting blinds or community hunting areas). Students themselves could also conduct general surveys of potential areas assessing hunting pressure by number of spent shotshells located. Once a study area has been selected, teachers should review, in the class, the rationale behind and the methodology of the sampling techniques to be employed in the field.

In the field, sampling should be undertaken along a straight line (transect), at least 400m in length, through the area under consideration. Ten to twenty sites could be sampled along the transect. Each site should be separated by a specified distance (e.g., 20 m) to get a good representation of the area. Using a transect allows a representative sample to be obtained in a specified area. If all samples were taken from only one small circumscribed area, the data would be considered biased, being non-random (i.e., not representative of the whole area). Data must be representative to allow for subsequent statistical comparisons with known random distributions, to test if the observed/collected data differs significantly (e.g., probability<0.05) from randomly generated data. Generally, the importance of data can only be ascertained if the data were collected randomly.

At each site, the quadrat (e.g., .25 m^2) should be dropped to the ground. All above-ground vegetation should be clipped to ground level and discarded. Steel shot laying on the ground surface can be picked up at this point, using a heavy duty magnet.

All soil and sediments within the quadrat and up to 20 cm down (typically, the depth of vegetative growth), should be dug up and placed in large plastic bags. Prior to sieving the soil samples, a small subsample (without pellets) should be collected in small, marked, zip-lock plastic bags that correspond to each site along the transect. These soil samples can be taken back to the class and the various physical characteristics of the soil (e.g., texture) should be noted, using a soil guide (e.g., Ontario Centre for Soil Resource Evaluation, 1993). It is important to identify the type of soil because soil type is known to influence the availability of pellets to waterbirds. Pellets distributed on fine soil type usually becomes unavailable to waterbirds, sinking down to great depths. Meanwhile, pellets deposited on more coarse soil material remains close to the surface and relatively more accessible.

Soil from each large plastic bag can be sieved in the field (or in the classroom) using water from pails. Below-ground vegetation should be removed from the sieved material and the remaining material should be examined for pellets. This methodology is repeated at each sample site. The pellets obtained can be tested back in the classroom for composition, using a magnet (steel pellets are magnetic, lead and bismuth are not) and/or pliers (steel does not deform, lead does, and bismuth does to a lesser extent). Data collected should be presented as number of lead (or steel) pellets per $0.2m^2$ of soil, so that results can be compared to the level of concern, one lead pellet per $0.2m^2$ of soil. Even when legislation is passed restricting the use of lead shotshell for migratory bird hunting, this hands-on activity can be continued, to assess compliance with the non-toxic regulations. That is, the proportion of steel to lead pellets in an area should increase, if people are complying with the new regulations.

A Simple Classroom Experiment

It has been estimated that lead shot can persist in the environment for up to 300 years, with the dissolution of the pellets being dependent on the acidity of the environment (Jorgensen & Willems, 1987). The more acidic the environment, the greater the dissolution of the lead pellets, and the greater the environmental threat (Jorgensen & Willems, 1987). On the other hand, steel shot quickly corrodes and even requires a rust inhibitor (Coburn, 1992).

A simple experiment can be performed in the classroom to examine the difference in degradation of lead and steel pellets. Two groups of 10 lead pellets each, should be weighed with the two weights recorded. Similarly, two groups with 10 steel pellets in each (these pellets must be the same size as the lead pellets, so that appropriate comparisons can be made), should be weighed separately, and the weights recorded. One group of 10 lead pellets and one group of 10 steel pellets should be placed into separate, marked, glass beakers, each containing normal rain or tap water. The remaining group of 10 lead pellets and 10 steel pellets should also be placed into individual, marked, glass beakers, each containing acetic acid (i.e., vinegar). The degradation of the two types of pellets in each type of solution can be recorded using two methods: qualitatively, documenting the amount of surface area visually corroded for each pellet type; or quantitatively, actually weighing the lead and steel pellets at specific time intervals. The relative effect of acidity can also be estimated by comparing same pellet type in different solutions (i.e., water vs. vinegar). This experiment should crudely show that even when lead shotshell is banned for all wild game hunting, the lead legacy is a lasting one.

Examining Grit For Pellets

Community involvement is important for this activity. Game bird samples can be collected from community members and empty gizzards returned for consumption. Whole body bird specimens and/or gizzards already removed from the body can be used (if the species is known), either fresh or after thawing. The use of whole specimens is advantageous because the class is able to see where the organs are actually located. An anatomy lesson could be incorporated as part of the lead module. If teachers are not comfortable with dissecting a whole specimen, students with experience "cleaning" wild game can be enlisted to help. In this way, teachers act as facilitators and students can teach by example. This process builds student self-esteem.

Once gizzards are obtained, they should be examined for entry wounds, that is, where pellets have penetrated the tissue. Subsequent to the initial examination, gizzards should be incised in a criss-cross pattern to allow for the emptying of gizzard contents. Gizzard contents should be emptied into a white-coloured bowl, to provide optimal contrast with the grit. All grit adhering to the inside of the gizzard should be rinsed with water into the bowl. The grit should then be washed with flowing water, using the hands to separate vegetation through floatation from the grit in the bowl. Vegetation is lighter than the grit so is easily separated from it. This vegetation, after removal, can be dried and examined to determine what the birds were eating. After the vegetation has been removed, the remaining water and grit can be separated by tilting the bowl, allowing the water to drain away. The remaining sediment (grit) can then be manually examined under magnification (e.g., a magnifying glass) for pellets and/or pellet fragments. The pellets/fragments obtained can be tested for composition as previously described. Pellets that exhibit uneroded "shot facets" (flat areas on the surface of the pellet), where an entry wound in the gizzard has been noted, cannot be counted as ingested; these pellets were shot in. Ingested pellets show signs of wear and may not be spherical in shape; flat discs have been noted (Tsuji et al. 1998).

Often, pellets/fragments can be missed during manual examination of the grit. Accuracy of detecting ingested pellets can be increased by approximately 20% using radiography (Anderson & Havera, 1985). Prior to radiographs, grit samples are placed in the bottom portion of individual 60 x 15 mm clear plastic petri dishes. Petri dishes with grit can then be placed, individually, on single Kodak Ultra Speed (size 4) occlusal film, and radiographed (70 kv, 7 ma, 18 msec). Alternatively, many petri dishes can be radiographed at one time, using larger x-ray film and a larger x-ray unit. Examples of processed radiographs (individual petri dishes) are presented in Figure 1. Grit samples with a corresponding radiograph showing a positive signature (Figure 1), must be subsequently re-examined for pellets to distinguish between the different shot types (Tsuji et al. 1998). Grit samples that did not contain pellets, should be dried for two days at room temperature, and then stored in marked paper envelopes. Hands must be washed any time grit or pellets are handled, to decrease the risk of lead exposure.

Radiographs can be taken and processed cheaply (approximately $1.00 to $3.00 Cdn per radiograph, depending on the size of film) by community dentists, using standard dental equipment or by x-ray technicians, employed at hospitals or nursing stations. Even remote communities have dental offices and radiographic facilities located in nursing stations or hospitals. Dentists and other health care professionals, should willingly cooperate; for them, it is a good public relations opportunity.

Data should be presented as the percent of individuals for a single species, ingesting lead pellets. The number of pellets ingested per bird within a species should also be reported. Data reported can remain descriptive or the frequencies of lead ingestion for each bird species can be tested against an expected lead ingestion rate of 5% (the arbitrary lower level of concern), using a Chi-square goodness-of-fit-test (Tsuji et al. 1998, information on this statistical test can be found in most statistic books).

Figure 1. Radiographs (x-rays) of grit (small stones) samples collected from bird gizzards. The radiograph above shows only grit, that is, there is no lead shot present. The radiograph below shows lead shot (the white round object) in the grit, thus, illustrating that the bird represented below ingested a lead pellet.

Determining Grit Size

Several factors can affect the susceptibility of different species of waterbirds with respect to the ingestion of lead pellets. In a study by Pain (1990), a strong relationship for bird species was demonstrated between the size of the grit ingested and the susceptibility to pellet ingestion. Bird species which ingested a large amount of grit greater than 2mm in diameter were found to be more susceptible to pellet ingestion. Pellets used to harvest these types of birds were generally larger than 2mm in diameter (Pain, 1990).

Grit samples that were dried and stored in marked paper envelopes in the previous activity can be used in the present activity. These samples were previously sorted to exclude any samples with a pellet, since the presence of pellets in the gizzard may have altered the normal composition of the grit for that particular individual (Pain, 1990). The methodology presented now is a simplified version of that used by Pain (1990). One hundred pieces of grit should be randomly selected for each bird with the species being identified. If less than 100 pieces of grit are present, use all the grit. Only the long axis for each piece of grit, should be measured (linearly), using a ruler or caliper (if available). Mean grit size should be calculated for each individual. Individual results should be grouped according to species. This information should help the student in answering the question: Is there any crude relationship between the size of grit utilized by a bird species and the probability that a bird species will ingest lead shot?

Follow-Up Writing Exercise

The writing of reports by small groups of students, using class generated data, would help students develop their writing skills, interpersonal skills, as well as their critical thinking. The data obtained can be discussed in class and the report given to the community, to increase public awareness to the lead shot problem. However, one must be aware of the limitations of the data collected. The data collected was to facilitate student education; if one of the objectives is to make the data available to interested parties, such as the Canadian Wildlife Service, the sampling procedure must be more rigorous than previously described and there must be an adequate amount of data from which to draw conclusions. For example, with respect to lead shot ingestion, it must be shown that the birds could not have been exposed to lead shot other than in the study area. The way to do this is by limiting the sample to fall migratory birds. There is a possibility that spring migratory birds may have ingested pellets while migrating through the United States. Moreover, if only hatch-year birds were collected, it is most probable that any pellets found in the gizzard would have been ingested locally. Aging of geese or ducks can be done accurately; experienced hunters as well as wildlife biologists would be of great help in this endeavour. High quality data, as described above, collected from various regions across Canada, would supply a more comprehensive picture of the lead poisoning problem of birds while in Canada (V. Thomas, pers. comm.). This type of data could be sent to the Canadian Wildlife Service for their use.

Discussion

Recently, experiential and hands-on educational approaches have become more widely accepted by educators. The "mainstreaming" of these educational approaches is apparent in the proliferation of journals and magazines such as, *Hands On!*, *Journal of Experiential Education*, *Holistic Education Review*, and the *Green Teacher*. It should be stressed that experiential and hands-on educational approaches have *always* been a part of traditional educational practices of Native North Americans. Most indigenous people do not flourish in educational settings that are textbook- and teacher-centred (Larose, 1991; Hampton, 1993). Effective Native education typically involves experiential and hands-on education that is delivered in a culturally appropriate manner (Lipka, 1990; Zwick & Miller, 1996). In an important study by Zwick & Miller (1996), the performance of two groups of Grade 4 schoolchildren were measured by the California Achievement Test 85. The control group consisted of 12 Native and 13 non-Native children. The experimental group contained 10 Native and 14 non-Native children. The control group received a "regular" classroom-based science education, while the experimental group was involved in an outdoor-based, hands-on educational experience (Zwick & Miller, 1996). Results of the study indicate that Native students provided with the outdoor-based, hands-on science curriculum scored significantly higher than Native students presented with a classroom-based, teacher- and textbook-centred teaching environment. In contrast, no significant differences in scores between non-Native students in the experimental and control groups were reported. Moreover, no significant differences were noted between scores of Native and non-Native students in the experimental group. It appears that Native children learn best in a outdoor-based (experiential setting), hands-on teaching environment, while non-Native students learn, at least, equally well in either educational setting (Zwick & Miller, 1996). Thus, Native children would benefit from the experiential and hands-on activities we have described with respect to the lead shot issue. Further, the education of non-Native children should not be negatively impacted upon using this type of approach.

The depth to which one wants to examine the spent lead shot issue determines the educational level that is appropriate (elementary or secondary). For example, a discussion of the "physics" involved in the ammunition issue (i.e., ballistics) is best handled at the secondary school level, while discussion of the ingestion of pellets and the anatomy of the bird can be done at both the elementary and secondary level.

The lead shot issue can also be approached holistically. Lead shot is not just a wildlife health issue, it is also a human health issue. It has been reported in several studies (e.g., Hubbard et al. 1965; Scheuhammer & Norris, 1995; Tsuji, Nieboer, Karagatzides, & Hanning, 1996) that a relatively large percentage of wild game harvested with lead shot becomes contaminated with lead, above the level set for human consumption (0.5 microgram of lead per gram of tissue wet weight - Health Canada, 1995). In addition, approximately 15% of randomly selected radiographic charts of subsistence harvesting people inhabiting the western James Bay region exhibited evidence of lead pellets in the digestive tract (Figure 2; Tsuji & Nieboer, 1997). Taking into account that ingested lead shot and leaded objects elevate blood lead levels of individuals (Biehusen & Pulaski, 1956; Greensher, Mofenson, Balakrishnan, & Aleem, 1974; Madsen, Skjodt, Jorgensen, & Grandjean, 1988), and that evidence is growing that any exposure to lead can be harmful (Schwartz, 1994; Rice & Silbergeld, 1996), then from a human health perspective, real concern exists about the continued use of lead shot for the harvesting of *any* wild game .

Figure 2. An abdominal radiograph illustrating that humans ingest lead pellets embedded in wildgame. The lead pellets (white round objects) are contained within the digestive tract.

In addition, even when lead shot is banned for the harvesting of all wild game, questions will remain about other "non-toxic" substitutes, such as bismuth/tin shot, as is described in Tsuji & Nieboer (1997).

Note

More information on the lead shot issue can be obtained on the INTERNET:

- http://www.ec.gc.ca/cws-scf/pub/ops/op88/home.html
- http://www.ec.gc.ca/cws-scf/pub/hunting/lead.html
- http://www.ec.gc.ca/cws-scf/pub/hunting/toxic.html
- http://www.ec.gc.ca/press/lead_n_e.htm
- http://www.ec.gc.ca/press/lead_b_e.htm

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