SETAC 1998 SYMPOSIUM SESSION:

" Hunting with Lead Shot - Wildlife and Human Health Concerns "

ABSTRACT AND PRESENTATION COLLECTION
SETAC 1998

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November 1998

Executive Summary:

Wildlife Effects from the Continued Use of Lead Shot:

Spent lead shot from the use of lead shotshell ammunition has been known to have toxic effects in waterfowl since the late 1800's. Primary lead poisoning from ingestion of lead shot has also been reported in upland game birds including mourning doves, northern bobwhite, gray partridge, pheasant, ruffed grouse, scaled quail, wild turkey and wood pigeon.

Secondary lead poisoning from the ingestion of lead shot embedded in prey has been recorded in raptors in North America, Europe and Asia. It has been documented most thoroughly for bald eagles (*Haliaeetus leucocephalus*) in the USA and has been documented in golden eagles (*Aquila chrysaetos*) in Canada, the USA and Europe.

The prevalence of lead poisoning in 130 bald and golden eagles found dead in Canada was reported to be 12 %. Elevated exposure, including poisoning, occurred in 23% of golden eagles and 16% of bald eagles. Lead-exposed bald eagles were found more frequently in areas of high waterfowl hunting than in areas where waterfowl hunting was low. In contrast, lead-exposed golden eagles were found more frequently in areas with low waterfowl hunting. Lead shot in crippled or sick waterfowl may be a major source of lead in bald eagles in Canada, however other sources of lead most likely explain elevated lead exposure in golden eagles.

Examination of over 600 eagles in the United States during the past two decades has revealed that the prevalence of lead poisoning in eagles has not declined since the U.S. prohibition on the use of lead shot for waterfowl hunting in 1991. These findings have forced researchers to question whether embedded shot in waterfowl is the primary source of lead exposure in eagles. Temporal analysis of lead exposure in eagles indicates that most lead poisoning cases in eagles is coincident with deer hunting seasons in the northern United States and the eagle's migration from the northern reaches of their range into the area.

In 1999, Canada will require the use of non-toxic shot for waterfowl hunting nation-wide following the actions taken in the USA in 1991. Increasing evidence of elevated lead exposure in wildlife from the continued use of lead shot has prompted some countries to restrict the use of lead shot for upland hunting. Denmark and the Netherlands require non-toxic shot for all hunting nationally. Canada requires the use of non-toxic shot for all hunting within National Wildlife Areas. Similar action has recently been proposed within National Wildlife Refuges in the United States. The effectiveness of these regulations in reducing lead exposure in wildlife, particularly eagles, will continue to be investigated.

Investigations into the use of lead ammunition on target shooting ranges has revealed that lead in the form of lead shot or bullets may be subject to dissolution and mobility under certain environmental conditions. Major influences on lead mobility are exerted by both extrinsic factors such as rainfall quality and quantity, and intrinsic factors such as soil pH and vegetative cover. The most viable options to control lead mobility at shooting ranges include lead recovery and recycling, control of runoff, control of pH with additions of agricultural lime, precipitation via additions of agricultural lime or phosphate, and sorption to clays. Appropriate environmental management of range conditions including deterrence of wildlife use of the area will minimize lead exposure to wildlife and range participants.

Human Health Effects from the Continued Use of Lead Shot:

Non-commercial food items including wild game are generally not subject to routine surveys to insure food quality standards. A national survey of wild foods conducted in Canada found biologically incorporated lead in game bird muscle tissues to be well below consumption guidelines established for lead in fish protein (0.5 ug/g ww), however elevated lead levels (> 0.5 ug/g ww) were found in 11 % of over 800 pooled game bird breast muscle samples. Some samples of muscle tissue from individual game birds contained hundreds of parts per million of lead, even though samples had been examined prior to processing to remove any embedded lead shot pellets. Following radiological exam, these elevated levels were found to be due to tiny fragments of metallic lead, most probably from partial disintegration of pellets passing through the tissue.

Approximately 15% of randomly selected radiographic charts examined at a regional hospital in the James Bay Region of northern Ontario had evidence of pellets lodged in the digestive system, intraluminally and/or in the appendix. In addition, 9% (33/731) of edible skeletal tissue samples from game birds harvested using lead shot in the region had lead levels greater than the Health Canada consumption guideline for fish protein of 0.5 ug/g ww (or ~2 ug/g dw). Elevated lead in these tissues was shown through radiography and subsequent atomic absorption spectrometry (AAS) to be the result of lead pellets/fragments embedded in the tissues. Elevated lead levels in tooth dentine in both adults and children have also been reported in the region. Researchers determined that dentine lead levels increased significantly with age and suggested that elevated lead accumulation might be related to the use of lead shot for subsistence harvesting in the region.

Results from a study conducted in the province of Québec, Canada, showed that 7.6% (n=238) of Inuit newborns from Nunavik had blood lead levels of 10 ug/dl or more, compared to 0.2% (n=955) of babies from the Southern part of Québec. Based on isotopic analysis of blood samples, researchers suggest that elevated lead levels observed in this region are consistent with exposure to lead shot through dietary consumption of waterfowl and other game containing embedded shot fragments.

Human ingestion of lead pellets or fragments through consumption of game harvested with lead shot, has been reported in the literature since 1842. Lead fragment ingestion has been most commonly reported in Canada and other countries with communities that consume harvested game. The amount of lead absorbed by the blood from the gastrointestinal tract of adults is typically 10 - 15 % of the ingested quantity, however, higher absorption levels often occur in pregnant women and children. Ingestion of lead shot pellets and fragments has resulted in elevated blood lead levels and gastrointestinal complications in some individuals; however, clinical evidence of lead poisoning is rarely reported. The possible adverse effects on human health from the consumption of game harvested with lead shot warrants further attention.

Since the early 1980s, the subtle neurological and neurobehavioral effects of low-level lead exposure in fetuses and young children have become major public health research priorities. Based on epidemiological evidence, the US Centers for Disease Control (CDC) revised its sanitary intervention threshold downward to 10 g/dl lead in whole blood in 1991. Effects of high lead exposure such as encephalopathy, anemia and chronic nepropathy are well known, but knowledge on the effects of chronic low dose exposure has progressed only in the recent years. Blood lead levels in the range of 10 - 15 g/dL in infants and young children are associated with neurobehavioural and cognitive impairment. No LOAEL has been defined for these effects, and their reversibility is uncertain. Other low dose exposure studies continue.

As long as lead shot and other lead ammunition continues to be used to harvest game, edible tissues will contain embedded lead fragments and pose a risk of elevated lead exposure to wildlife and human consumers of wild game.

Stacey Money
National Wildlife Research Centre
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" Hunting with Lead Shot - Wildlife and Human Health Concerns "

Order of Presentations

Presentation : 1

Lead Shot and the Environment: Going Beyond Wetlands.

Thomas, V.G., Dept. of Zoology, University of Guelph, Guelph, Ontario.

Lead in its various forms has long been recognized as toxic to human and wild life. A general lead toxic syndrome exists, whose signs vary little, especially among vertebrate species. The toxicity posed by spent lead shot is just a subset of this general syndrome. Effective substitutes for lead shot, derived from either iron, tin, bismuth, or tungsten, have been developed and are marketed in a small number of countries. However,only a small proportion of those nations which report lead shot toxicosis in their wild life have either considered or begun remediation involving phase-out of lead shot use. Lead shot toxicosis is associated mainly with waterfowl and their predators, which explains why most nations have regulated lead shot use only for wetland hunting. Many tons of lead shot are discharged by hunters over upland sites each year. Sporting clay target shooters deposit an even greater tonnage over both upland and wetland sites each year. Those shot also cause lead toxicosis of wild life and long-term contamination of soil, surface water, and ground water. The regulation of the use of lead shot should extend to all forms of shooting activities as it has in Denmark and The Netherlands. The ranges of migratory birds often covers several nations where lead toxicosis is prevalent, as in Western Europe-Scandinavia, and North-Central America. Requiring the use of non-toxic shot in only one, or a minority, of jurisdictions is not effective remediation, especially if the wintering grounds which harbour large concentrations of birds continue to receive spent lead shot. Successful remediation of lead toxicosis requires securing the entire flyway. Secondary lead poisoning of human beings , especially native people who consume large amounts of wild waterfowl, is a significant toxic risk, and constitutes yet another reason to require the use of lead-free shot for hunting.

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Ancient Awareness of Lead Toxicity

Benjamin Franklin, 1786

… the Opinion of this mischievious Effort from Lead is at least above Sixty Years old: and you will observe with Concern how long a useful Truth may be known and exist before it is generally receiv'd and practis'd on.

The Human Capacity for Self-deception

Externalizing consequences of behaviour to other entity or group so that we may continue with that behaviour for personal gain.

The Problem of Resolution

- Lead toxicosis is a singular phenomenon whose manifestations depend upon the taxon and the physical - chemical properties of the lead source.

- Remediation and prevention is hindered by fragmentation:

- Discrete syndromes in different organisms

- Different levels of government have different jurisdictions

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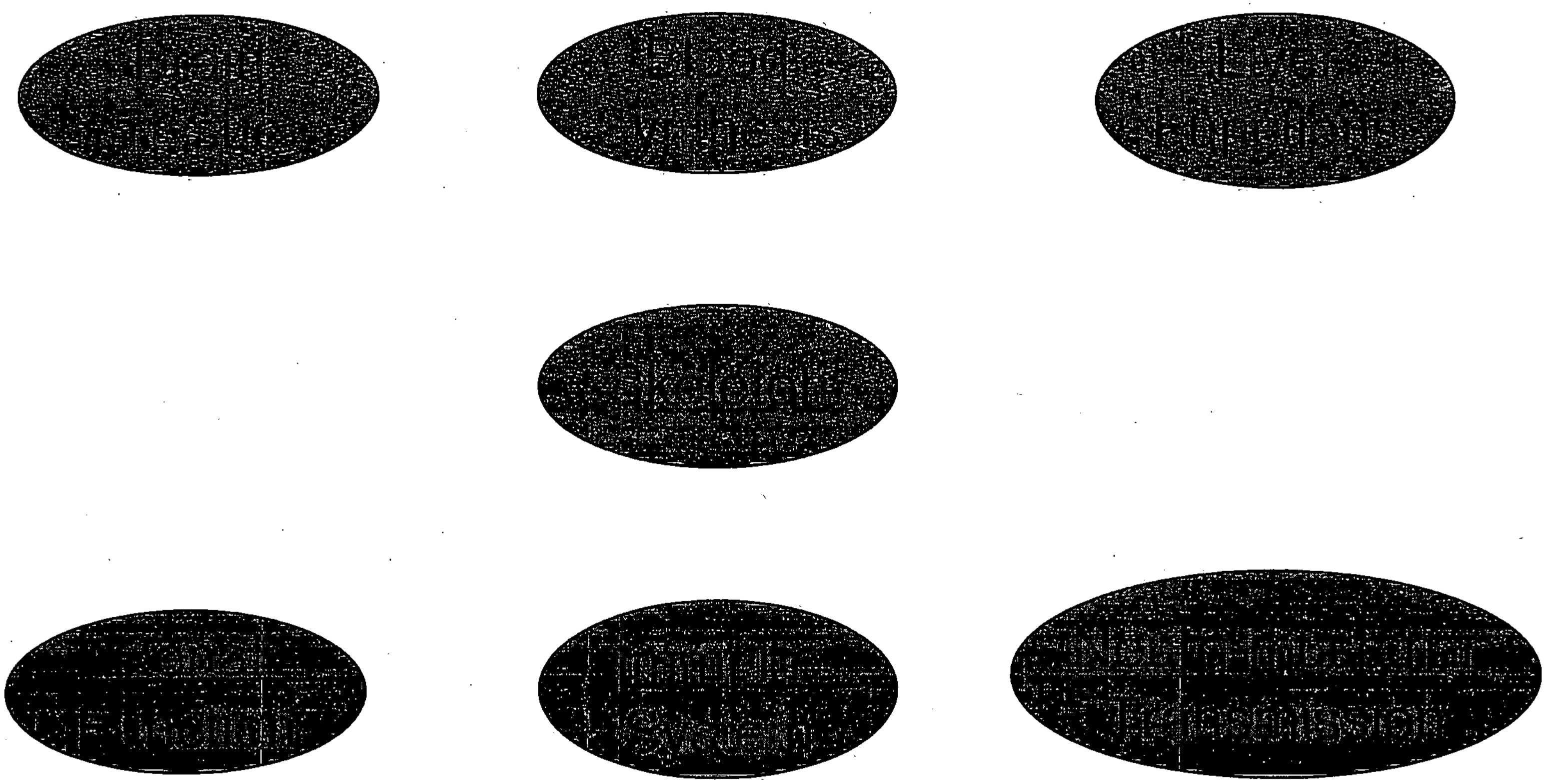
Discrete Manifestations of Lead Toxicosis

- Lead shot ingestion by waterfowl
- Lead sinker ingestion by piscivores
- Lead shot contamination of soil and water
- Lead smelter dust contamination of soils
- Lead in paints (PICA)
- Lead in glass, solders, pewters
- Lead in drinking water and food
- Lead in gasoline

Body Systems Affected by Lead



The Problems of Split Jurisdictions

Shot in birds	Migratory - Federal
	Residential - State/Province
Fishing weights	Victims - Federal
	Fishing Regulations - State/Province
Agency competition	USFWS vs. USEPA

Potential role for the NAFTA?

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Commons Committee on Environment

1995. Recommendation 74

The committee recommends that the Minister of the Environment take regulatory action under the CEPA with the goal of eliminating by May 31, 1997, the import, sale, manufacture and use of lead shot in Canada.

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Effective Substitutes for Lead Shot

• Iron Shot	Full Approval
• Bismuth/Tin	" "
• Tungsten/Iron	Conditional Approval
• Tin	" "
• Tungsten/Plastic	" "

The same materials can be used for fishing weights.

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Quo Vadis On Shot Issue

- Evaluate risks to health of native peoples
- Evaluate risks to upland species of birds
- Evaluate risks to soil biota
- Extend science to policy - regulative arenas

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REDIG

Presentation: 2

Sixteen years of lead poisoning in eagles, 1980-1995: An Epizootiologic View.

Kramer, J.L. and P.T. Redig*. The Raptor Center, St. Paul, Minnesota.

A 16y (1980-1995) retrospective study was conducted to assess differences in the prevalence of lead poisoning (Pbtx) in Bald (Haliaeetus leucocephalus') and Golden (Aquila chrysaetos') Eagles admitted to The Raptor Center at the University of Minnesota. These years encompass the period before and after federal legislation was enacted restricting the use of lead shot for hunting waterfowl on federal lands (1991). Additional data from 1996 through 1998 has been added to the database without fundamentally changing the conclusions. Of 654 eagle admissions reviewed, all of whom were analyzed for presence of lead residues at the time of admission, 138 eagles exhibited elevated lead residues and were further evaluated for the following: recovery location (generally the upper Midwest), blood lead concentration, month of admission, radiographic evidence of lead in the ventriculus and primary cause of admission. The prevalence of Pbtx in eagles did not change after 1991, but mean blood lead concentrations of lead in the same population decreased. These finding call into question current theories regarding the sources of lead for eagles (i.e. waterfowl) and and suggest alternative sources. There was a coincidence of the greatest rate of admissions of eagles with lead poisoning and the timing of deer seasons and migration from northern reaches of their range into the area. Lead poisoning is a continuing problem both regionally and internationally, and man variable related to this toxicity have yet to be conclusively defined.

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Related Reference:

Kramer, J.L. & Redig, P.T., 1997. Sixteen years of lead poisoning in eagles, 1980-95: an epizootiologic view. J. of Raptor Res. 31: 327-332.

REDIG

Lead Poisoning in Bald Eagles

Dr. Patrick T. Redig

The Raptor Center
University of Minnesota

Introduction

- The purpose of this study was to compare the prevalence and clinical characteristics of lead poisoning in Bald Eagles pre- and post- 1991

Lead Toxicity in Waterfowl

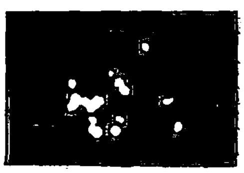
- Bellrose 1959: Il Nat. Hist. Surv. Bull.
- Others

Lead Toxicity in Bald Eagles

- Benson et al 1974
- Jacobson et al 1977
- Redig 1980: MNDNR study

Lead, Eagles and Waterfowl

- Patee et al 1981: Patuxent
- Hennes 1983: Chippewa Nat'l Forest



The Raptor Center and Bald Eagles

- Rehabilitating Eagles and Other Raptors Since 1974
- 10,916 raptors as of Nov. 1, 1998
- Over 850 Bald Eagles
- Lead Poisoning Recognized since 1976

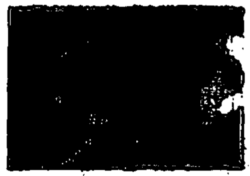
REDIG

Causes of Admission

- Trauma (75%)
  - Collisions (vehicles, windows, powerlines)
  - Shooting
  - Trapping
- Orphans and Translocations (10%)
- Toxicities (5%)
  - Lead
  - Cholinesterase inhibitors
- Miscellaneous (10%)

Admission Procedures

- Physical Exam
- Radiograph
- Blood Samples
  - Complete Blood Count
  - Lead analysis -- atomic absorption -- eagles only
- Admission Treatment: for eagles, includes chelation until lead results are known (6 - 48 hours)

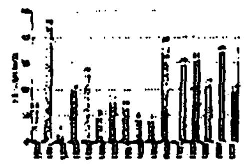


Clinical Categories of Lead Toxicity

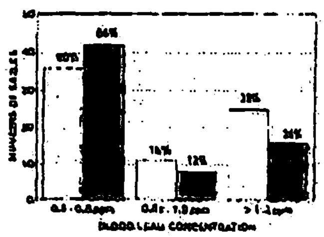
< 0.2 ppm	Background
0.2 ppm - 0.6 ppm	Subclinical
0.61 ppm - 1.1 ppm	Clinical and Treatable
> 1.11 ppm	Clinical and Fatal

Gross Results

- 654 Eagles sampled from 1980 through 1995
- Lead residues encountered in 138 (22%)
  - Before 1991: 72 (17.5%)
  - After 1991: 66 (26.8%)
- Difference not statistically significant



Distribution by Clinical Category



Conclusions

- Acute, fatal lead poisoning reduced
- Chronic, debilitating or compromising lead poisoning the same or increased
- WHY??????????????

Other Sources of Lead

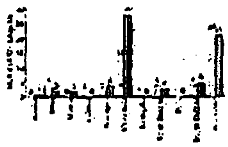
- Non-compliance with steel shot
- Sources in Canada – carried by migrating eagles
- Upland Game
- Big Game

Big Game as a Source of Lead

- California Condors
- Shrapnel suspected in four lead poisoned condors

Geo-Temporal Relationships

- **States of Origin**
- Timing of Occurrence
- Deer Kill in Minnesota, Wisconsin, Michigan
- Gut piles as food source (Postupalsky, personal comm.)



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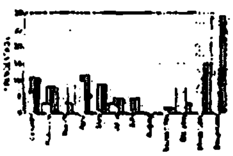

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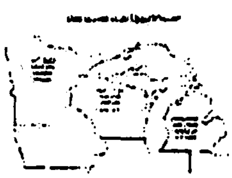

Geo-Temporal Relationships

- States of Origin
- Timing of Occurrence
- Deer Kill in Minnesota, Wisconsin, Michigan
- **Gut piles as food source (Postupalsky, personal comm.)**

Concluding Hypothesis (untested)

- Lead munitions used for hunting deer and possibly upland small game constitutes a source of toxic material that has resulted in a persistent occurrence of lead poisoning in bald eagles.
- Banning of lead shot for hunting waterfowl mitigated the overall circumstance by reducing the incidence of acute, fatal lead poisoning from ingestion of large amounts of shot acutely.

Presentation: 3

Lead exposure in bald eagles and golden eagles from the Canadian prairie provinces.

Wayland, M.*, Environment Canada, Saskatoon, SK, Canada; Bollinger, T., Canadian Co-operative Wildlife Health Centre, Saskatoon, SK, Canada; Scheuhammer, A., National Wildlife Research Centre, Hull, PQ, Canada.

Lead poisoning has been recorded in raptors in North America, Europe and Asia. It has been documented most thoroughly for bald eagles (*Haliaeetus leucocephalus*) in the USA and has occurred in golden eagles (*Aquila chrysaetos*) in the USA and Europe. The major source of lead is believed to be lead shot and lead bullet fragments in tissues of game animals. While there is a strong association between ingestion of lead ammunition from various types of prey and lead poisoning in raptors, the importance of lead shot in waterfowl is less certain. It is important to distinguish between waterfowl and other prey as the main sources of lead exposure in raptors because, in several countries, lead shot has been or will soon be regulated for waterfowl hunting but not for other hunting. In this study, we examined lead poisoning and high lead exposure in bald eagles and golden eagles from the Canadian prairie provinces. Approximately 130 dead eagles were autopsied and their liver and/or kidney lead levels were determined. The prevalence of lead poisoning was approximately 12% in both species. Elevated exposure (including poisoning) occurred in 23% of golden eagles and 16% of bald eagles. Lead-exposed bald eagles were found more frequently in areas of high waterfowl hunting than in areas where waterfowl hunting was low. In contrast, lead-exposed golden eagles were found more frequently in areas with low waterfowl hunting. Lead shot in crippled or sick waterfowl may be a major source of lead in bald eagles. Other sources of lead more likely explain high lead exposure in golden eagles.

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Related References:

Wayland, M. and Bollinger, T. 1999. Lead exposure and poisoning in bald and golden eagles from the Canadian prairie provinces. Environ. Pollut. (in press).

Miller, M.J.R., Restani, M., Harmata, A.R., Bortolotti, G.R., & Wayland, M., 1998. Comparison of blood lead levels in bald eagles from two regions of the North American great plains. J. of Wildl. Dis. 34: 704-714.

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Canadian Wildlife Service

Environment Canada Environnement Canada

Canada

Lead Exposure in Bald Eagles and Golden Eagles from the Canadian Prairie Provinces

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Lead Poisoning in Birds: Recent History

- Waterfowl and other waterbirds
  - first documented in 1800's, well-established by 1960
- Raptors, especially Bald Eagles
  - first documented in late 1960's

Regulations

- 6 Countries
  - waterfowl hunting / hunting in wetlands
- 4 Countries
  - phasing out almost all uses of lead shot

(Scheuhammer and Norris 1996)

Bald Eagles and Waterfowl: the Lead Shot Connection

(Pattee and Hennes 1983)

WAYLAND

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Golden Eagles

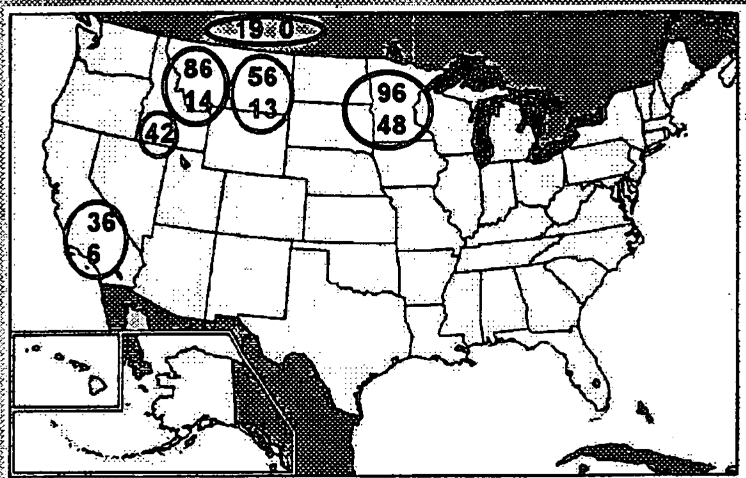
- Evidence of lead poisoning (USFWS 1986; Craig *et al.* 1990)
- Prevalence of lead exposure comparable to Bald Eagles

Golden Eagles

Source of Lead Exposure

- Lead shot / lead ammunition in mammals
  - large game, ground squirrels and coyotes (Patee *et al.* 1990)
  - ground squirrels and waterfowl (Harmata and Restani 1995)
  - game species other than waterfowl (Craig *et al.* 1990)
  - non-waterfowl game species (Kendall *et al.* 1996)

Prevalence of Lead Exposure in Eagles



Species
GOEA ◯ BAEA ◯

Lead Exposure (%)
Elevated Toxic

Diet

- Bald Eagles
  - 60 - 98% waterfowl (midcontinental North America, fall and winter)
- Golden Eagles
  - 80 - 95% mammals (ground squirrels, rabbits, hares, prairie dogs and large game, North America, breeding season)

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Methods

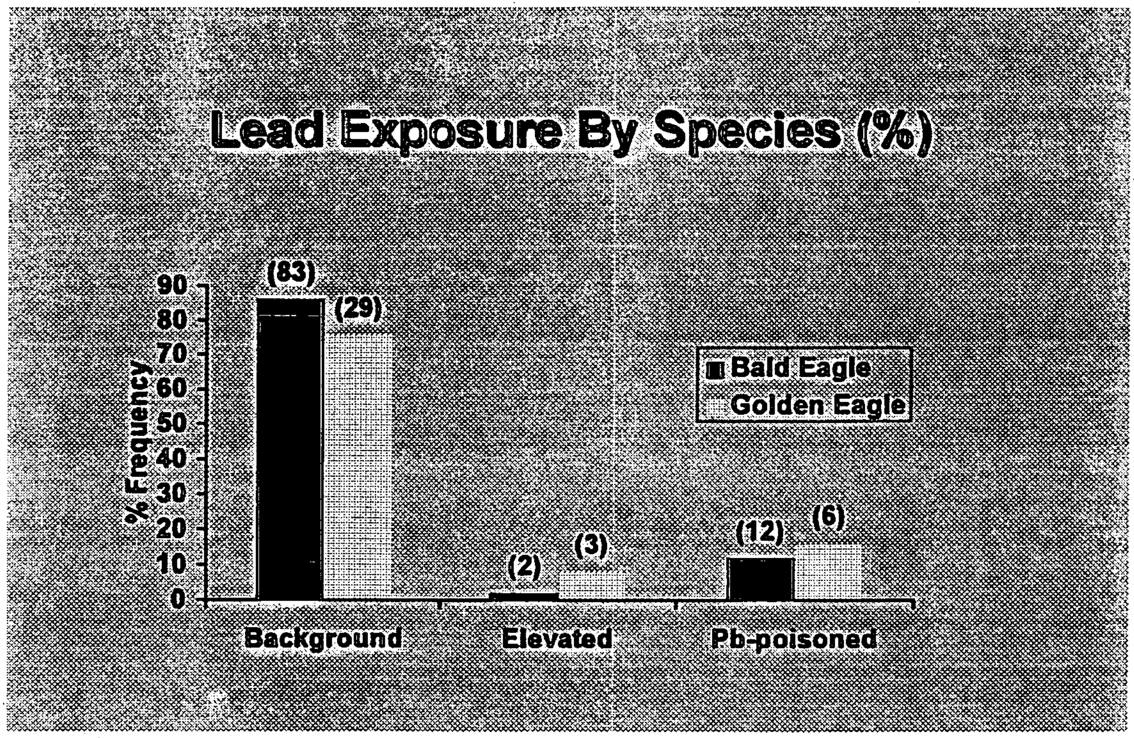
- Dead eagles received from provincial wildlife agencies
- Date, location, species and age recorded
- Autopsies
- Lead analyses of liver and kidney at NWRC

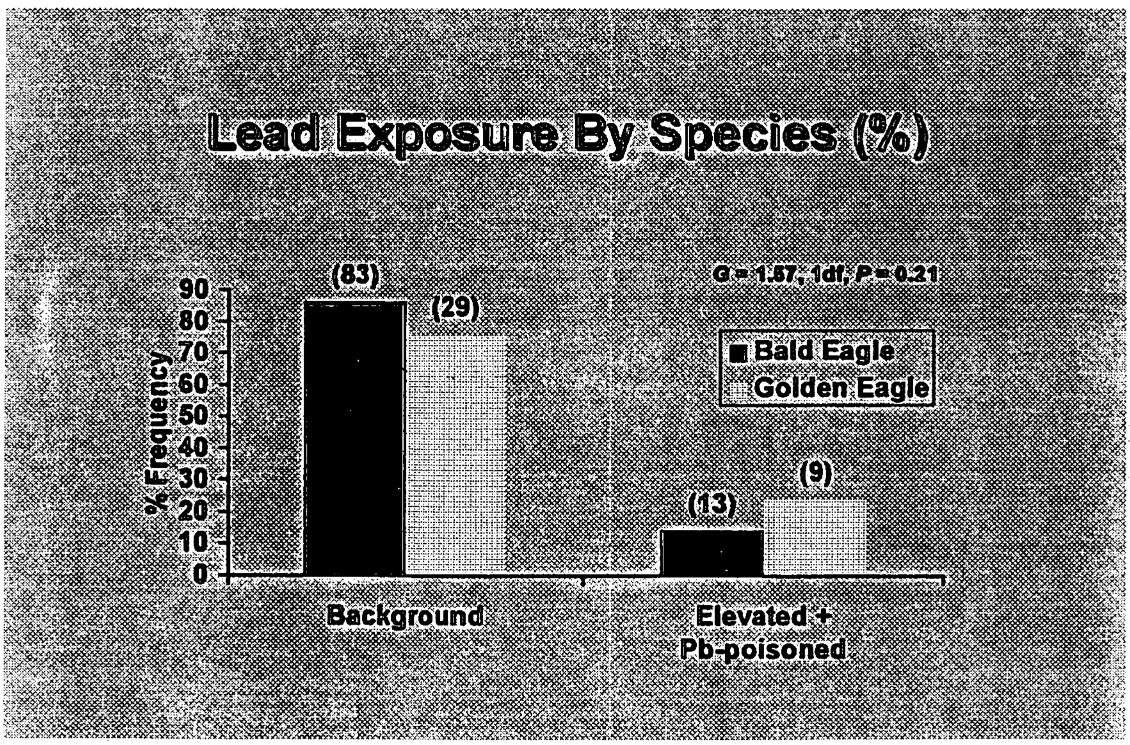
Diagnostic Tissue Lead Levels

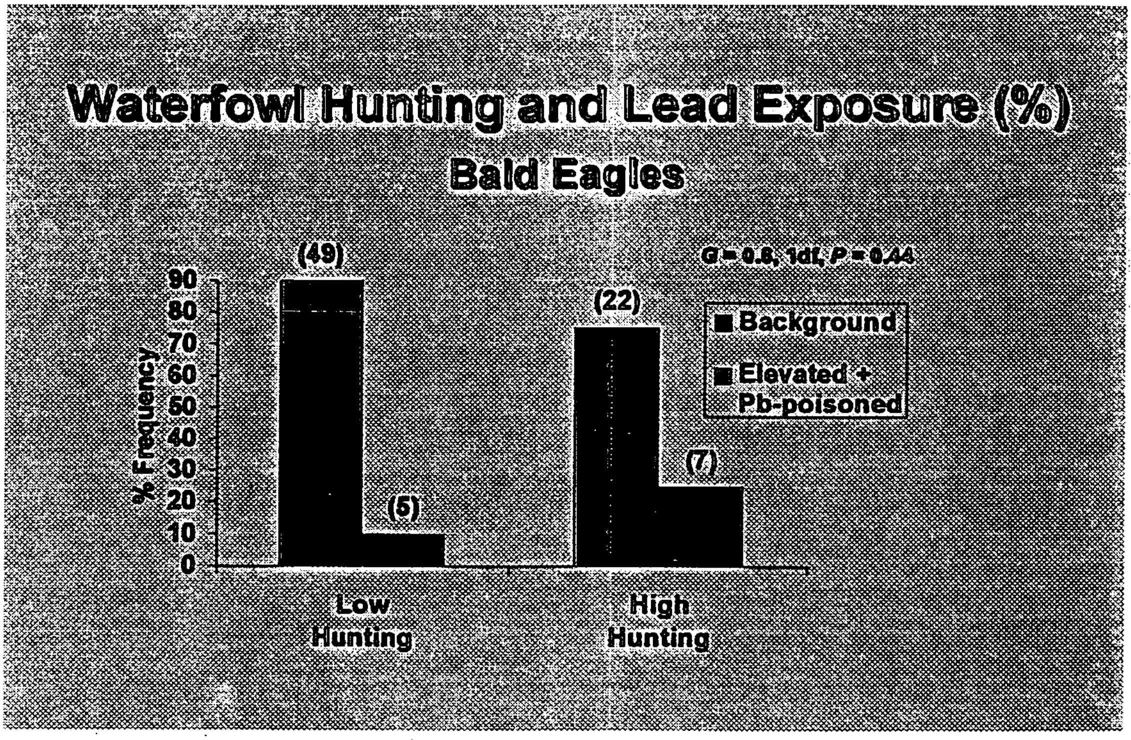
Lead Exposure	Liver	Kidney
Background	< 6	< 8
Elevated	$6 \leq Pb \leq 30$	$8 \leq Pb \leq 20$
Pb-poisoned	≥ 30	≥ 20

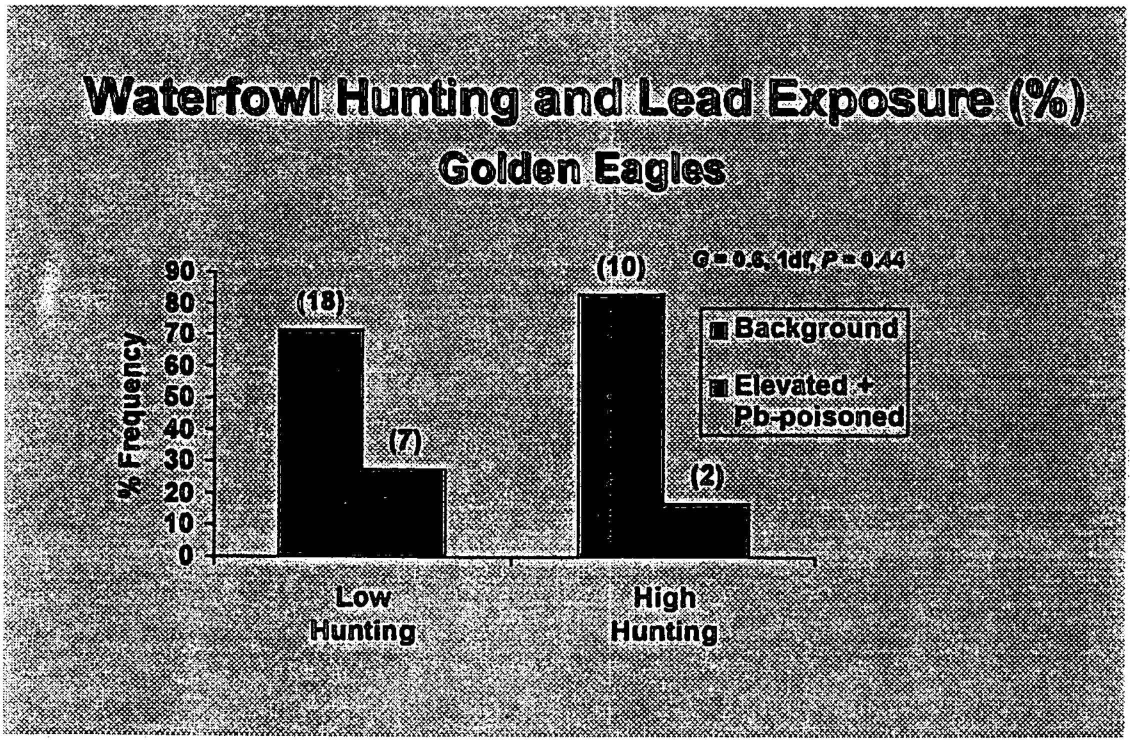
ppm, dry wt

(Pattee *et al.* 1981; Pain *et al.* 1994; Franson 1996; Wayland & Bollinger *in press*)


Lead Exposure By Species (%)
% Frequency
90
80
70
60
50
40
30
20
10
0
(83)
(29)
(2)
(3)
(12)
(6)
Bald Eagle
Golden Eagle
Background
Elevated
Pb-poisoned


Lead Exposure By Species (%)
G = 1.57, 1df, P = 0.21
% Frequency
90
80
70
60
50
40
30
20
10
0
(83)
(29)
(13)
(9)
Bald Eagle
Golden Eagle
Background
Elevated +
Pb-poisoned


Waterfowl Hunting and Lead Exposure (%)
Bald Eagles
G = 0.6, 1df, P = 0.44
% Frequency
0
10
20
30
40
50
60
70
80
90
(49)
(5)
(22)
(7)
Background
Elevated + Pb-poisoned
Low Hunting
High Hunting


Waterfowl Hunting and Lead Exposure (%)
Golden Eagles
G = 0.6, 1df, P = 0.44
% Frequency
0
10
20
30
40
50
60
70
80
90
(18)
(7)
(10)
(2)
Background
Elevated + Pb-poisoned
Low Hunting
High Hunting

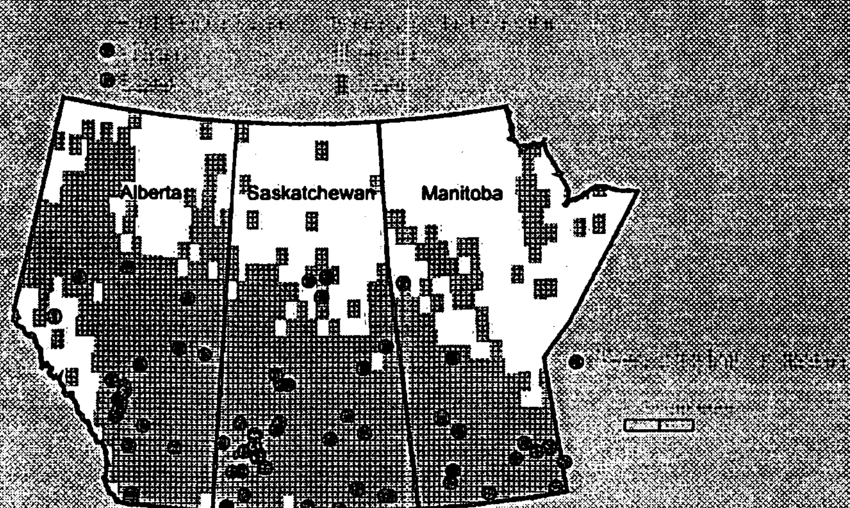
WAYLAND

Geographic Association Between Waterfowl Hunting and Lead in Eagles

- Eagle locations (by lead exposure category) overlaid on map of waterfowl hunting intensity

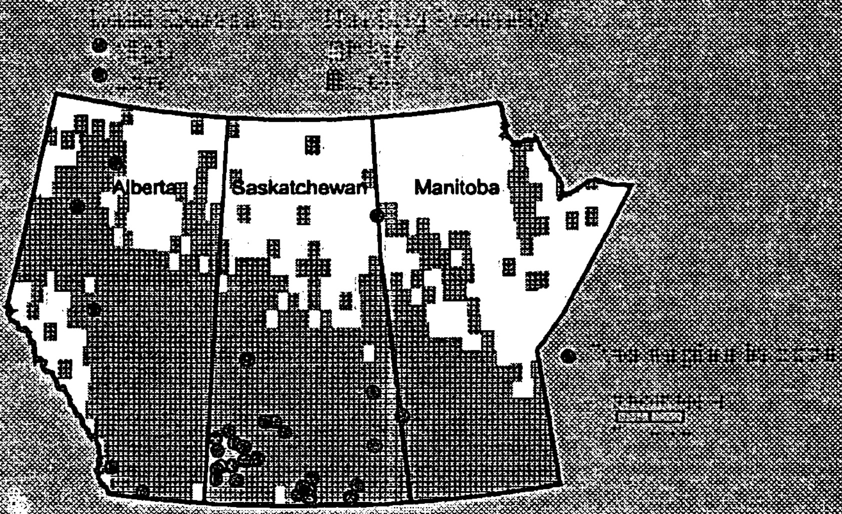
Bald Eagles

Lead Exposure / Hunting Intensity



Golden Eagles

Lead Exposure / Hunting Intensity



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Distribution of Waterfowl Hunting

- Low hunting
  - less than or equal to 1000 hunter-days / year
- High hunting
  - greater than 1000 hunter-days / year

Source: CWS - National Harvest Survey

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Conclusions

- Bald Eagles
  - elevated lead associated with waterfowl hunting
- Golden Eagles
  - no such association
- Lead exposure in Golden Eagles greater than or equal to lead exposure in Bald Eagles

Conclusions

- Lead exposure in wildlife not simply a waterfowl hunting issue

Presentation: 4

Environmental Behaviour and Management of Lead at Shooting Ranges.

Byrne, R.L., Wildlife Management Institute, Washington, D.C.

This paper addresses the environmental mobility of lead in surface water, ground water, sediment and soil, the factors controlling that mobility, and methods of managing lead mobility at shooting ranges. The mobility of lead derived from bullets and shot is controlled by a number of geological processes, chief among which are oxidation/reduction, precipitation/dissolution, absorption/desorption and complexation/chelation. The interaction of these processes with physical processes such as erosion are important. Site-specific conditions determine which processes and interactions are most important at any particular range. The primary chemical factors influencing lead mobility at shooting ranges are pH, precipitating agents (e.g. phosphates, sulfates, sulfides, carbonates), and sorbents (e.g. clays, organic carbon, iron and manganese oxides and hydroxides). Major influences on lead mobility are exerted by both extrinsic factors such as rainfall quality and quantity, and intrinsic factors such as soil pH and vegetative cover on the range. Natural conditions on some ranges keep lead mobility at t minimum. If lead mobility of a potential concern, intrinsic factors can be managed to accommodate extrinsic factors in an environmental stewardship program to control lead mobility. The most viable options to control lead mobility at shooting ranges include lead recovery/recycling, control of runoff, control of pH with additions of agricultural lime, precipitation via additions of agricultural lime or phosphate, and sorption to clays. Optimum control may require a combination of options selected and applied in response to site-specific geochemcial and physical conditions.

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BYRNE

Environmental Behavior and Management of Lead at Shooting Ranges

Presented at:
Society of Environmental Toxicology and Chemistry Annual Meeting
Charlotte, NC
November 15-19, 1998

by:
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Abstract

This paper addresses the environmental mobility of lead in surface water, ground water, sediment and soil, the factors controlling that mobility, and methods of managing lead mobility at shooting ranges. The mobility of lead derived from bullets and shot is controlled by a number of geochemical processes, chief among which are oxidation/reduction, precipitation/dissolution, adsorption/desorption and complexation/chelation. The interaction of these processes, with physical processes such as erosion , also is important. Site-specific conditions determine which processes and interactions are most important at any particular range. The primary chemical factors influencing lead mobility at shooting ranges are pH, precipitating agents (e.g., phosphates, sulfates, sulfides, carbonates) and sorbants (e.g., clays, organic carbon, iron, and manganese oxides and hydroxides). Major influences on lead mobility are exerted by both extrinsic factors such as rainfall quality and quantity, and by intrinsic factors, such as soil pH or vegetative cover on the range. Natural conditions on some ranges keep lead mobility at a minimum. If lead mobility is a potential concern, intrinsic factors can be managed to control it. The most viable options to control lead mobility at shooting ranges include lead recovery/recycling, control of runoff, control of pH with the additions of agricultural lime, precipitation via additions of agricultural lime or phosphate, and sorption clays. Optimum control may require a combination of options selected and applied in response to site-specific geochemical and physical conditions.

Introduction

Results are presented of two projects dealing with the chemistry of lead mobility in soil and water, and the factors controlling that mobility. Both projects were conducted by EA Engineering, Science and Technology (EA) under contract with the Sporting Arms and Ammunition Manufacturers Institute (SAAMI) and the National Shooting Sports Foundation (NSSF). The Wildlife Management Institute (WMI) managed these projects.

Phase I of these projects was an extensive literature review on lead mobility in soils. This project cumulated in a "guide" entitled *Lead Mobility at Shooting Ranges.* Phase II developed a practical "best management practices/guidance document" entitled *Environmental Aspects of Construction and Management of Outdoor Shooting Range*s. Both documents are available from NSSF.

These projects were undertaken because of the real need to provide shooting ranges, as well as the public and environmental regulators, with accurate information on the mobility of lead and, if possible, practicable means to manage any adverse impacts that it may cause. The shooting industry and sportsmen's clubs that run the majority of ranges have a long and proud history in the forefront of habitat protection, wildlife restoration and other environmental issues. Their collective concern for the environment clearly includes the ranges on which they shoot. This concern is also tempered by the reality that shooting sports are facing and likely will continue to face challenges related to environmental issues.

At present, there are no environmental regulations specifically written for outdoor shooting ranges. However, regulations written for general purposes are being applied to shooting ranges. The two environmental protection laws being used most frequently to challenge shooting ranges are the Resource Conservation and Recovery Act (RCRA) and the Clean Water Act (CWA). Relatively few ranges have been challenged on the basis of these statutes. Only three cases have proceeded through the courts and exist as case law.

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Phase I

Lead Mobility at Shooting Ranges: A Literature Review

This literature review included 101 citations from both published and unpublished sources. Approximately 300 additional citations were also reviewed but not included. The review was published as a "guidance" document entitled *Lead Mobility at Shooting Ranges,* which is available from NSSF.

The major findings of the literature review were:

1) Geochemistry of soils are very complex. However, the soil chemistry of lead is reasonably well known and generalizations about the behavior of lead in soil can be made.

2) The major geochemical processes that control lead mobility are: (a) oxidation/reduction; (b) precipitation/dissolution; © adsorption/desorption; and (d) complexation/chelation.

3) The primary chemical factors influencing lead mobility at shooting ranges are: (a) pH; (b) precipitating agents (e.g., phosphates, sulfates, sulfides, carbonates); and © sorbants (e.g., clays, organic carbon, iron, and manganese oxides and hydroxides).

4) Major influences on lead mobility are exerted by both extrinsic factors such as the quality and quantity of rainfall, and by such intrinsic factors as soil pH or vegetative cover.

5) Active management can control lead mobility at a specific site. However, management activities will have to be tailored to the specific site and likely will require multiple approaches.

Geochemical Processes

Oxidation/Reduction

Oxidation rates vary considerably depending on the site. Estimates of dissolution rates of metallic bullets and shot are reported to be 2 percent in 50 years (Battelle 1987), 0.3-1.0 percent per year (Jorgensen and Willems 1987) and 1 percent per year (Von Bon and Boersema 1988). However, civil war bullets have existed for more than 130 years with as much as 95 percent of the material still intact (SAAMI 1996).

The presence of other reactants (e.g., acids, bases, sulfate, carbonate) also will affect the dissolution rates. Selective chemicals (e.g., phosphate) can form a protective, nonreactive layer that retards dissolution (SAAMI 1996).

The ratio of surface area to mass of the projectile is important. Large bullets and shot are expected to corrode at a substantially slower rate than smaller projectiles.

Precipitation/Dissolution

The dominant factors affecting the solubility of lead include: pH; Eh; and the concentration of carbonate, sulfate, sulfide, phosphate and chloride. The minerals likely to precipitate out under conditions present at shooting ranges include lead oxides, hydroxides, carbonates, sulfates, sulfides and phosphates (Jorgensen and Willems 1987; Hem 1976; and Rai et. al. 1984) . The solubility coefficient (K_{sp}) of these various precipitates varies widely. However, many of these minerals have very low dissolution rates or are insoluble. Mineral availability and pH generally determine which precipitates are present at any given time.

Only a fraction of lead present on a shooting range is likely to be to be present in a potentially soluble form. These potentially mobile forms coupled with the site-specific characteristics are likely to establish upper solubility limits, and thus act to limit the mobility of lead in dissolved forms. Within the suite of precipitates available, there likely will be one low solubility precipitate that can be "encouraged" through management activities.

Lead phosphate are highly insoluble and effectively limit the solubility of lead at very low levels under nearly all naturally occurring Eh and pH conditions. Ma et. al. (1993, 1994, 1995) determined that lead phosphates effectively controlled lead and greatly reduced its bioavailability. Lead-contaminated soils treated with phosphate have been shown to pass

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Toxicity Characteristic Leaching Procedure (TCLP) extractions successfully (SAAMI 1996).

Lead sulfide often is the primary solubility control in anoxic sediments or seasonally flooded soils with high organic content. The lead in lead sulfide has been shown to be generally unavailable to benthic organisms (Casas and Crecelius 1994).

Adsorption/Desorption

Adsorption is the process through which dissolved ions are taken out of solution by binding to the surfaces of soil/sediment particles in contact with the solution. The distribution coefficient (K^d) is the ratio of material adsorbed to the amount remaining in solution. The cation exchange capacity (CEC) is another measure of a soil's ability to adsorb cations. This adsorption process exchanges a weakly held cation for a more strongly held cation. Adsorbed chemicals are generally considered to be less bioavailable and therefore less toxic (Gunn, 1989). Dissolved lead generally exists in a cationic Pb^{+2} form. Adsorption processes are extremely complex and not well understood.

Effective sorbants include iron-manganese (Fe-Mn) oxides, organic matter and clays. Adsorption of lead is affected by pH, concentration of lead and the concentration of competing ions, and the amount and types of sorbants available. Numerous studies using a variety of study designs have generally concluded that lead tends to be strongly adsorbed to soils and sediments and is not mobile under most conditions (Wieland 1993; Talbot 1989; Turner 1985).

Complexation/Chelation

Complexation and chelation are chemical processes by which metal ions combine with other dissolved constituents to form a new dissolved species. These processes tend to allow more of the metal to dissolve in solution. Fulvic acid is the only common complexing agent likely to be encountered at a shooting range. While chelated lead may increase its solubility it also decreases its bioavailability (Denduluri 1993).

Literature Review--Summary

Metallic lead is slowly oxidized (corroded) to forms that dissolve and become slightly mobile in the environment. However, dissolution rates can be counteracted by precipitation as lead minerals. In addition, lead has a strong affinity to adsorb to naturally occurring minerals which further limits its mobility. While these processes are site specific, they can be manipulated through active management (SAAMI 1996).

Phase II

Environmental Aspects of Construction and Management of Outdoor Shooting Ranges

The results from Phase I indicated that a variety of active management options existed for shooting ranges operators to control lead mobility. These options were assembled and further refined as a "best management practice/guidance document" entitled *Environmental Aspects of Construction and Management of Outdoor Shooting Ranges* (Range Guidance). This booklet is available from NSSF. The Range Guidance recommendations were reviewed by more than 20 organizations, including national shooting sports organizations and environmental protection agencies.

The *Environmental Aspects of Construction and Management of Outdoor Shooting Ranges* contains general overviews of : (1) the legal and regulatory context of managing lead on shooting ranges; (2) the science behind controlling lead mobility; (3) potential issues regarding environmental management; (4) suggested actions for managing lead mobility at shotgun ranges, and rifle and pistole ranges; (5) suggested ideas for the development of safety and community relations plans; and (6) development of a range-specific "Environmental Stewardship Plan."

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Best Management Practices for Controlling Lead Mobility

Controlling pH

Based on the literature review, pH is a controlling factor in all of the processes that affect lead mobility. Generally, mid-range pHs are desirable to minimize lead mobility. Mid-range pHs also encourage increased adsorption of lead ions to sorbants such as clay and organic material. The addition of agricultural lime to soils in order to maintain the pH in the 6.5 to 8.5 range is preferred (Lund 1991; Stansley 1992; NSSF 1997). Agricultural lime is relatively inexpensive but will require periodic replacement. However, drastic changes in pH should be avoided because it may adversely affect existing vegetation. A gradual reduction in pH in this situation is recommended in order to allow plants to adjust to the new pH or allow new plant communities to become established.

Addition of Phosphate

Lead phosphate is insoluble under most environmental conditions. Addition of finely ground phosphate rock or phosphate fertilizer to shooting range soils may provide one of the least expensive means to control lead mobility. However, even moderate amounts of phosphate may adversely affect nearby water bodies. Careful management and monitoring of phosphate additions are recommended to ensure that water quality is not impaired.

Addition of Clays and Clay Liners

Clay particles are one of the primary sorbants to which lead ions attach. Tilling clay material into existing soils, particularly sandy soils, may reduce lead mobility. The addition of a clay liner in the shot fall or impact areas also may be useful. Obviously, these are more easily accomplished when the shooting range is constructed. Selecting sites that already have a clay layer present or a significant amount of clay in the existing soils also is advantageous. Some caution in the addition of clay is warranted because clays can be difficult to work with, tend to erode and do not easily establish vegetation.

Erosion Control and Stormwater Management

Erosion may transport soil with lead attached to adjacent properties. The loss of topsoil can also degrade water quality and make vegetation difficult to maintain. Establishing water diversions, increasing infiltration rates, installing terraces and/or developing temporary retention areas will assist in controlling runoff and lead mobility.

Vegetation Management

Encouraging and maintaining vegetation to control runoff are highly desirable. However, the vegetation should be carefully selected and managed so that it is not preferred wildlife habitat. Encouraging wildlife in shot fall or berm areas increases their risk of exposure. Low quality, rank-grasses will control runoff while discouraging wildlife usage. In many situations, woody vegetation also should be discouraged because it may interfere with future lead-reclamation operations.

Phytoextraction of Lead in Soils

Several plants species (i.e., *Brassica* spp. and *Cynodon* spp.) have demonstrated an ability to take up and concentrate lead from soils (Kumar et al. 1995; Bricka et al. 1993). This ability is being utilized in some "brownfield" situations, and the technology has promise for limiting lead mobility at shooting ranges. However, additional research needs to be conducted, and several policy questions need to be addressed before this technique can be widely applied.

Lead Recovery/ Recycling

Routine recovery and recycling of lead may be among the most basic and cost-effective environmental actions that a range manager can undertake. Any lead that is removed and recycled cannot cause problems. However, in some instances, lead recovery may cause significant site disturbance. Recovery may not be a viable option in sensitive areas such as wetlands. In addition, the current technology used for shot recovery is extremely limited. Current requirements are relatively flat, dry terrain which is free of rocks and woody vegetation. Improvements in technology are being encouraged.

Avoiding Sensitive Areas

Ranges should be careful to prevent having shotfall zones in sensitive areas. In particular, shotgun ranges should not be over water or wetlands. Reorienting the direction of a range so that the shot falls onto dry land is recommended and urged. However, if this is not possible, nontoxic shot should be used.

Combined Approaches and Developing an "Environmental Stewardship Plan"

Several options are available to control lead mobility and reduce any environmental risks associated with shooting ranges. Often, no single management technique will accomplish all of the needs, thus an approach featuring several options is needed. An "Environmental Stewardship Plan " should be developed that documents and plans these approaches.

Importantly, not all of the items identified in an "Environmental Stewardship Plan" need to be done at once. A "phased" approach, whereby selected items are prioritized and implemented based on a predetermined schedule, often will reduce costs and allow for orderly implementation.

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Shortcomings and Future Needs

Whereas the literature review determined a scientific basis for on-site management to control lead mobility, it also identified several areas needing additional work. These include:

1) Environmental influences on corrosion rates are not well understood. Investigation of these influences and interactions would enhance the predictability and accuracy lead mobility estimates.

2) Generic EPA fate and transport models for metals also need further refinement. This refinement would allow potential lead mobility to be predicted prior to construction of a range.

3) Critical values for major controlling factors, such as how much phosphate is sufficient to limit lead mobility, and the interactions among these factors, such as the influence of organic material on increasing lead mobility, need to be demonstrated in relation to conditions typical of ranges.

4) Improvement of tests to measure and predict lead mobility is needed. TCLP tests tend to over predict mobility because this test does not simulate conditions typical at ranges (SAAMI 1996; NSSF 1998).

5) Additional research on phytoremediation techniques is needed.

4) Improved reclamation capacity and technology are critical needs.

Conclusion

The scientific literature provides a basis to understand lead mobility. Based on the typical relationships of major controlling factors, it is unlikely to be a serious environmental problem at most locations. However, unusual conditions at some ranges could result in legitimate lead mobility concerns. Active management of lead mobility at shooting ranges can further minimize any risk that may be present.

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Lead Mobility at Shooting Ranges, Environmental Aspects of Construction and Management of Shooting Ranges and *Synopsis of Application and Limitations of TCLP and SPLP at Outdoor Shooting Ranges* are available from the National Shooting Sports Foundation, Newtown , CT for a nominal fee. Call (203) 426-1320 to order copies.

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Environmental Behavior and Management of Lead at Shooting Ranges

Presented by:

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In Cooperation with:

Sporting Arms and Ammunition Manufacturers' Institute, Inc.,

National Shooting Sports Foundation and

EA Engineering, Science, and Technology, Inc.

Phase I:

Literature Review on Mobility
"Lead Mobility at Shooting Ranges"

Phase II:

Develop "Best Management Practices" Guidebook

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Literature Review

"Lead Mobility at Shooting Ranges"

<u>Goals</u>:

- Determine major processes controlling lead mobility at ranges.
- Identify options that may be useful in controlling lead mobility.

Sources:

- Scientific journals
- Government reports
- “Grey” literature
- 101 citations
- Over 300 sources examined

MOBILITY - **Refers to lead dissolving and remaining in solution in surface or ground water, including interstitial water in soil or sediment.**

Literature Review:

- Lead chemistry has been sufficiently researched and is known sufficiently to understand processes controlling lead mobility.
- A variety of factors interact in complex way to determine lead mobility.

Literature Review:

- The major chemical factors are:
  - pH
  - Precipitating agents (carbonates, phosphates, sulfates, etc.)
  - Sorbents (iron & manganese oxides & hydroxides, clays, organic matter, etc.

Literature Review:

- Actual lead mobility at any particular range can only be determined by appropriately designed site-specific evaluation.

Literature Review:

- Concerns may be based on perceptions rather than science.

Literature Review:

- Lead mobility unlikely to be a serious environmental problem at most ranges based on typical relationships of major controlling variables.
- Unusual conditions may occur at some ranges that could result in legitimate mobility concerns.

PHASE II

"Environmental Aspects of the Construction and Management of Outdoor Shooting Ranges"

"Best Management Practices"

Review Committee

- Massachusetts Dept. of Environmental Protection
- Wisconsin Dept. of Natural Resources
- Wildlife Management Institute
- Izaak Walton League of America
- Amateur Trapshooting Association
- Blue Trail Range
- Cleary, Gottlieb, Stein & Hamilton
- Dept. of Defense-U.S. Navy
- Federal Cartridge Company
- Markham Park Range
- National Rifle Association of America
- National Shooting Sports Foundation
- National Sporting Clays Association
- Remington Arms Company
- Sporting Goods Properties
- Sturm, Ruger & Company
- Wilman, Harrold, Allen & Dixon
- Winchester Division/Olin Corporation

BMPs:

- Environmental guidance for range construction and range management

  a. Legal background

  b. Scientific basis

  c. Generic plans with guidance on developing individual range plans

  d. Environmental Stewardship Plans

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BMP's Promising lead mobility control options:

- Recovery/recycling
- Control of surface runoff

BMP's Promising lead mobility control options:

- Addition of lime
- Addition of phosphate
- Clay layers/mixing

BMPs:

- Optimum control strategies are likely to use a combination of options tailored to site-specific conditions.

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BMP's Sensitive Areas

- Do not shoot over water/wetlands
  - Reorient range
  - Use non-toxic shot

BMP's -- Other Sources

- U.S. EPA - Region 2
- Massachusetts DEP
- Department of Navy
- Private Consultant Developed

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Future Needs:

- Lead recovery is a key element in management
- Current capacity is inadequate
- Current technology requires:
    - dry soils
    - flat terrain
    - vegetation free

Engineering Design Contest

- Innovative technologies
- Small scale
- Difficult terrain
- Water
- Sound abatement
- Prize money

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Conclusions:

- Lead mobility is not likely to be a serious environmental problem at most ranges
- Management practices exist that can control lead mobility

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Presentation: 5

Use of lead shot for harvesting game animals: Continued deposition of lead into the environment and implications for human consumers of harvested game.

Money, S.L.*; Braune, B.M.; Fontaine, A. National Wildlife Research Centre, Hull, Quebec, Canada.

Environmental deposition of lead in the form of lead shot used to harvest game in Canada is estimated to be at least 2000 tonnes annually, equaling the estimated releases of lead from industrial sources. In 1997, Environment Canada amended the Migratory Birds Regulations prohibiting the use of lead shot for hunting most migratory game birds nationwide. With the full implementation of this ban in 1999, and continued industrial declines in emissions, upland game hunting and target shooting, which will continue to use lead shot, will represent an increasing proportion of the total amount of lead discharged into the Canadian environment. Fragments of lead shot found in edible tissues of harvested game pose a direct risk of lead exposure to consumers of these tissues, including humans. Although the overall incidence of lead shot retention in humans may be low, there are subpopulations that traditionally harvest and consume above-average quantities of wild game, an activity that may increase their risk of lead exposure.

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Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Use of Lead Shot for Harvesting Game Animals:

1. Wildlife / Environment
2. Human Health

Stacey Money, Birgit Braune, Alain Fontaine
Canadian Wildlife Service, Environment Canada

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Overview

- Wildlife / Environment
  - Summary of wildlife effects
  - Requirement for non-toxic shot use
  - Remaining lead deposition in the form of lead shot
- Human Health
  - Summary of lead concentrations in edible tissues
  - Incidence of ingestion of lead shot pellets in humans

1a. Lead Shot and Wildlife:

- **Waterfowl**
  - primary lead poisoning from ingestion of lead shot
- **Eagles**
  - secondary lead poisoning from eating waterfowl and upland game with ingested or embedded shot
- **Upland Game Birds**
  - primary lead poisoning reported in:
    - mourning dove
    - northern bobwhite
    - gray partridge
    - ring-necked pheasant
    - ruffed grouse
    - scaled quail
    - wild turkey
    - wood pigeon

Current Non-Toxic Shot Regulations:

Non-Toxic Shot Zones	Waterfowl / Wetland Areas	All Hunting
Australia	Canada	Denmark
Mexico	Finland	Netherlands
Sweden	Norway	
Switzerland	United States	

1b. Lead Shot and the Environment: Estimating Lead Use for Hunting

Calculation: Number of shots fired / bagged bird
Weight of Pb in shotshell
Number of game harvested

Example: 6
1¼ oz. (35 g)
4.9 M waterfowl

TOTAL: 1000 metric tonnes

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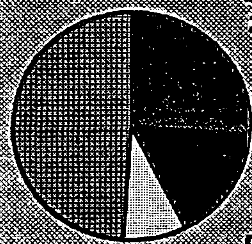
Annual Lead Deposition in Canada from Game Hunting:

Game	Estimated Harvest (millions)	Estimated Pb Deposition (metric tonnes)
Waterfowl	4.9	1000
Upland Birds	4.7	800
Small Mammals	2.6	500
TOTAL		2300

Environmental Lead Deposition: Hunting *vs* Industry in 1999

- Hunting:
  - Upland Birds = 800 t
  - Small Mammals = 500 t
  - Target Shooting < 260 t
- Industry:
  - Releases = 1500 t
  - Transfers = 1300 t



Wildlife / Environment Summary:

- upland game / predators exposed to Pb shot
- some countries have restricted upland use of Pb shot
- an estimated 1300 tonnes of Pb deposited / yr in Canada from upland hunting activities
- Pb shot represents increasing proportion of total Pb depostion

2. Lead Shot and Human Health:

- commercial food items subject to routine surveys
- Health Canada tissue residue guideline:
  - Pb in fish = 0.5 mg/kg ww
- country foods not subject to surveys
- Canadian survey initiated in 1988:
  - biologically incorporated Pb low
  - elevated Pb levels found in 11 % of samples

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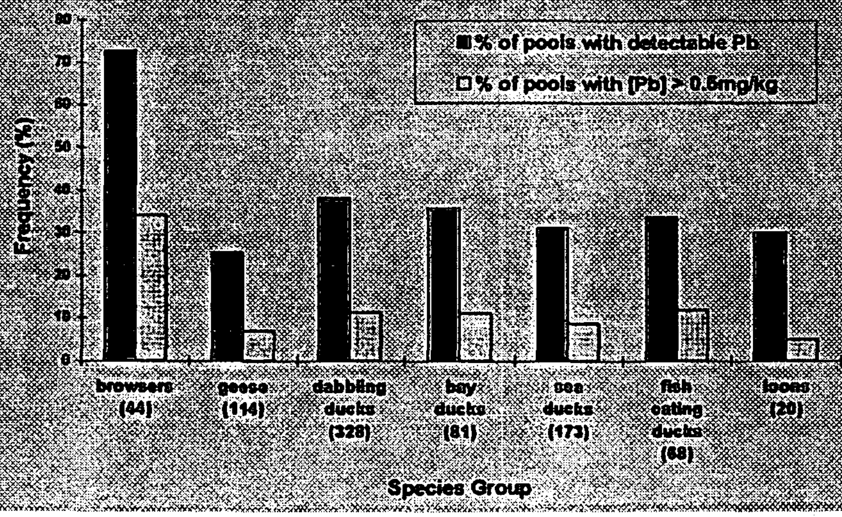
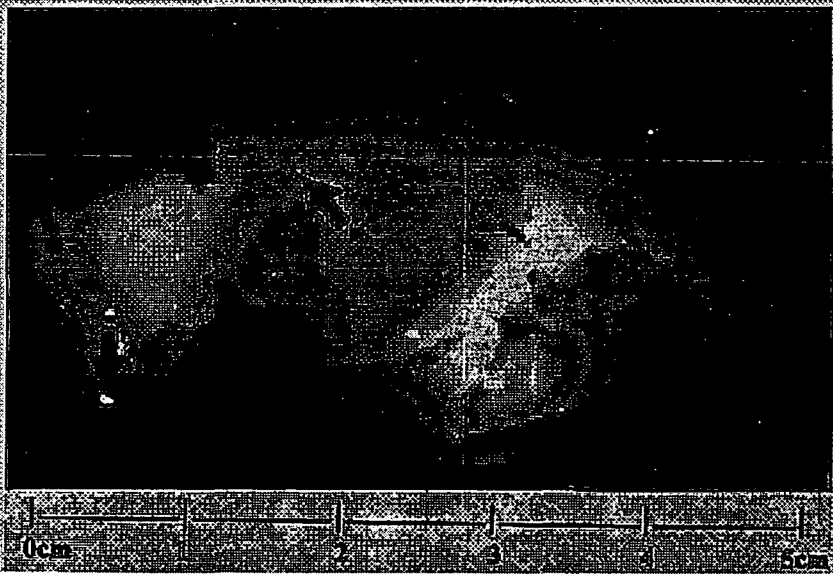
Frequency of Pb Detection in Game Breast Muscle Tissue:



Radiograph of Game Bird Breast Muscle Tissue Showing Embedded Pb Fragments:



[Pb] in breast muscles of individual birds with >100 ug/g dw in right muscle:

	Species	Left Breast	Right Breast
Waterfowl	Bufflehead	ND	176.7
	Mallard	ND	237.2
	Merganser	ND	689.1
	Snow Goose	ND	112.3
	Snow Goose	ND	728.5
	Snow Goose	ND	3909.6
Upland Birds	Spruce Grouse	ND	103.8
	Spruce Grouse	22.39	418.5
	Woodcock	183	844

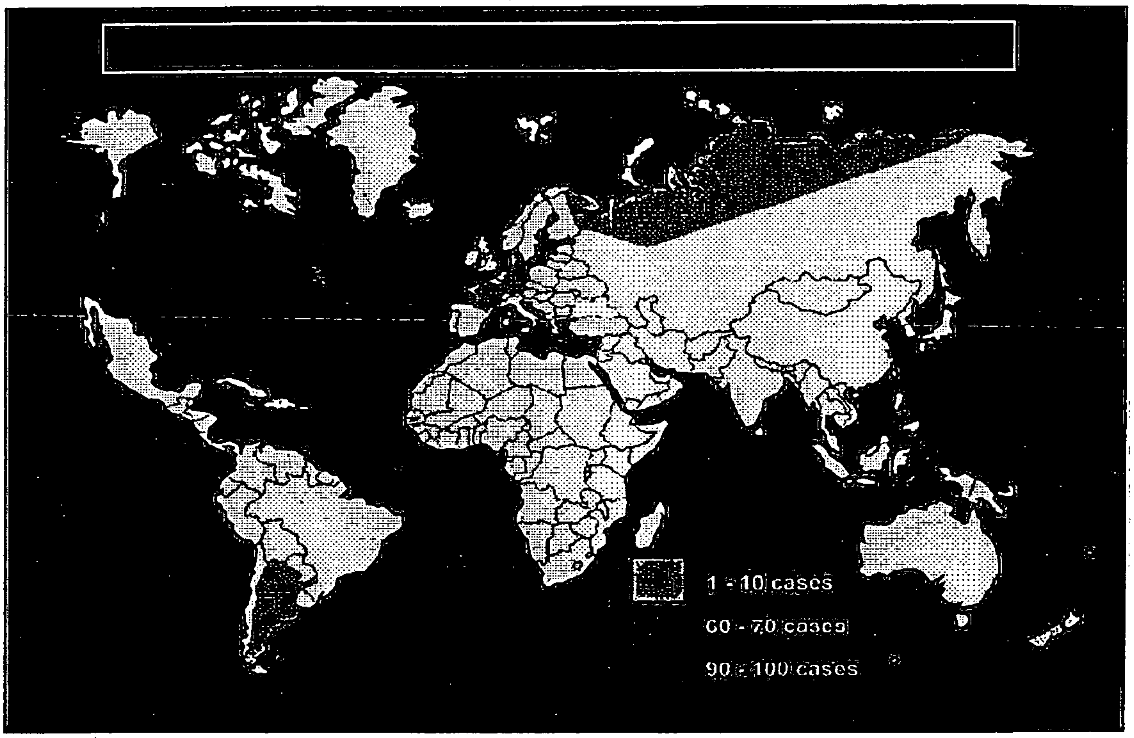
ND = Not Detected, < 1 µg/g dw

Embedded Shot in Game Birds:

Game	Frequency of Embedded Shot (%)
Ducks	12 - 68
Geese	20 - 42
Upland Game	5

Lead Shot Ingestion in Humans:

- First case reported in USA in 1842
- Only large quantities of pellets are reported, cases of only a few ingested pellets are rarely recorded



Summary of Lead Shot Ingestion Cases in Humans:

Country	N cases	# Pb pellets/ person
Argentina	1	99
Canada	92	1 to >500
Denmark	7	1 - 2
France	1	29
Germany	4	10 - 98
New Zealand	1	multiple
Siberia	5	7 - 75
United Kingdom	1	2
United States	63	1 -122
Total	175	1 to > 500

Effects of Lead Shot Ingestion in Humans:

- typically 10 - 15 % of ingested quantity of lead is absorbed; higher absorption rates in children and pregnant woman
- small fragments undoubtedly pass through
- larger fragments may be retained, possible GI complications
- most individuals with retained shot were asymptomatic
- elevated blood lead levels have been reported in individuals found to retain 1 - 2 pellets in appendix

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Human Health Summary:

- The flesh of animals killed with Pb shot ammunition contains metallic Pb fragments of varying size, from microscopic 'dust' to whole pellets a few mm in diameter
- Embedded fragments are a source of dietary Pb for predatory wildlife and human consumers of wild game
- Possible health significance of ingestion and retention of lead shot fragments warrants further investigation

Summary:

- Use of lead shot to harvest game provides a source of dietary lead for wildlife and human consumers of country foods

Presentation: 6

Lead Levels in Mourning Doves from South Carolina: Potential Hazards to Doves and Humans.

Burger, J., Rutgers University, Piscataway, NJ; Kennamer, R.A., Savannah River Ecology Laboratory, Aiken, SC; Brisbin, I.L., Jr.*, Savannah River Ecology Laboratory, Aiken, SC; and Gochfeld, M., UMDNJ-RWJ Medical School, Piscataway, NJ.

Levels of lead and other environmental contaminants were determined in muscle samples from mourning doves (Zenaida macroura) foraging on a contaminated Superfund waste site at the 780-km2 Department of Energy's Savannah River Site (SRS) near Aiken, South Carolina. These contamination levels were compared to those of doves collected during fall hunts on public dove fields located on lands surrounding the SRS. Lead levels were the highest in muscles of birds collected off of the SRS in fields with prior histories of dove hunting. Levels of all metals including lead were generally within the lower range of those reported in the literature for all birds, and were unlikely to pose health risks to the birds themselves. Lead levels in doves from the public hunting fields were well below reference levels for adult human intake and only would have been a problem if a growing child ate 120 g or more of dove meat every day of the year. Thus, the doves from a contaminated waste site of the SRS were less likely to pose a human health risk from lead if eaten, than those from offsite public hunting areas where exposure to spent lead shot apparently has increased lead contamination levels in these birds.

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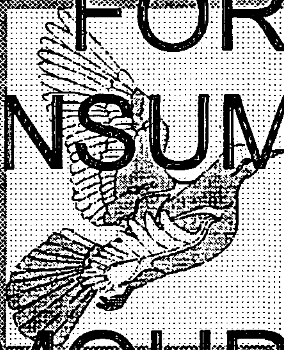
Related Reference:

Burger, J., Kennamer, R.A., Brisbin, I.L. and Gochfeld, M. 1997. Metal levels in Mourning Doves from South Carolina: potential hazards to doves and hunters. Environ Res. 75: 173 - 186.

BURGER

FOR CONSUMERS OF MOURNING DOVES



Joanna Burger[1], Robert A. Kennamer[2], I. Lehr Brisbin, Jr.[2] and Michael Gochfeld[1]

1. Environmental and Occupational Health Sciences Institute (EOHSI), Rutgers University

&

Consortium for Risk Evaluation with Stakeholder Participation (CRESP)

2. Savannah River Ecology Laboratory, Aiken, South Carolina

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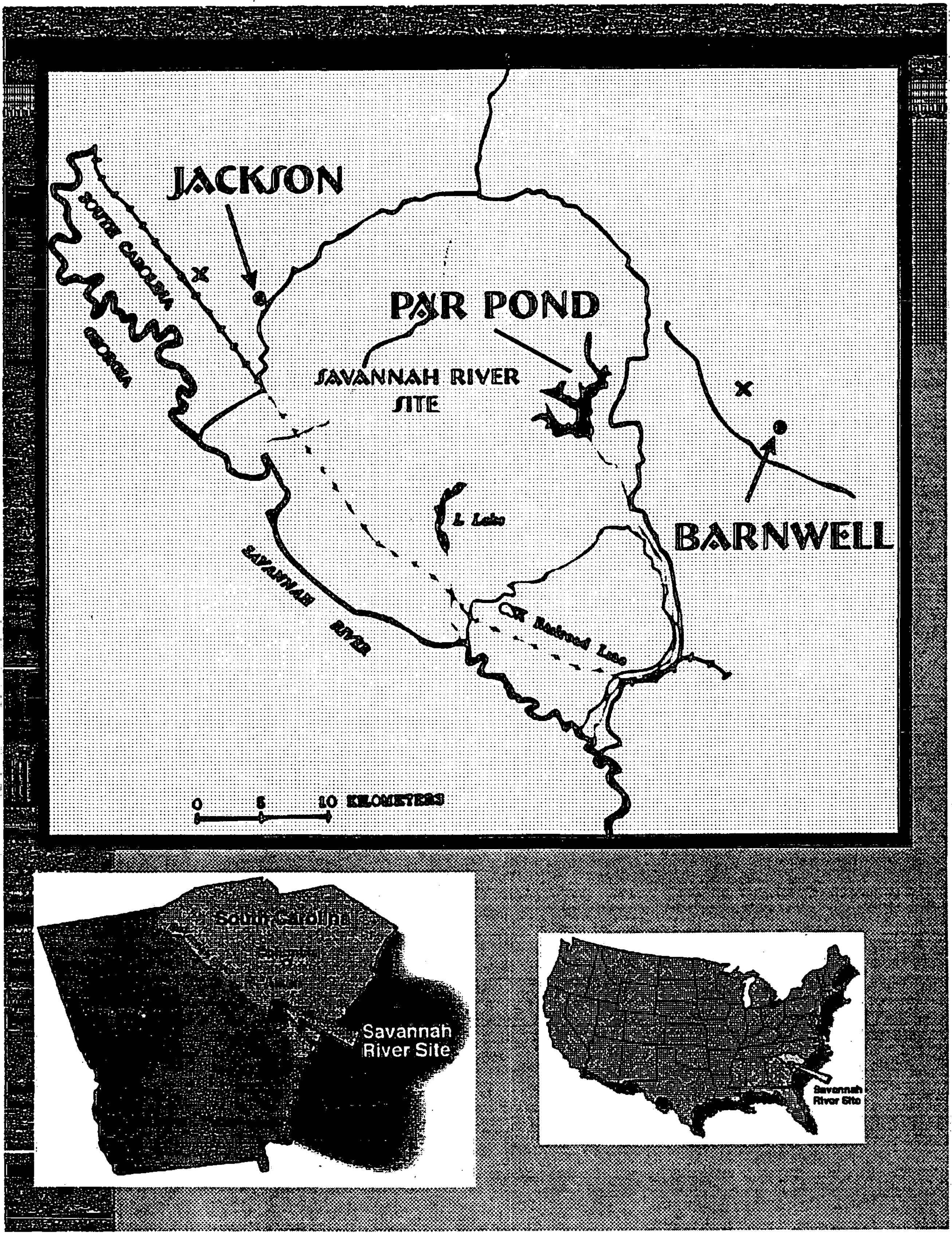
JACKSON
PAR POND
SAVANNAH RIVER SITE
BARNWELL
SOUTH CAROLINA
GEORGIA
L Lake
SAVANNAH RIVER
0 5 10 KILOMETERS
South Carolina
Savannah River Site
Savannah River Site

OBJECTIVES/HYPOTHESES

1. To examine levels of heavy metals and radiocesium in tissues of Mourning Doves, and to determine whether these are detrimental to Doves.

2. To conduct a risk assessment for humans consuming meat from Mourning Doves.

3. To test the null hypothesis

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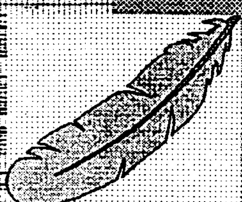
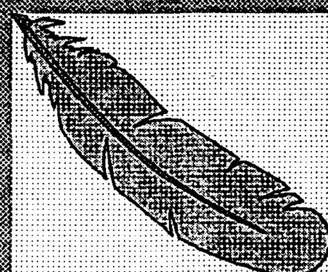
HEAVY METAL AND SELENIUM LEVELS (PPB) IN SOUTH CAROLINA MOURNING DOVE MUSCLE

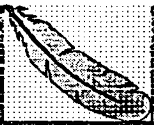
	BARNWELL	JACKSON	PAR POND	P
LEAD	10.6(A)	7.1(A)	5.3(A)	NS
CADMIUM	5.4(A)	2.5(B)	7.4(A)	0.005
SELENIUM	140.7(A)	215.8(B)	315.0(C)	000
MANGANESE	491.7(A)	421.4(A)	838.5(B)	0.0001
CHROMIUM	69.9(A)	68.8(A)	28.8(B)	0.007

HEAVY METAL & SELENIUM LEVELS (PPB) IN SOUTH CAROLINA MOURNING DOVE FEATHERS

	BARNWELL	JACKSON	PAR POND	P
LEAD	459.5(A)	1328.0(A)	15.4(B)	0.0001
CADMIUM	101.7(A)	67.3(A)	121.0(A)	NS
SELENIUM	543.2(A)	487.0(A)	579.7(A)	NS
MANGANESE	2625.4(A)	5107.2(B)	4623.1(B)	0.01
CHROMIUM		369.[illegible]	659.2(A)	0.005





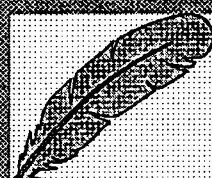


HEAVY METAL AND SELENIUM LEVELS (PPB) IN SOUTH CAROLINA MOURNING DOVES

Geometric means are given. Letters denote significant differences (Duncan Test)

	BARNWELL	JACKSON	PAR POND	P
FEATHERS				
LEAD	459.5(A)	1328.0(A)	15.4(B)	0.0001
CADMIUM	101.7(A)	67.3(A)	121.0(A)	NS
SELENIUM	543.2(A)	487.0(A)	579.7(A)	NS
[illegible]NESE	2625.4(A)	5107.2(B)	4623.1(B)	0.01
[illegible]UM	658.9(A)	369.8(B)	659.2(A)	0.005
[illegible]				
[illegible]	10.6(A)	7.1(A)	5.3(A)	NS
[illegible]M	5.4(A)	2.5(B)	7.4(A)	0.005
[illegible]M	140.7(A)	215.8(B)	315.0(C)	0.0001
[illegible]NESE	491.7(A)	421.4(A)	838.5(B)	0.0001
[illegible]UM	69.9(A)	68.8(A)	28.8(B)	0.007
[illegible]				
[illegible]	251.6(A)	134.8(A)	30.9(B)	0.04
[illegible]M	150.2(AB)	121.7(A)	225.9(B)	0.02
[illegible]M	434.3(A)	339.9(A)	728.8(B)	0.0001
[illegible]NESE	3668.4(A)	4769.3(B)	6513.3(C)	0.0001
[illegible]UM	219.8(A)	83.6(B)	170.4(A)	0.0001

[illegible]etters denote significant differences (p<.05)



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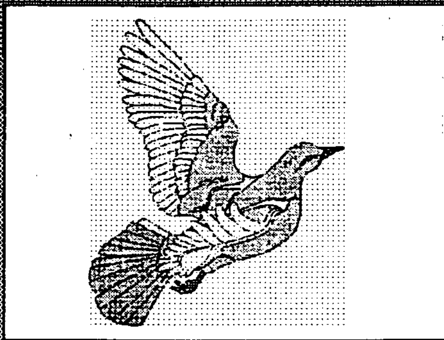
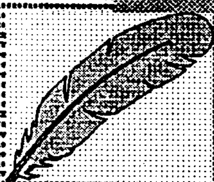
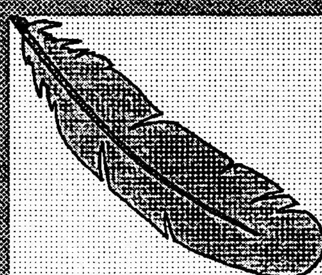
CONCENTRATIONS OF 137Cs (BQ/G WET MASS) IN WHOLE-BODY AND MUSCLE TISSUE OF MOURNING DOVES

Given are arithmetic means; all significant at $p<0.001$



	Barnwell	Jackson	Par Pond
Sample Sizes	48, 49	60	72
Whole Body ^{137}Cs	0.001±0.001(A)	0.002±0.001(A)	0.156±0.013(B)
Muscle ^{137}Cs	0.006±0.002(A)	0.009±0.001(A)	0.220±0.017(B)





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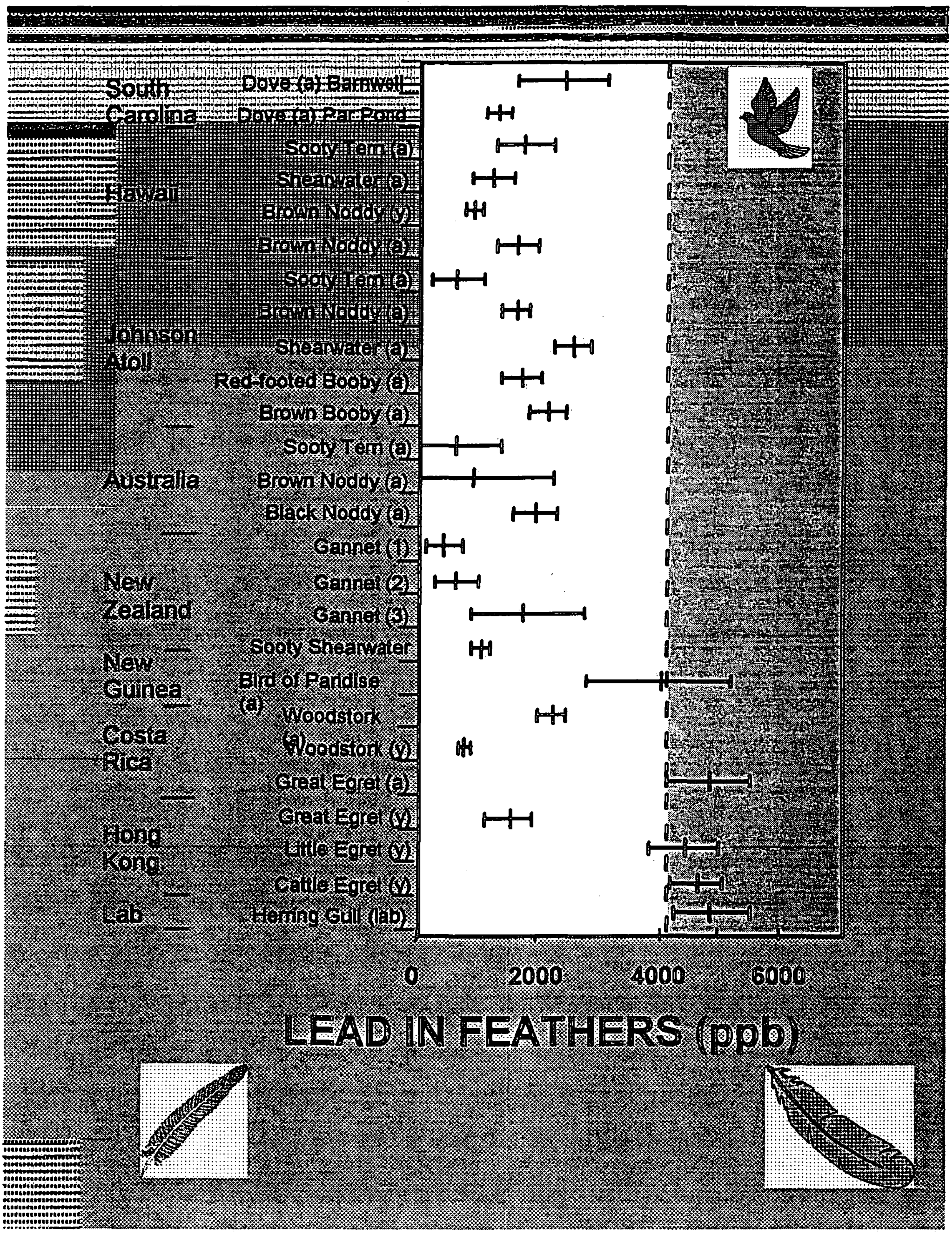
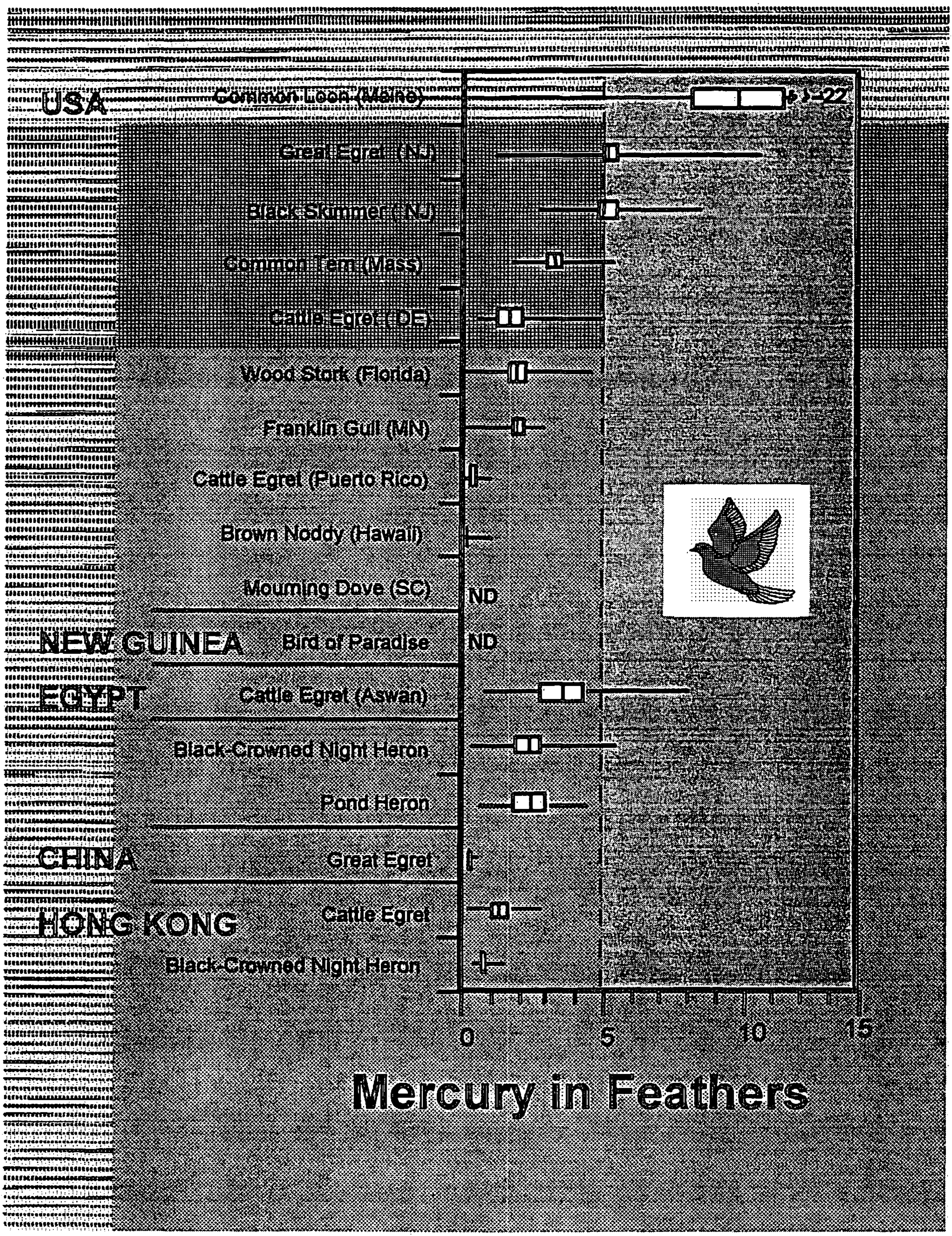
CONCENTRATIONS OF ^{137}Cs

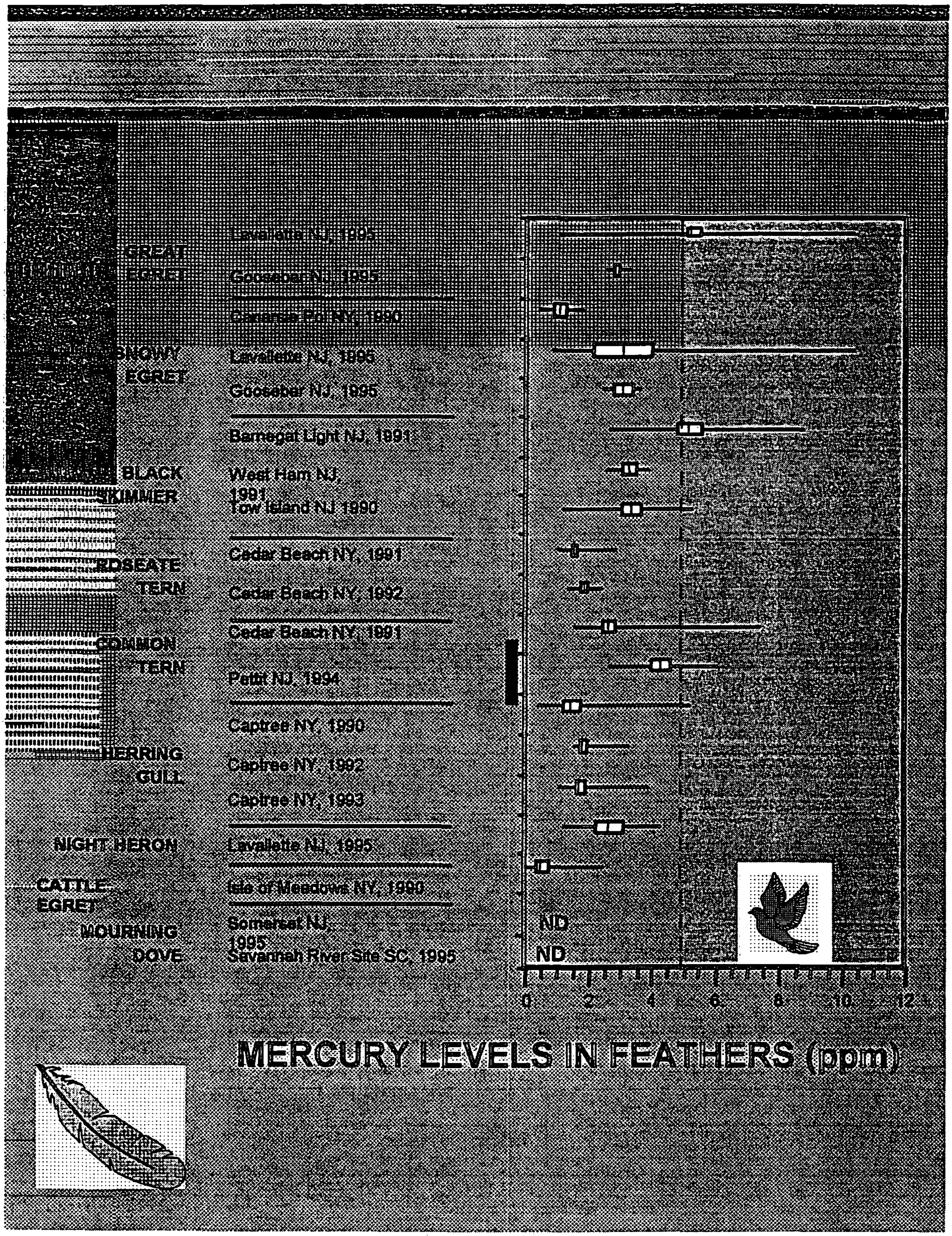
(BQ/G WET MASS) IN MOURNING DOVES FROM SRS'S PAR POND RESERVOIR

	1992	1993	1994
Sample Sizes	27	45	38
Whole Body 137Cs	0.240±0.027(A)	0.106±0.007(B)	0.046±0.004(C)
Muscle 137Cs	0.299±0.036(A)	0.172±0.011(B)	0.083±0.005(C)
Ingesta 137Cs	0.557±0.065(A)	0.248±0.018(B)	0.048±0.013(C)

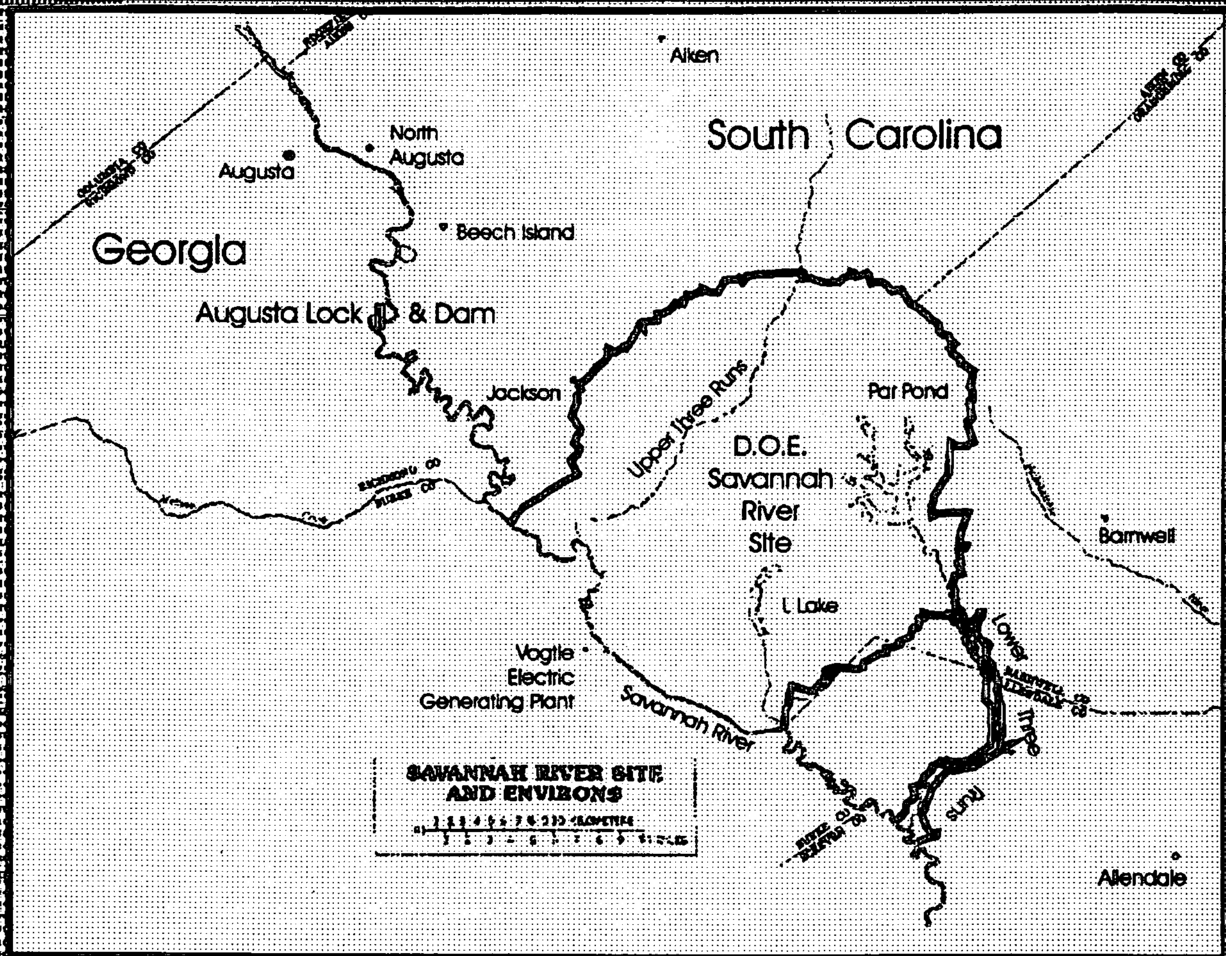
BURGER


South Carolina
Dove (a) Barnwell
Dove (a) Par Pond
Hawaii
Sooty Tern (a)
Shearwater (a)
Brown Noddy (y)
Brown Noddy (a)
Johnson Atoll
Sooty Tern (a)
Brown Noddy (a)
Shearwater (a)
Red-footed Booby (a)
Brown Booby (a)
Australia
Sooty Tern (a)
Brown Noddy (a)
Black Noddy (a)
New Zealand
Gannet (1)
Gannet (2)
Gannet (3)
Sooty Shearwater
New Guinea
Bird of Paridise (a)
Costa Rica
Woodstork (a)
Woodstork (y)
Hong Kong
Great Egret (a)
Great Egret (y)
Little Egret (y)
Cattle Egret (y)
Lab
Herring Gull (lab)
0
2000
4000
6000
LEAD IN FEATHERS (ppb)


USA
Common Loon (Maine)
22
Great Egret (NJ)
Black Skimmer (NJ)
Common Tern (Mass)
Cattle Egret (DE)
Wood Stork (Florida)
Franklin Gull (MN)
Cattle Egret (Puerto Rico)
Brown Noddy (Hawaii)
Mourning Dove (SC)
ND
NEW GUINEA
Bird of Paradise
ND
EGYPT
Cattle Egret (Aswan)
Black-Crowned Night Heron
Pond Heron
CHINA
Great Egret
HONG KONG
Cattle Egret
Black-Crowned Night Heron
0
5
10
15
Mercury in Feathers


GREAT EGRET
Lavallette NJ, 1995
Goosebar NJ, 1995
Canarsie Pol NY, 1990
SNOWY EGRET
Lavallette NJ, 1995
Goosebar NJ, 1995
BLACK SKIMMER
Barnegat Light NJ, 1991
West Ham NJ, 1991
Tow Island NJ 1990
ROSEATE TERN
Cedar Beach NY, 1991
Cedar Beach NY, 1992
COMMON TERN
Cedar Beach NY, 1991
Pettit NJ, 1994
HERRING GULL
Captree NY, 1990
Captree NY, 1992
Captree NY, 1993
NIGHT HERON
Lavallette NJ, 1995
CATTLE EGRET
Isle of Meadows NY, 1990
MOURNING DOVE
Somerset NJ, 1995
Savannah River Site SC, 1995
ND
ND
0
2
4
6
8
10
12
MERCURY LEVELS IN FEATHERS (ppm)

BURGER


Aiken
South Carolina
North Augusta
Augusta
Georgia
Beech Island
Augusta Lock & Dam
Jackson
Par Pond
Upper Three Runs
D.O.E. Savannah River Site
Barnwell
L Lake
Lower Three Runs
Vogtle Electric Generating Plant
Savannah River
Allendale
SAVANNAH RIVER SITE AND ENVIRONS

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Assumptions for Humans

- 35 grams edible meat per dove
- 4 doves eaten per day (140 g/d)
- Doves consumed daily for hunting season (76 days)

Hazard Index = daily intake / reference dose

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Risk to a Child from Consumption of Mourning Dove

Metal	Reference Dose µg/kg/day	PAR POND Daily Intake µg/day	PAR POND Daily Dose µg/kg/day	BARNWELL Daily Intake µg/day	BARNWELL Daily Dose µg/kg/day
Cadmium	1	0.29	0.02	0.29	0.02
Chromium III	1000	0.87	0.05	2.04	0.12
Chromium VI	5	0.87	0.05	2.04	0.12
Lead	no RfD	2.33	0.13	4.08	0.23
Manganese	100	23.0	1.32	16	0.92
Selenium	3	9.62	0.55	4.96	0.28
Mercury	all mercury levels were below detection limit				

Assumes that a 4 year old (ave wgt. 17.4 kg) consumed 4 doves per day = 140 g/day for 76 days.

Ingested Reference Doses (RfDs) based on EPA's Intergrated Risk Information System (IRIS) data base (EPA 1991 and subsequent).

Daily intakes are based on the mean value for each metal in dove muscle.

Samples were analyzed for total chromium.

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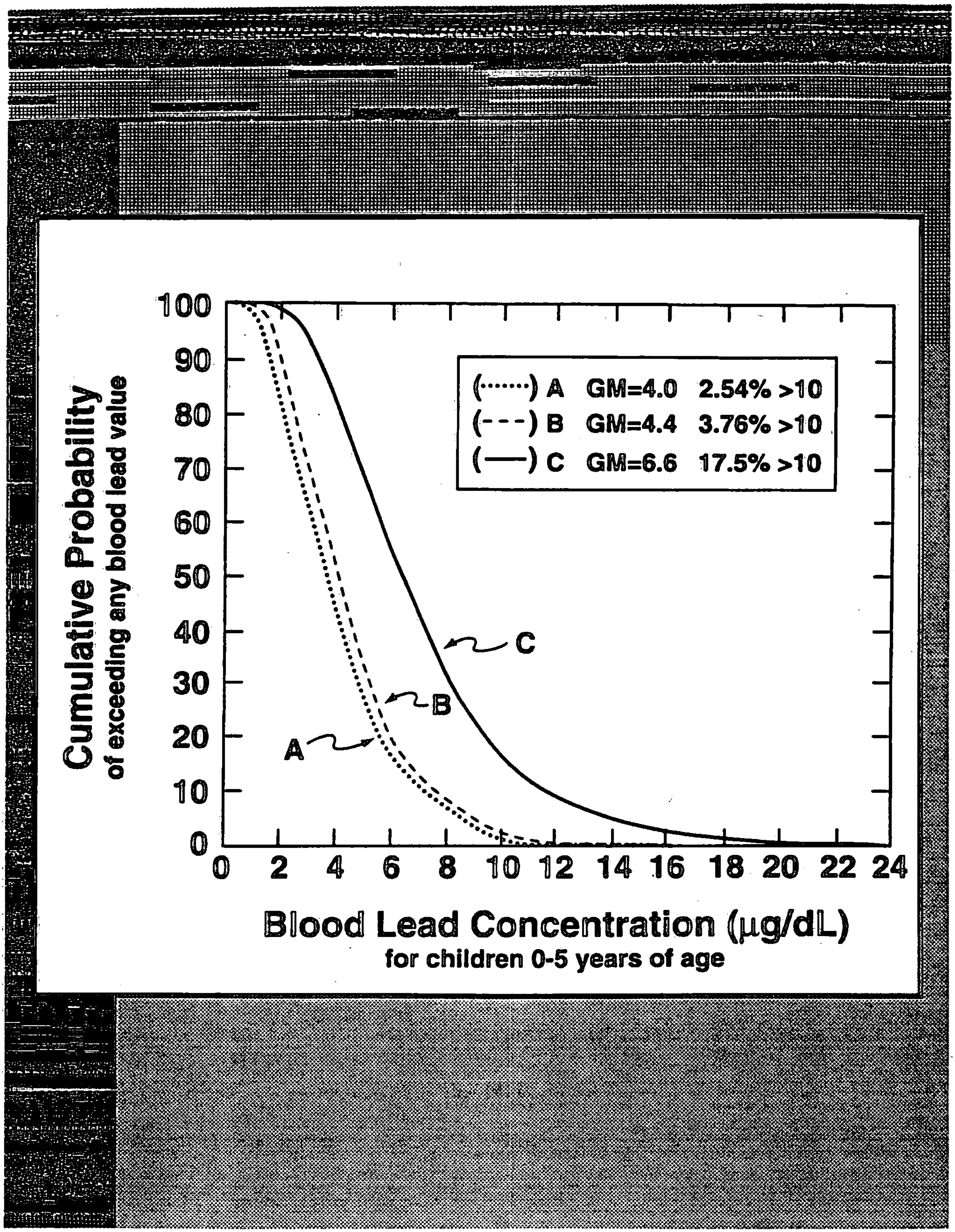

Cumulative Probability
of exceeding any blood lead value
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24
(·······) A GM=4.0 2.54% >10
(- - -) B GM=4.4 3.76% >10
(——) C GM=6.6 17.5% >10
A
B
C
Blood Lead Concentration (µg/dL)
for children 0-5 years of age

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MAXIMUM NUMBER OF DOVE THAT CAN BE EATEN WHILE STILL MAINTAINING THE RISK AT LESS THAN 1 IN A MILLION FROM ^{137}Cs

	pCi/g	g/year	Doves/year
Par Pond, overall mean	5.943	5320	152
Par Pond, overall 1992	8.089	3912	112
Par Pond, hot arm overall	6.122	5165	148
Par Pond, hot arm 1992	11.630	2721	78
Par Pond, hot arm[a], 1992, maximum	22.030	1436	41
Par Pond geometric mean	11.103	2853	82
Jackson	0.235	133000	3800

[a] Hot Arm of Par Pond had the highest levels of ^{137}Cs overall.

CONCENTRATIONS OF ^{137}Cs (BQ/G WET MASS) IN WHOLE-BODY AND MUSCLE TISSUE OF MOURNING DOVES

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Ingesta ^{137}Cs	0.557±0.065(A)	0.248±0.018(B)	0.048±0.013(C)

BURGER

Presentation: 7

Human health risk associated with environmental lead exposure.

Kosatsky, T. Montreal Public Health Department, Montreal, Quebec

While lead has been in use since ancient times, its toxic effects are still under study. Effects of high exposure such as encephalopathy, anemia and chronic nepropathy are well known. But knowledge on the effects of chronic low dose exposure has progressed only in the recent years. Cohort studies on low exposure of children demonstrated that blood lead levels in the range of 0.48 - 0.72 mol/L (10-15 g/dL) in infants and young children are associated with neurobehavioral and cognitive impairment. No LOAEL has been clearly defined for such an effect and its reversibility is uncertain. Other subtle effects of low dose exposure in adults are still under study : elevation of blood pressure, impairment of renal function and fertility. Acceptable concentrations of lead in blood samples will also be discussed.

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T: 514- 5282400-3285
F: 514- 5282459
Email: tkosatsk@santepub-mtl.qc.ca

KOSATSKY

1.

◊ **Effects of Lead on Human Health**

◊ **Game Hunting and Eating and Lead Uptake : two case studies**

Tom Kosatsky, MD
McGill University and
Montreal Public Health Departement

Thanks : Cree Board of Health and Social Services of James Bay,
Dr Elizabeth Robinson
Vision 2000, Health Component, Health Canada
Raymond Przybysz

2.

STUDIES OF HUMAN HEALTH EFFECTS OF LEAD

1st Generation

- Descriptive
- High level
- Industrial

2nd Generation

- Subtle low level
- Physiologic

3rd Generation

- Prospective and retrospective epidemiology

3.

Major Occupations Associated with Risk of Inorganic Lead Poisoning

Battery makers	Metal grinders/burners/refiners
Brass workers	Painters
Bronzers	Pigment makers
Cable makers/splicers	Pipe cutters
Chemical operators	Pottery workers
Demolition workers	Printers (lino/electrotype)
Firing range personnel	Shipburners
Foundrymen	Solderers
Glass makers/polishers	Stained glassmakers
Gunstock/barrelmakers	Tetraethyl lead manufacturers
Jewelers	Welders
Lead burners	

4. 1st generation notions of lead toxicity

CONTINUUM OF SIGNS AND SYMPTOMS ASSOCIATED WITH LEAD TOXICITY

Mild Toxicity	Moderate Toxicity	Severe Toxicity
Myalgia or paresthesia	Arthralgia	Paresis or paralysis
Mild fatigue	General fatigue	Encephalopathy ⇨ may abruptly lead to seizures, changes in consciousness, coma, and death
Irritability	Difficulty concentrating	Lead line (blue/black) on gingival tissus
Lethargy	Muscular exhaustibillity	Colic (intermittent, severe abdominal cramps)
Occasional abdominal discomfort	Tremor Headache Diffuse abdominal pain Vomiting Weight loss Constipation	

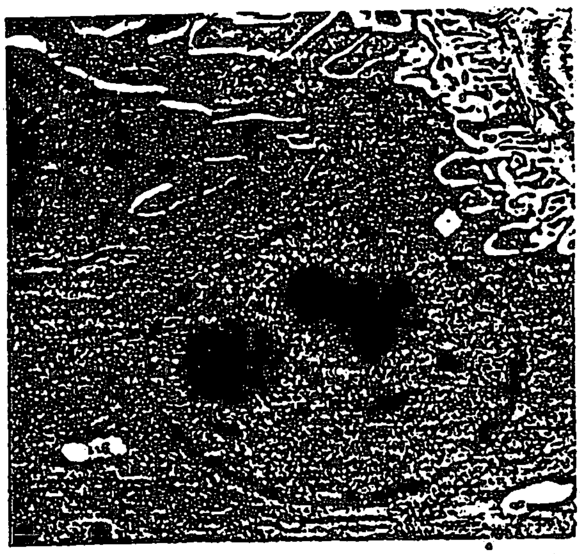
5.

intestinal lead flakes on X-ray - lead paint as an important source of child lead exposure

6.

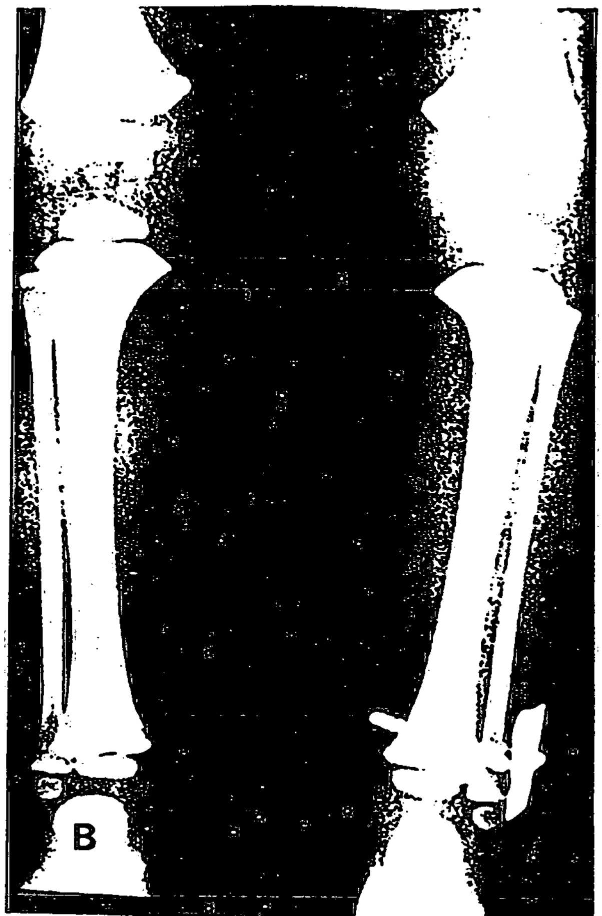
Lead line. Blackish discoloration in gum margins, here most marked in upper teeth. The line is caused by precipitation of sulfur salts from oral bacteria by lead.

7.



Lead-induced inclusion bodies in nucleus of renal tubular lining cell.

8.



long bone X-ray - increased mineralization and secondary rickets

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9.

SI μmol/L	1.25 25 μg%	2.5 25–50 μg%	4.0 50–80 μg%	≥ 80 μg% or greater
BLOOD-LEAD LEVELS				
Symptoms	None	None	Mild, nonspecific complaints	Colic, irritability, drowsiness, nausea and vomiting, convulsions, coma
Pathophysiologic effects				
Metabolic	Unknown	Urinary ALA may increase.	Increase in urinary ALA + coproporphyrins, increased EP	Same as 50–80 μg%
Hematologic	Unknown	Unknown	Decreased RBC survival, increased RBC production (reticulocytes, basophilic stippling)	Same as 50–80 μg%
Renal	Unknown	No acute effects; possible chronic nephritis	Minimal acute dysfunction. Chronic irreversible nephritis	Fanconi-like syndrome (reversible)
CNS	Unknown	Unknown	Unknown	Minimal to severe brain damage (permanent)
Peripheral nervous system	Unknown	Possible decreased nerve conduction	Decreased nerve conduction	Child: weakness or paralysis; neuropathy rare.
Residual effects	Unknown	Unknown	Unknown	From minimal learning disability to profound mental and behavioral deficiency, convulsions, and blindness

10.

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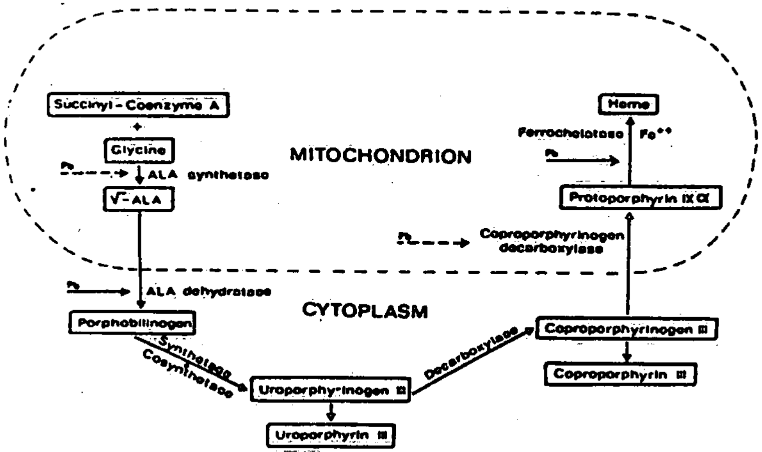
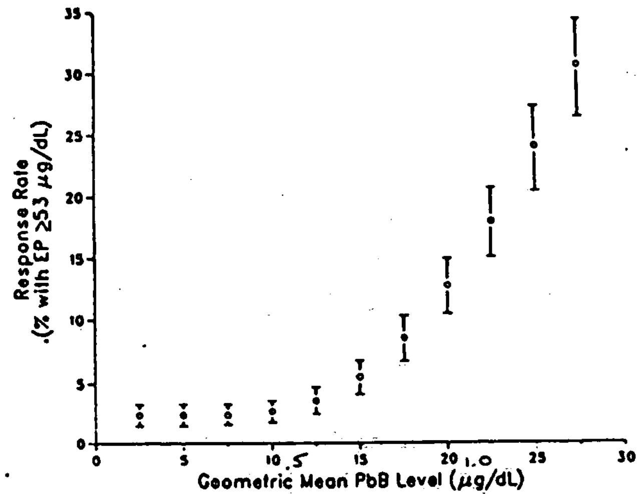


Schematic outline of heme synthesis. The steps where the lead-induced inhibition is strong and well established are indicated by *solid arrows*. *Dotted arrows* indicate steps where inhibition is less marked. *From Hernberg, S: Lead. In Zenz C, editor:* Occupational medicine: principles and practical applications, *Chicago, 1988, Mosby.*

effects of lead on heme (hemoglobin) synthesis

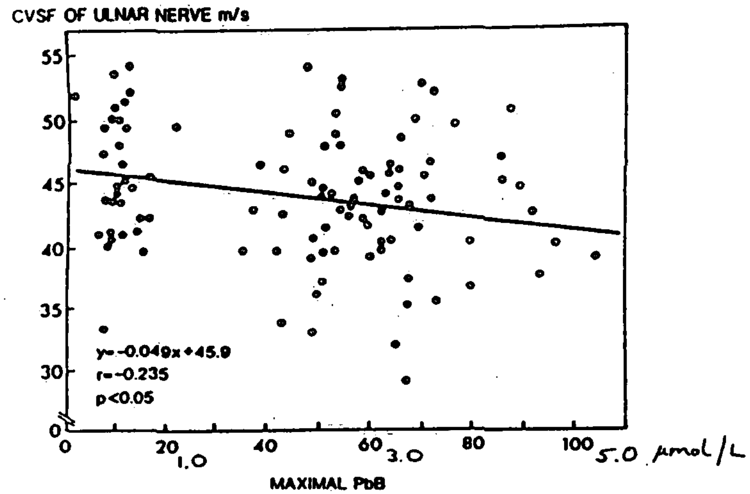
12.



Risk results for the occurrence of EP level ≥ 53 μg/dL (median values are indicated by circles and 90% CIs by bars extending above and below the median values).

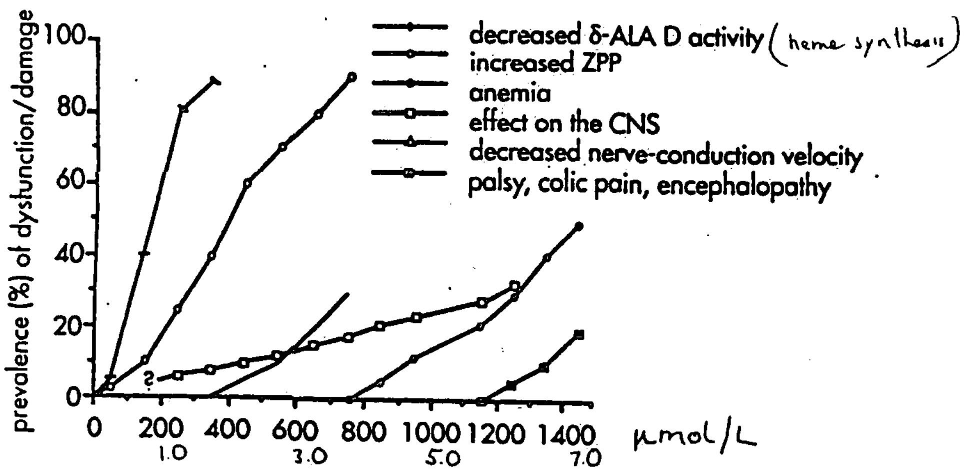
threshold for effects on EP (erythrocyte - red cell protoporphyrin)

3.



Relationship between blood lead concentration and conduction velocity of the slow fibres of the ulnar nerve.

14. dose response recapitulated



Concentration of lead in blood (µg Pb/L). *Modified and adapted from Elinder C-G, et al:* Biological monitoring of metals in man, *Geneva, 1993, World Health Organization (in press).*

5.

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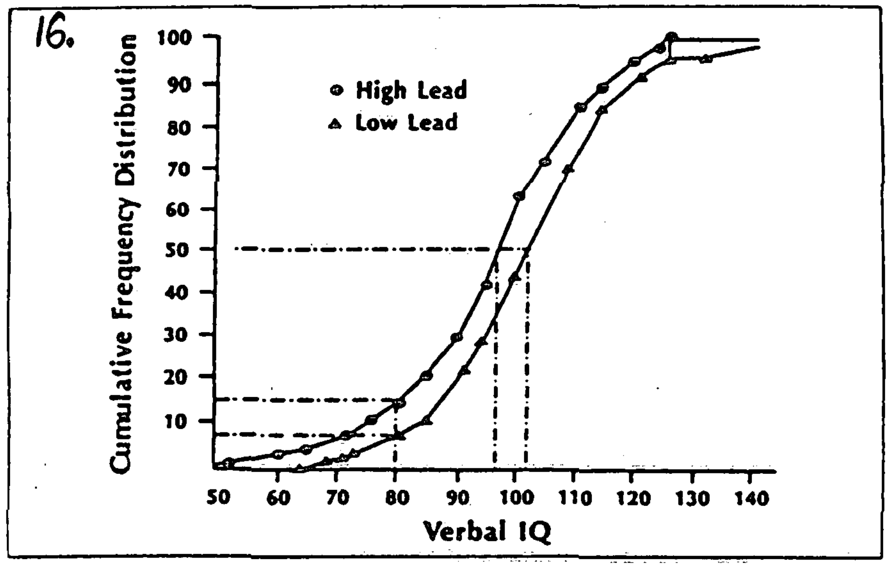
16.



Cumulative frequency distribution of verbal IQ scores in children with high and low* [postnatal] *blood lead levels.

Source: Needleman et al, 1979. Reprinted with permission from The New England Journal of Medicine, 300: 689-95.

postnatal effect

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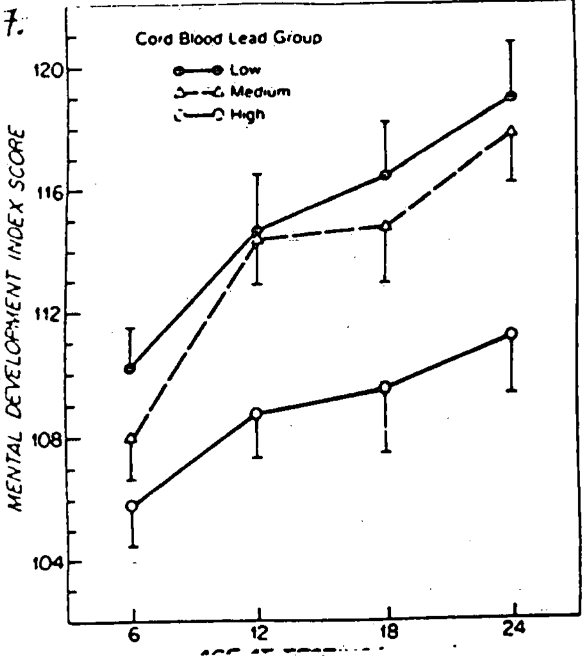
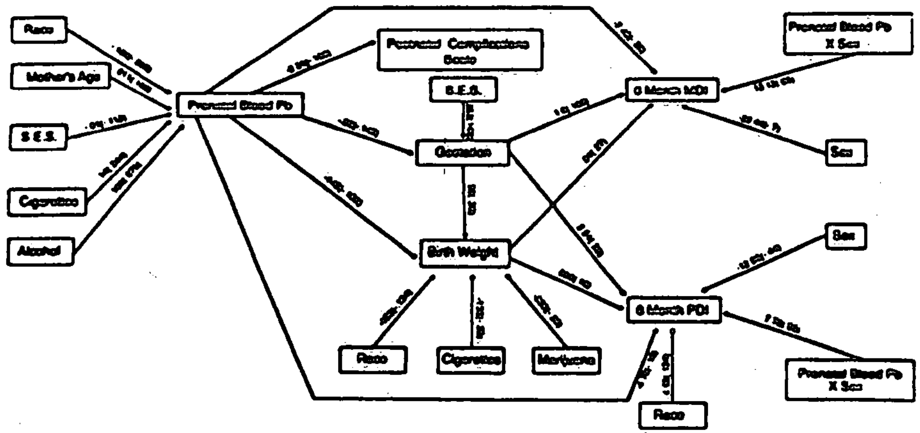
17.



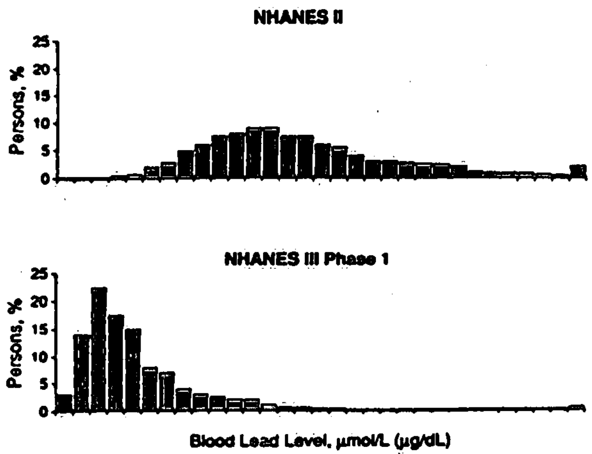
18.



A structural equation model of Mental Development Index (MDI) and Psychomotor Development Index (PDI) scores at 6 months of age for infants in the Cincinnati Prospective Lead Study (Buncher et al., 1991). The number on a path represents a regression coefficient (standard error). "S.E.S." is socioeconomic status.

importance of modifying and counfounding factors

19.



Blood lead levels for persons aged 1 to 74: U.S., Second National Health and Nutrition Examination Survey (1976 to 1980, top) and phase 1 of the Third National Health and Nutrition Examination Survey (1988 to 1991, bottom). [From Pirkle, et al. (1994), with permission.]

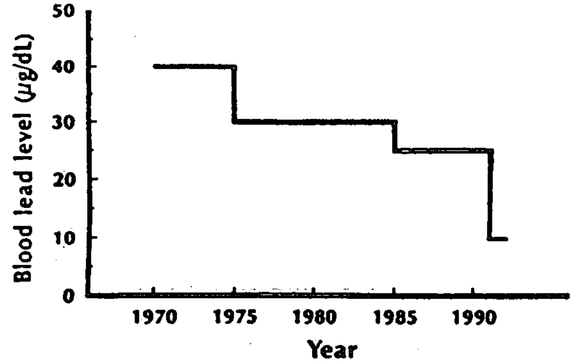
declining US lead exposure

20.

DEATHS AND ACUTE, SEVERE ILLNESS FROM LEAD POISONING ARE NOW RARE. HOWEVER, WE NOW KNOW THAT LARGE NUMBERS OF CHILDREN MAY SUFFER ADVERSE HEALTH EFFECTS AT BLOOD LEAD LEVELS THAT WERE ONCE CONSIDERED SAFE.

21.

Blood lead levels considered elevated by CDC



22.

BENEFITS OF PREVENTING LEAD EXPOSURE

THE BENEFITS WE QUANTIFIED ARE:

- REDUCED MEDICAL COSTS
- REDUCED SPECIAL EDUCATION COSTS
- INCREASED FUTURE PRODUCTIVITY
- REDUCED INFANT MORTALITY

Average benefits of preventing
Blood lead levels from rising above 24 µg/dL:

Avoided medical costs	$1,300 per child
Avoided special education costs	$3,331 per child

A 1 µg/dL increase in blood lead level, regardless of starting blood lead level:

Increased lifetime earnings	$1,147 per µg/dL per child
Reduced infant mortality	$ 300 per µg/dL per newborn

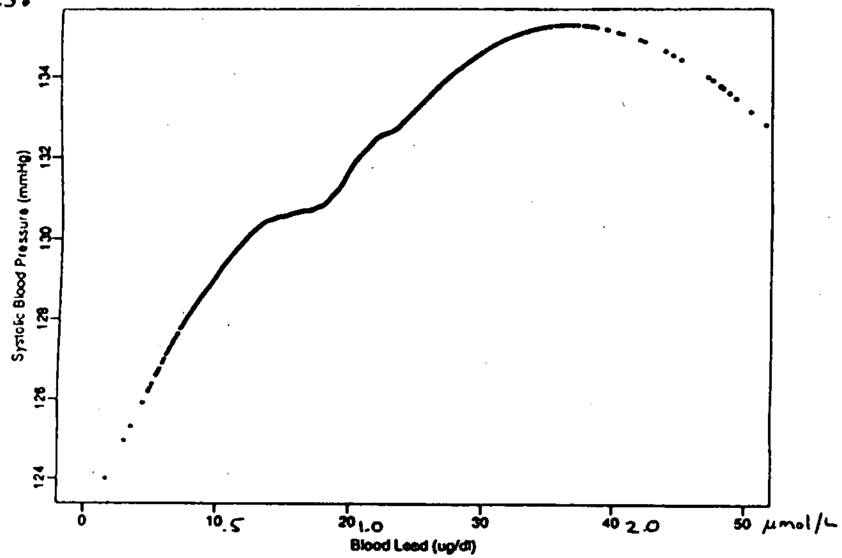
EXAMPLE:

The benefits of preventing a child's blood lead level from rising from 24 µg/dL to 34 µg/dL are:

Avoided medical costs	$ 1,300
Avoided special education costs	$ 3,331
Increased lifetime earnings ($1,147 per µg/dL • 10 µg/dL)	$11,470
Total	$16,101

U.S. PHS lead policy

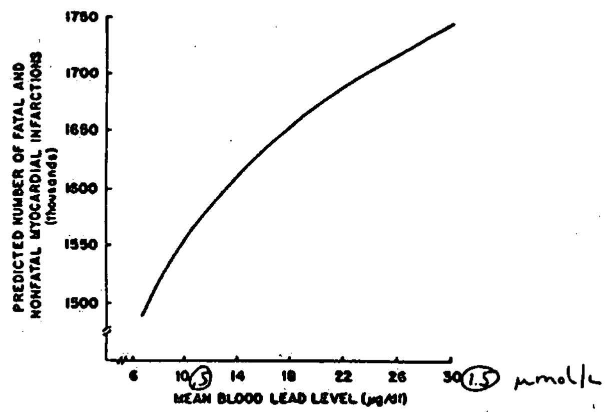
23.



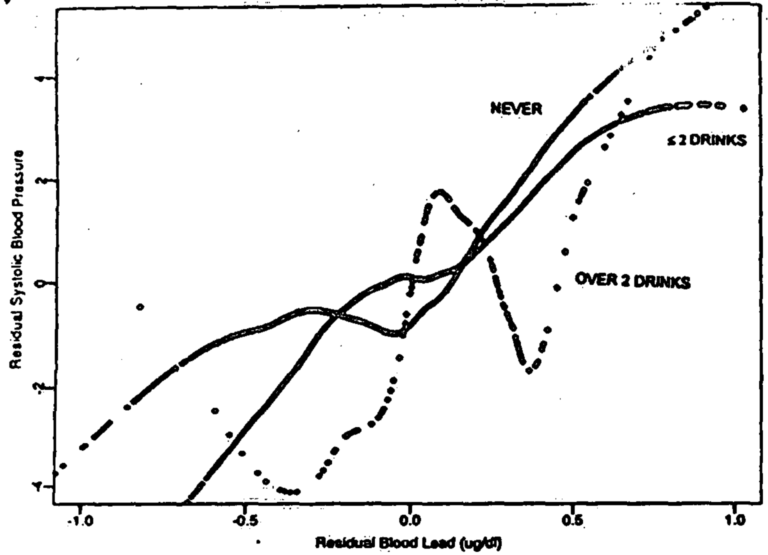
A smoothed plot of adjusted systolic blood pressure (after control, by regression, for age, age squared, body mass index, and race) versus the adjusted blood lead level in adult males in the Second National Health and Nutrition Examination Survey (NHANES II).

effects on adult blood pressure

24.

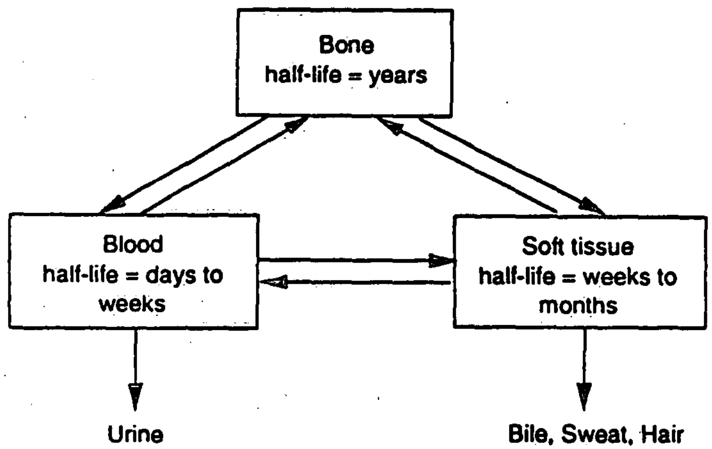


Predicted number of fatal and nonfatal myocardial infarctions for a follow-up period of 10 years (using the Pooling Project multiple logistic regression coefficients) and mean population blood lead levels for white males aged 40–59 years, NHANES II. Men with a history of a heart attack were excluded.



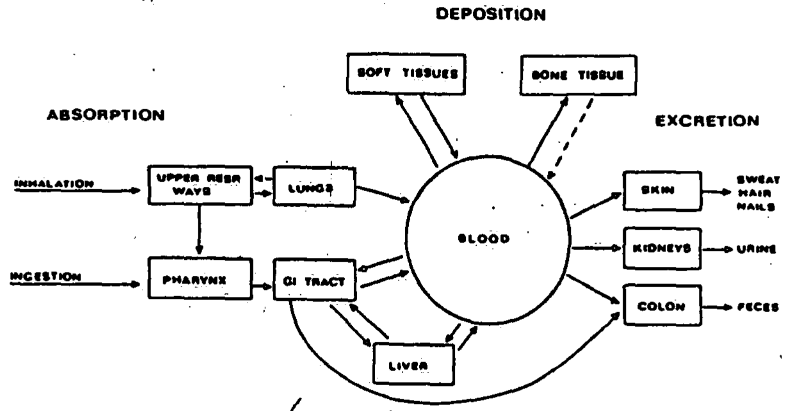
The smooth plots of residual systolic blood pressure (after control, via regression, for age, age squared, body mass index, and race) versus residual blood lead for three categories of alcohol consumption: never drinker, less than two drinks per day, and greater than two drinks per day. The relationship is much noisier in the heavy drinkers.

7. DISTRIBUTION



The three-compartment model for distribution of lead in the body. Estimates of half-lives are given for each compartment. In the steady state, almost all lead is stored in bone, so only very small amounts are excretable by other compartments.

26. METABOLISM



Simplified model of the metabolism of lead in man. *From Hemberg S:* Lead. *In Zenz C, editor:* Occupational medicine: principles and practical applications, *Chicago, 1988, Mosby.*

28. Montreal study of high and low - level sportfish consumers

Blood lead in St. Lawrence River sportfishers (1995-6), by hunting activity

Variable	Coefficient (β)	Standard error	95% CI	t	*P* Value
Intercept	4.47	.18	4.11 *to* 4.82	25.3	.000
Consumer status (*high/low*)	23	.10	.03 *to* .44	2.22	.029
Sex (*female/male*)	-.55	.14	-.84 *to* -.26	-3.80	000
Hunting activity (*yes/no*)	.35	.15	.05 *to* .66	2.30	.024

Model R^2 = 25

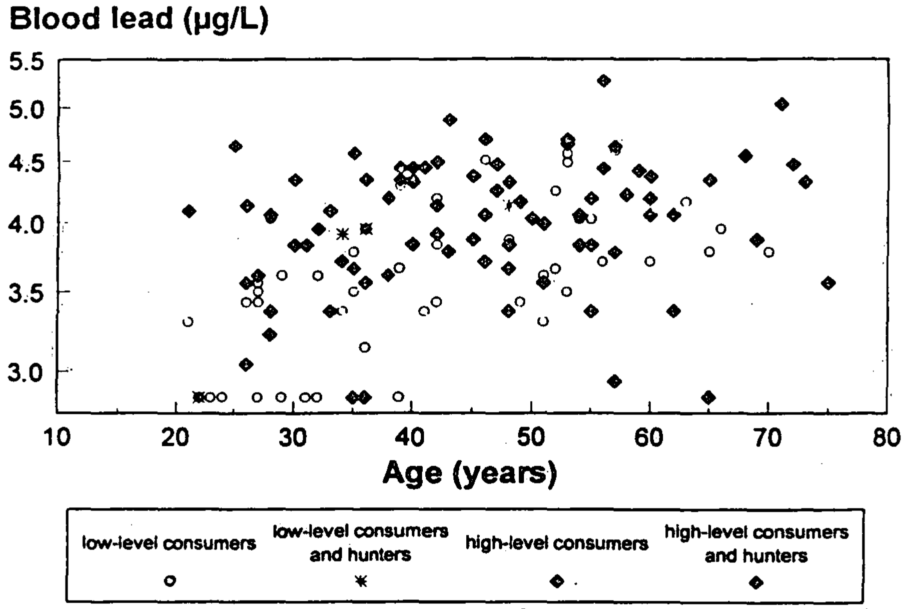
Source of variation	Crude Means (μg/L)	Adjusted[1] Means (μg/L)
Consumer status		
low	47.5	47.0
high	58.7	59.2
Sex		
male	65.1	67.1
female	34.8	32.6
Hunting activity		
⇒ no	44.3	42.8
yes	75.3	80.0

[1] adjusted for all model factors

ie after adjusting for sex and level of sportfish consumption, hunting is an important predictor of blood lead in Montreal sportfishers

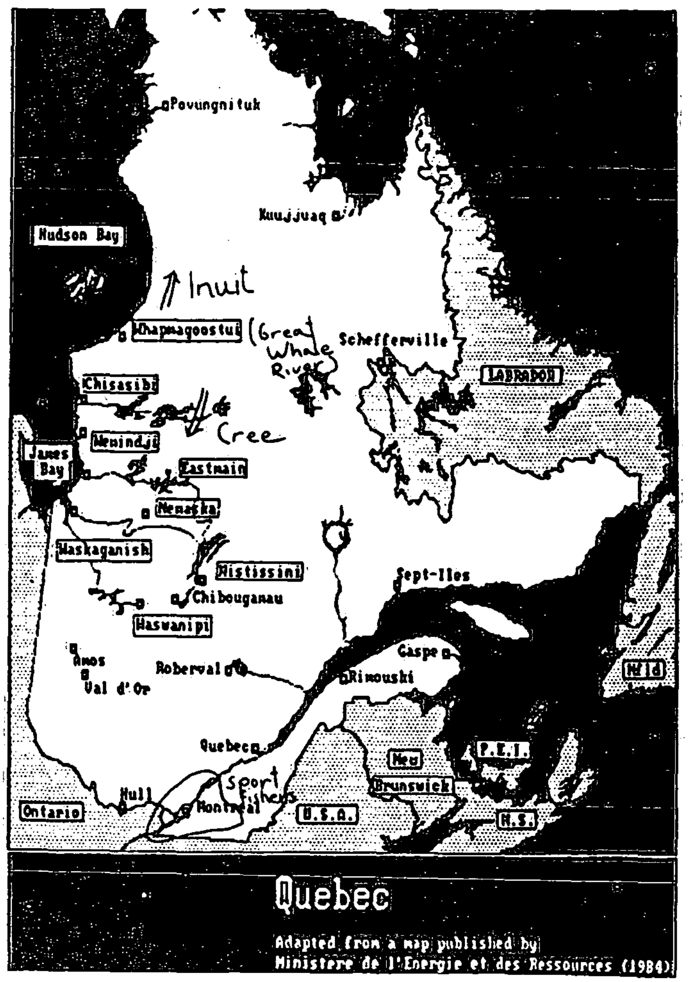
29.

Blood lead and hunting activities versus age, by level of sportfish consumption:
fall 1995, winter 1996 and fall 1996 phases.



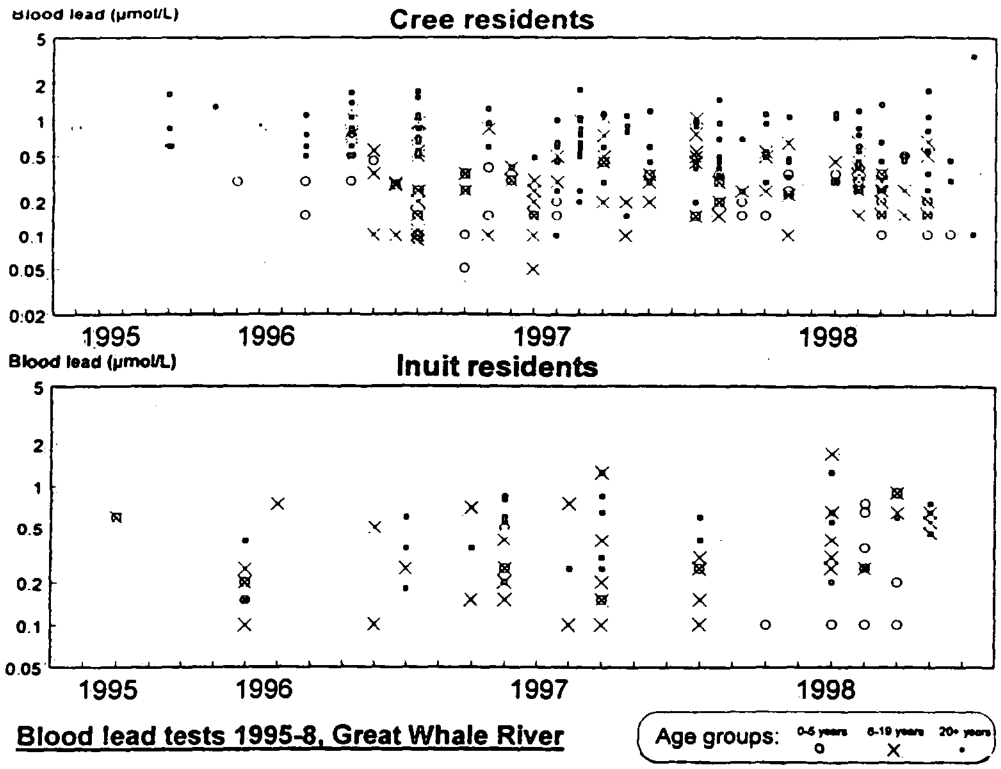
independent effects of fish consumption, hunting

30.



KOSATSKY

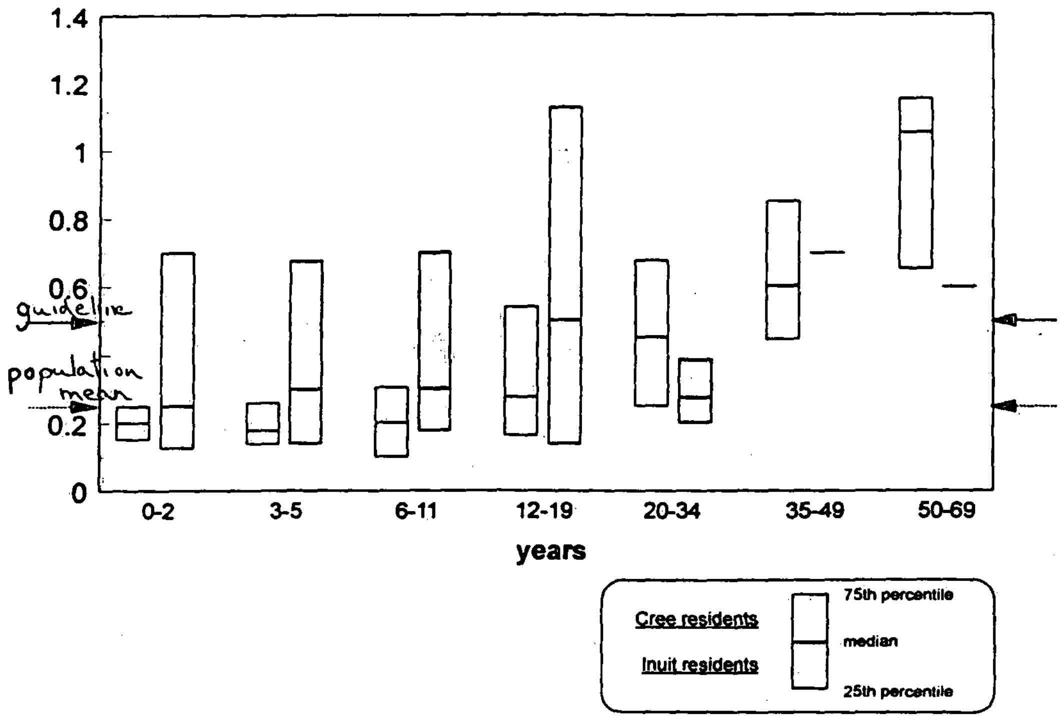
31.



Blood lead tests 1995-8, Great Whale River

32.

Initial blood lead level (µmol/L) by age for Cree and Inuit residents



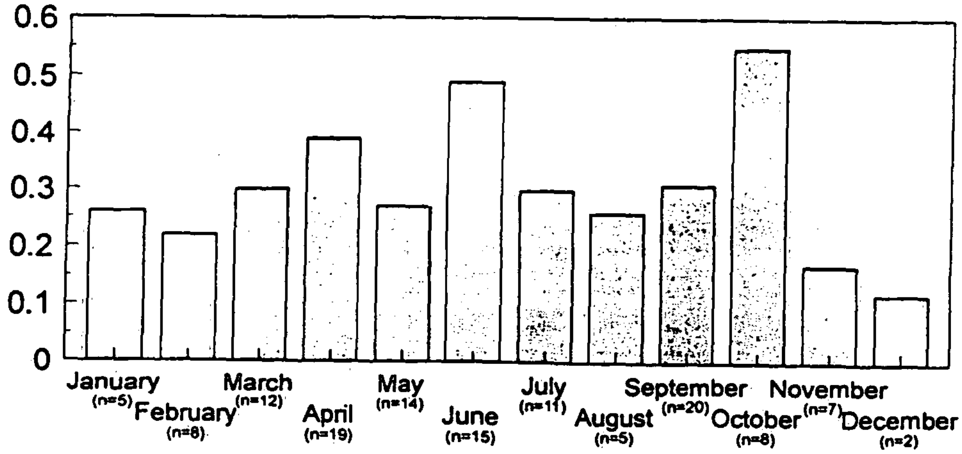
KOSATSKY

first test

Cree residents

Initial blood lead level* (µmol/L)

33.

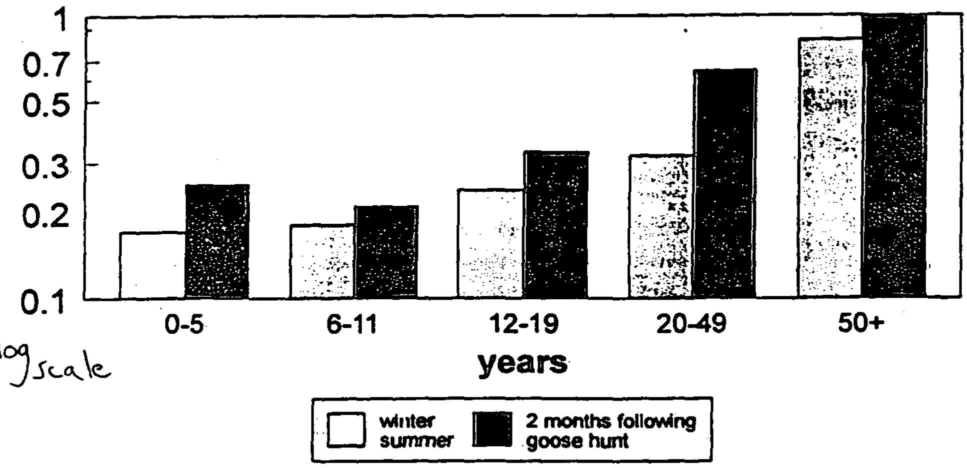


* ANOVA means, adjusted for test year, sex and age group.

Cree residents

Initial blood lead level* (µmol/L) by age and goose month

34.

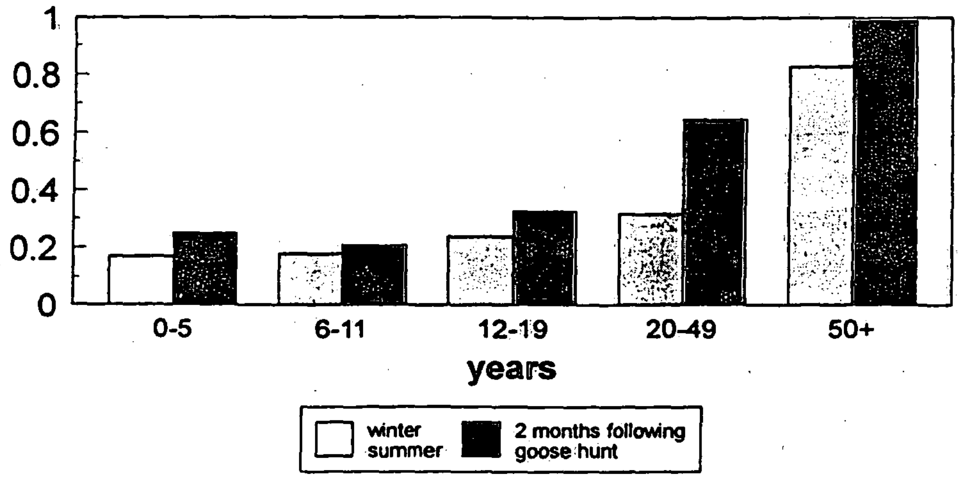


* ANOVA means, adjusted for test year and sex

Cree residents

Initial blood lead level* (µmol/L) by age and goose month

35.



* ANOVA means, adjusted for test year and sex

KOSATSKY

Presentation: 8

Ingested and retained lead shot in the gastrointestinal tracts of humans.

Reddy, E.R. Memorial University of Newfoundland, St. John's, Newfoundland

Seventy patients with retained lead shot in their gastrointestinal tracts from eating wild game, discovered during routine radiographic studies, were followed for periods ranging from two months to thirteen years. The largest number of lead shot accumulated in the appendices. The number varies from 1 to over 200. Twenty patients who had barium studies showed no obstruction of the bowel or any evidence of luminal obstruction of their appendices. Eight patients who had appendectomies showed no evidence of appendicitis on tissue examination. Non of the other patients developed any clinical evidence of appendicitis or lead poisoning. It is concluded that no casual relationship exists between ingestion and retention of lead shot, their number, duration of their presence in the gastrointestinal tracts of the humans and appendicitis.

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Fax: 709-737-6792

Related Reference:

Reddy, E.R. 1985. Retained lead shot in the appendix. J. Can. Assoc. Radiol. 36: 47-48.

REDDY

100

RETAINED LEAD SHOT IN THE APPENDIX**

E.R. Reddy, MD*

ABSTRACT

Sixty-two patients with retained lead shot in their appendices, discovered during routine radiographic studies, were followed for periods ranging from two months to 13 years. The number of lead shot in the appendices varied from one to over 200. Twenty patients who had barium studies showed no evidence of luminal obstruction of their appendices. Eight patients who had appendectomies showed no evidence of appendicitis on tissue examination. None of the other patients developed any clinical evidence of appendicitis or lead poisoning. It is concluded that no causal relationship exists between retention of lead shot, their number, the duration of their presence in the appendix, and appendicits.

RÉSUMÉ

Soixante et deux patients avec billes de plomb (chevrotine) dans l'appendice, notées au cours d'examen radiographiques, ont été observés au cours d'intervalles de deux mois à 13 ans. La quantité de plombs dans l'appendice variait de un à 200. Vingt patients qui ont subi des examens au baryum ne présentaient aucune occlusion de lumière appendiculaire. Huit patients qui ont subi une appendicectomie n'ont présenté aucun signe histologique d'appendicite. Aucun des autres patients n'a développé de signes cliniques d'appendicite ou de saturnisme. Il en ressort qu'il n'y a aucun rapport entre la rétention, le nombre ou la durée de rétention de plombs dans l'appendice et l'appendicite.

KEY WORDS: Appendix, appendicitis, lead shot, foreign bodies.

Introduction

Foreign bodies of various types have been found in the appendix (1). Retained lead shot in the appendix have been occasionally reported as a cause of acute (2,3) and chronic appendicitis (4) and lead poisoning (5). The present study was undertaken to review the clinical course of patients with retained lead shot in their appendices.

Patients and Methods

Thirty-four men and 28 women, with their ages ranging from 22 to 74 years, discovered to have lead —

Figure 1A — Barium colon examination in a 60-year-old woman with a six-month history of diarrhea shows lead shot filled appendix.

Figure 1B — Same patient after 13 years, with symptomatic cholelithiasis, again shows an elongated appendix filled with barium and lead shot. Also note the different sized lead shot (arrow heads).

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Charles S. Curtis Memorial Hospital
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**Presented at the Annual Meeting of
The Canadian Association of Radiologists
Vancouver, B.C. June 1984

REDDY

shot in their appendices on routine radiographic studies done for acute and chronic abdominal conditions, were included in the present study. They were followed for periods ranging from two months to 13 years. Eight patients had appendectomies. All of the patients' charts were reviewed for any clinical or pathologic evidence of appendicitis or lead poisoning.

Results

All of the patients were native to Northern Newfoundland and Labrador and included Inuit, Eskimo and settler populations. Eating of wild game was the source of lead shot. The number of lead shot in their appendices varied from one to over 200. In the lumen of the appendix the lead shot appeared as a single row with a beaded appearance, or as a conglomerate mass. Lead shot of varying sizes in the appendiceal lumen suggested that these might have been ingested at different times (Figs. 1A,1B). In 20 patients having barium studies, lead shot filled the appendices which showed no luminal obstruction. Though barium emptied well from these appendices, lead shot remained within the appendiceal lumen. Eight patients who had appendectomies showed no evidence of appendicitis on tissue examination. None of the other patients developed any clinical evidence of appendicitis or lead poisoning.

Discussion

Most foreign bodies, including lead shot seen in the gastrointestinal system are ingested unnoticed and forgotten, and many pass through the gastrointestinal tract and are eliminated. However, occasionally a heavy small smooth and rounded body such as a lead shot is likely to drop by its own weight from the semi-liquid contents of the cecum into the orifice of the appendix and settle in the appendix. The site of the appendix and the mild peristaltic action of the appendix in expelling shot also appear to favour the accumulation of a large number of lead shot in the appendix in time.

Retained lead shot is reported as a cause of appendicitis (2-4), acute perforation of the appendix (3) and lead poisoning with neuro-muscular symptoms (5). In the present study the blood lead levels were not done but clinically there was no evidence to suggest lead poisoning in any of the patients.

Chemical composition of lead shot in its lead content and alloy is variable depending upon the manufacturer. It is not clear whether this has any role in causing appendicitis or lead poisoning as the analysis of chemical composition of the lead shot was not mentioned in the earlier reports and it was not done in the present study.

Clinical, pathologic and radiologic observations of the patients in this report suggest that no causal relationship exists between retained lead shot in the appendix, their number and the duration of their presence in the appendix and development of appendicitis. The finding of lead shot in the appendix, in the absence of any clinical symptoms, does not warrant surgical intervention.

REFERENCES

1. Balch CM, Silver D. Foreign bodies in the appendix. Report of eight cases and review of the literature. Arch Surg 1971: 102: 14-20

2. Hitchings FW, Sloan HG. Appendicitis following ingestion of shot for "cuban itch." JAMA 1914: 62: 1322-1323

3. Carey LS. Lead shot appendicitis in northern native people. J Can Assoc Radiol 1977: 28: 171-174

4. Horton BT. Bird shot in vermiform appendix. A cause of chronic appendicitis. Surg Clin North 1933: 127: 1005-1006

5. Hillman FE. A rare case of chronic lead poisoning: polyneuropathy traced to lead shot in the appendix. Indus Tr Med Surg 1967: 36: 488-492

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Submitted July 9, 1984
Returned for revision August 22, 1984
Accepted for publication October 2, 1984

The physician ascertains on the screen only the shadows and light areas which constitute normal and abnormal shadows. All deductions useful in medicine are based on the analysis of these shadows.

F. Barjon (trans J.A. Honeij)
Radio-Diagnosis of Pleuro-Pulmonary
Affections (1918)

Presentation: 9

The Use of Lead Shotshell for Subsistence Harvesting by First Nation Cree: Human Health Concerns.

Tsuji, L.J.S.*, York University, Toronto, Canada; Nieboer, E., McMaster University, Hamilton, Canada; Karagatzides, J., Trent University, Peterborough, Canada; Katapatuk, B., Weeneebayko General Hospital, Moose Factory, Canada.

Lead exposure for First Nation Cree of the western James Bay area through ingestion of wild game harvested with lead shot is of concern because we have shown that approximately 15% of randomly selected radiographic charts examined at the regional hospital had evidence of pellets lodged in the digestive system, intraluminally and/or in the appendix. Further, we have found that 9% (33/731) of edible skeletal tissue samples, obtained through the harvesting of wild game with lead shot in the region, had lead levels greater than the Health Canada guideline of 0.5 :g/g ww. Elevated lead levels in these tissues were shown through radiography and subsequent atomic absorption spectrometry (AAS) to be the result of lead pellets/fragments being embedded in the tissues. We will also present evidence illustrating elevated dentine (tooth) lead levels in both adults and children of the region. Adult teeth were collected during the period 1989 to 1995 from patients who needed their tooth extracted for carious or periodontal reasons. One hundred and thirty two teeth were collected from 89 individuals, 54 males and 35 females. Root dentine samples were analyzed by flameless AAS. Dentine lead data were not significantly different for the sexes. Significant differences between several age categories were found and dentine lead levels increased significantly with age. The observed lead levels were found to be comparable in magnitude to those reported in other studies, even though our samples were from individuals living in a remote region. Similarly, elevated lead levels in dentine chips were found for naturally exfoliated primary teeth (15 of 61 teeth had lead levels >10 :g/g dw). When these data are considered as a whole, it appears that lead shot is a major source of lead exposure in subsistence harvesting Cree of the western James Bay region.

Contact:

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Fax: 416-736-5989

Related References:

Tsuji, L.J.S. and E. Nieboer. 1997. Lead pellet ingestion in First Nation Cree of the western James Bay region of northern Ontario: Implications for nontoxic shot alternative. Ecosystem Health 3(1): 54-61.

Tsuji, L.J.S., Nieboer, E., Karagatzides, J.D. and R.M. Hanning. 1996. Spent lead shot and the environment: Fort Albany First Nation. Special Environmental Health Report #2. Unpublished report.

TSUJI

Lead poisoning among children must be eliminated. Lead, which is not an essential element, damages all bodily systems but has its most devastating effects on the developing brain (United States Centers for Disease Control, 1991).

suggest that a concurrent blood lead level of 10 micrograms/dL does not protect against lead-induced behavioral deficits (Rice & Silbergeld, 1996).

Tests of specific functions in children have revealed...increased distractibility, inability to inhibit inappropriate responding, and decreased ability to follow sequences of directions in addition to global decrements in IQ...potential long-term sequelae such as school drop-out and increased antisocial behavior (Rice & Silbergeld, 1996).

SPENT LEAD SHOT AND THE ENVIRONMENT: HUMAN HEALTH CONCERNS IN THE MUSHKEGOWUK TERRITORY

PAST SOURCES OF ENVIRONMENTAL LEAD EXPOSURE
.lead in gasoline
.lead in solder
.lead in paint
.lead in the plumbing system

LEAD SHOTSHELL USED IN HUNTING
.2,000 tonnes/year in Canada
.34 tonnes/year in Mushkegowuk Territory

THREE STUDIES IN THE MUSHKEGOWUK TERRITORY
.OMHE(1989)/OMH(1993)
.Hanning et al. (1994), cord and maternal blood lead correlated significantly with the consumption of wildgame

POTENTIAL SOURCES OF LEAD EXPOSURE IN THE MUSHKEGOWUK TERRITORY
.houses
.canned goods
.water from rivers, lack of indoor plumbing
.school water supplies
.soil and air lead levels
."white lead" ($PbCO_3$, linseed oil)

SOURCES OF LEAD EXPOSURE DURING HARVESTING ACTIVITIES
.nation-wide ban for migratory birds 1999
.airborne lead, lead styphnate, abrasion
.warning label
."soiled nest"

CONSUMPTION OF WILDGAME HARVESTED WITH LEAD SHOT AS A SOURCE OF LEAD EXPOSURE
.biologically incorporated lead
.embedded whole pellets/fragments

LEAD POISONING IN WATERFOWL
.ingestion of lead shot
.disproportionate accumulation
.loss of "evasive response"
.5/233(2%), >0.5µg/g ww

EMBEDDED LEAD SHOT/FRAGMENTS IN EDIBLE SKELETAL TISSUE
.impacting of lead shot on bone
.33/371(9%), >0.5µg/g ww
.19,900 µg/g ww
.CWS (1995), 34/227 pooled breast samples
.Hubbard et al. (1965), upland game birds, 12/12
.Hecht (1985), wild ruminants, microscopic lead fragments

LEAD PELLET INGESTION IN FIRST NATION CREE OF THE MUSHKEGOWUK TERRITORY
.15% of randomly selected radiographs
.lead pellets in the gastrointestinal tract increases lead body burden

ELEVATED DENTINE LEAD LEVELS IN ADULTS FROM THE MUSHKEGOWUK TERRITORY
.tooth contains enamel, dentine, and cementum
.stable, indicator of chronic exposure
.root dentine levels in adults comparable to results of other studies

ELEVATED DENTINE LEAD LEVELS IN CHILDREN FROM THE MUSHKEGOWUK TERRITORY
.mean dentine lead levels for exfoliated incisors greater than levels of children from large urban centres
.19.4% dentine lead levels in medium to high range (10-20µg/g dw)
.46/47 children surveyed consumed some type of wildgame

OUTLINE OF PRESENTATION

- Study background and location
- Description of Study Group; Inclusion/Exclusion Criteria
- Characteristics of Mothers and Neonates
- Lead levels in cord blood, maternal blood, breast milk and infant blood
- Inter-relationships of the various lead levels and correlation with maternal consumption of traditional meats
- Conclusions

TSUJI

FOOD FREQUENCY QUESTIONNAIRE

- Information on consumption of wild fowl [by species (n=14) including eggs and fat]
- Mammals [by species (n=10) including fat, marrow]
- Fish [by species (n=8) including roe and fat]
- Over the previous year, by season
- Including frequency of consumption and usual amount
- Including mode of presentation/preparation: fresh, frozen, smoked, dried, in fat, in salt

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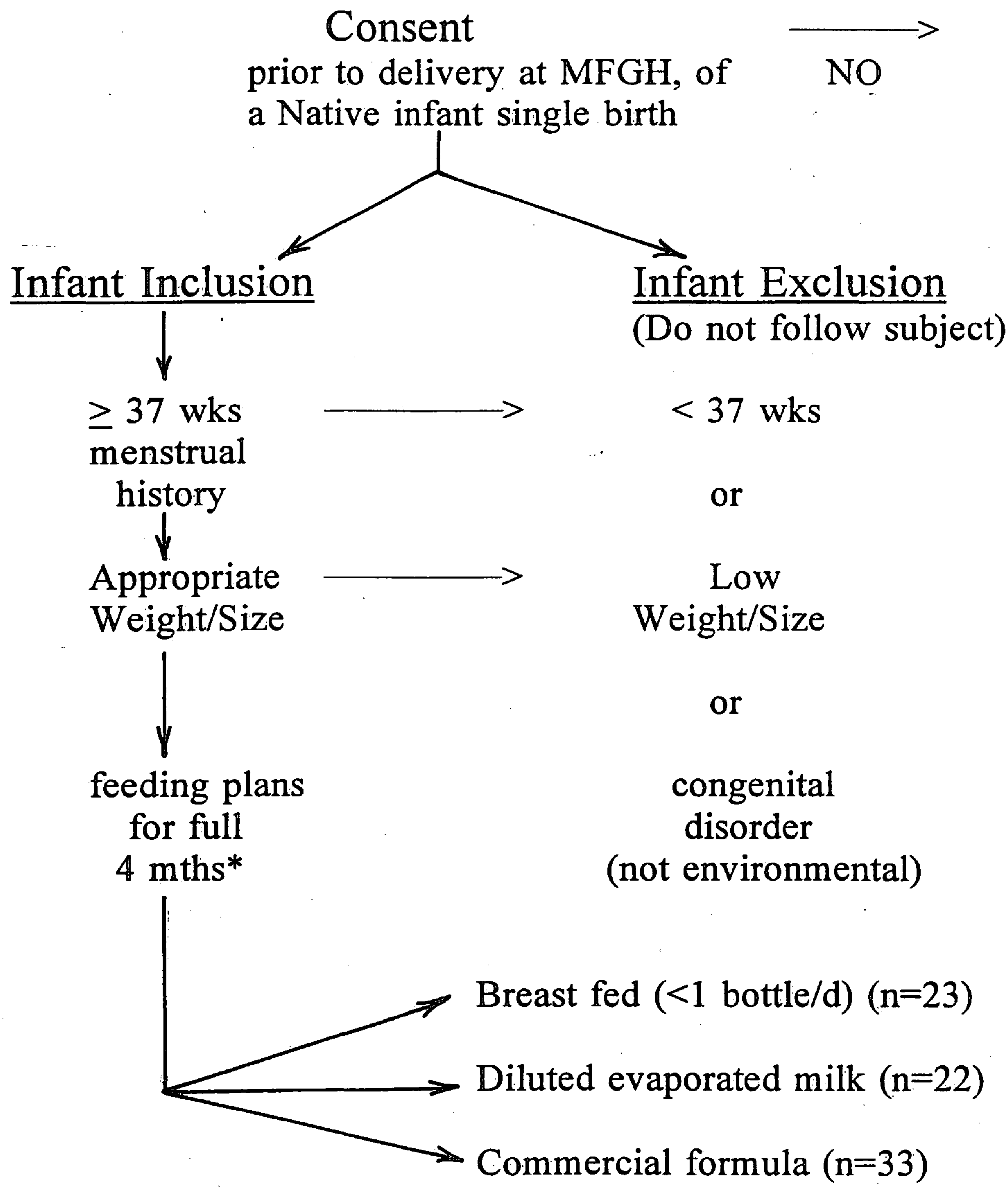
DETERMINATION OF Pb AND Cd IN WHOLE BLOOD
Electrothermal Atomic Absorption Spectrometry

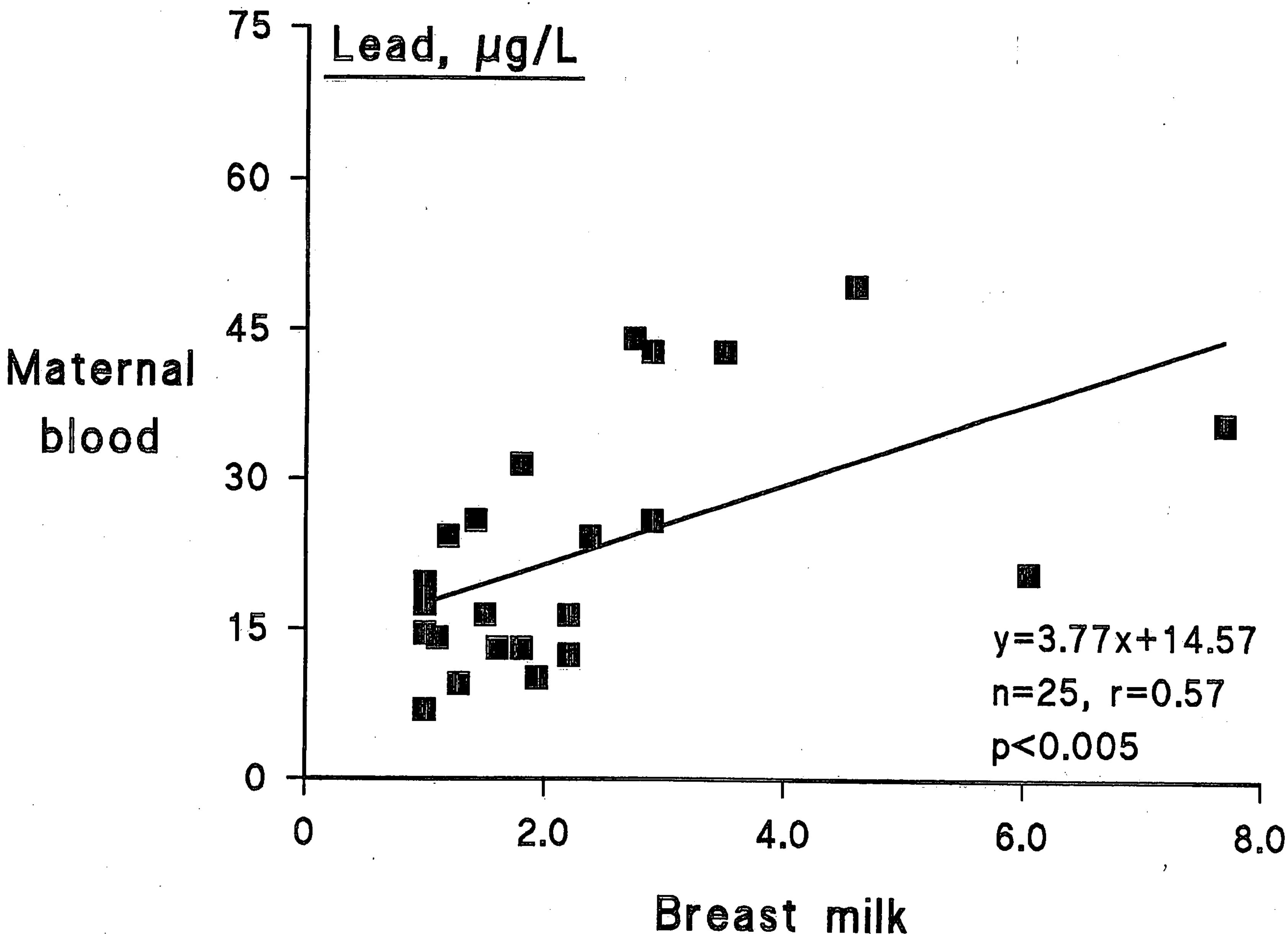
Cadmium	Lead
Blood, 200 µL	Blood, 200 µL
Deproteinate with 600 µL of 1M HNO_3	Deproteinate with 600 µL of 1M HNO_3
Vortex 30 sec	Vortex 30 sec
Centrifuge 15 min, 900 g	Centrifuge 15 min, 900 g
Supernatant (500 µL) + 25 µL 0.1% Triton X-100 50 µL Pd modifier	Supernatant (500 µL) + 25 µL 0.1% Triton X100 50 µL of 1% $NH_4H_2PO_4$
AAS, matrix matched calibration curve (Cd standards in 0.8 M HNO_3 + Pd modifier)	AAS, matrix matched calibration curve (Pb standards in 0.8 M HNO_3 + $NH_4H_2PO_4$ modifier)
Determine Cd: Drying 130°C, 10s; charring 350°C, 10s; atomization 1600°C, 5s	Determine Pb: Drying 120°C, 10s; charring 700°C, 10s; atomization 1800°C, 5s

INFANT FEEDING STUDY INCLUSION FLOWCHART



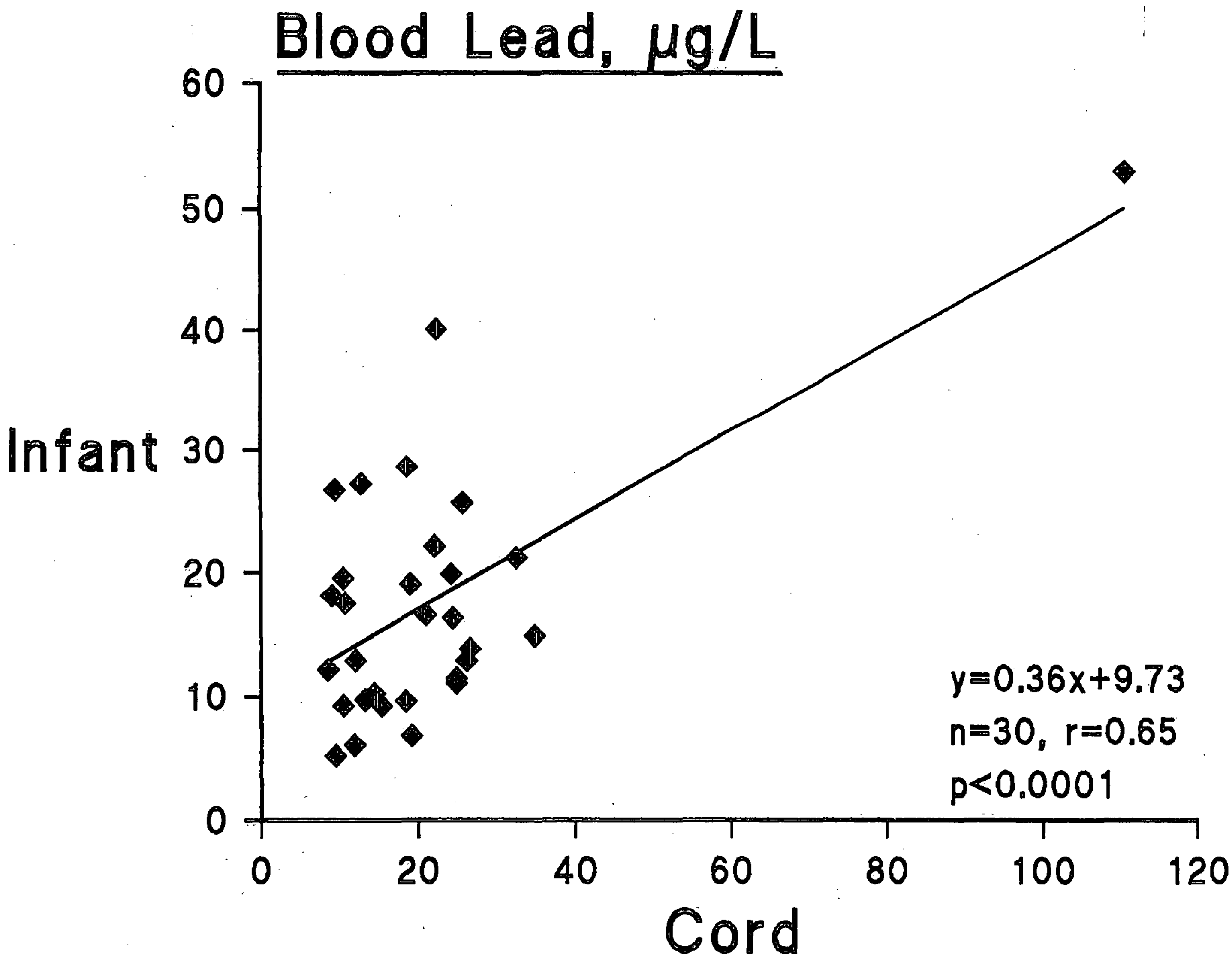
* failure to provide samples will not preclude involvement

TSUJI



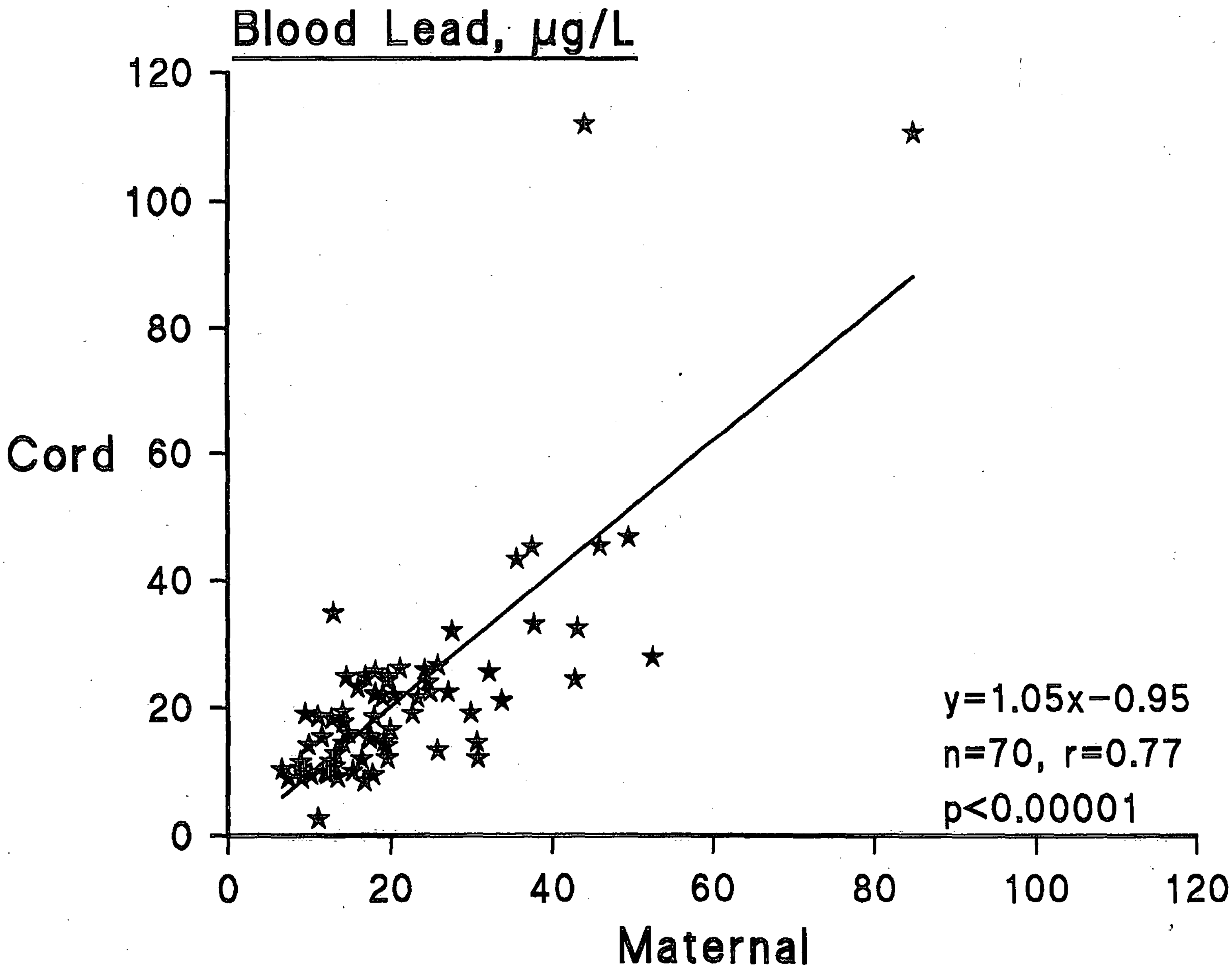
Scatter diagram for lead in maternal blood and breast milk.

TSUJI



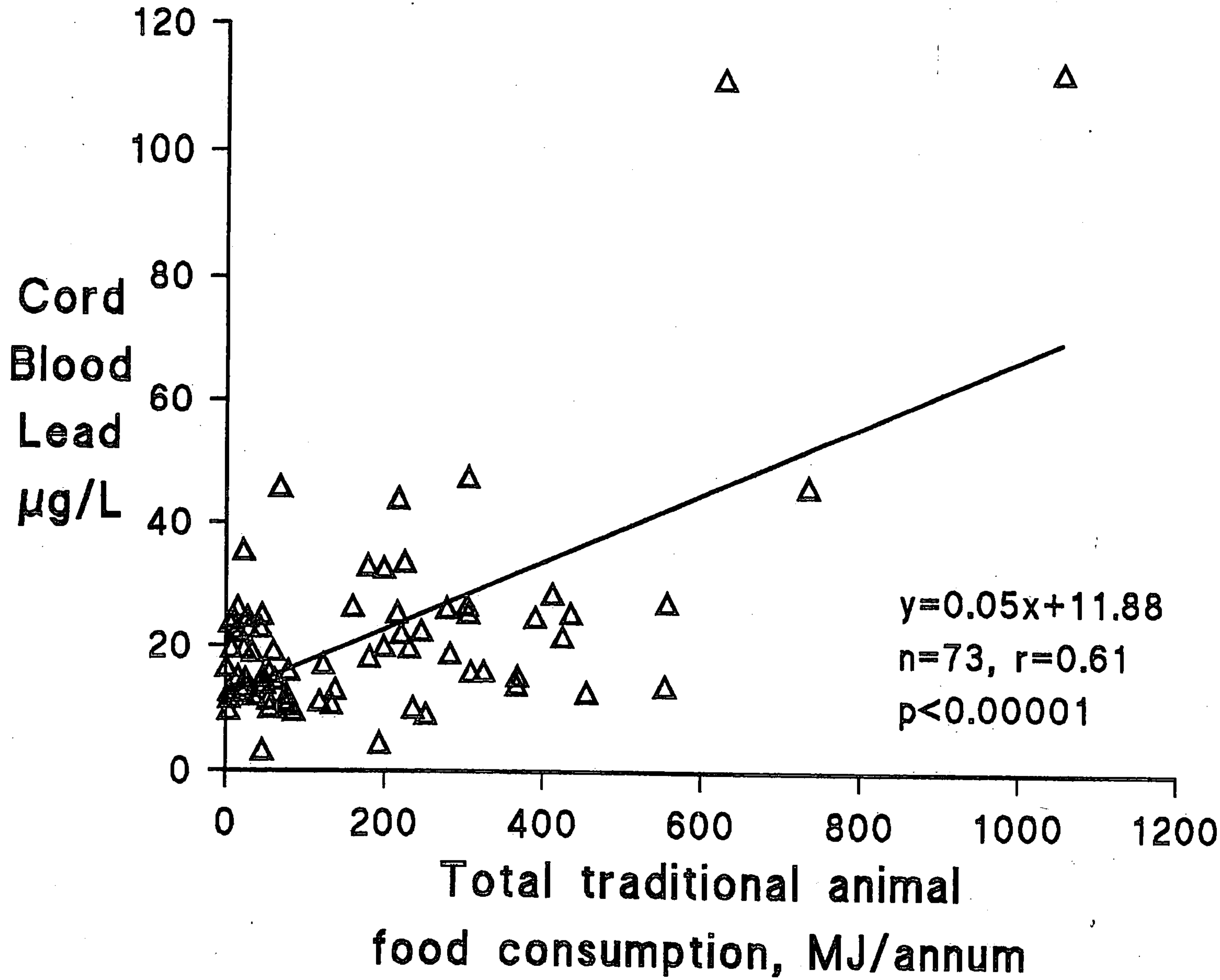
Scatter diagram for lead in infant and cord blood

TSUJI



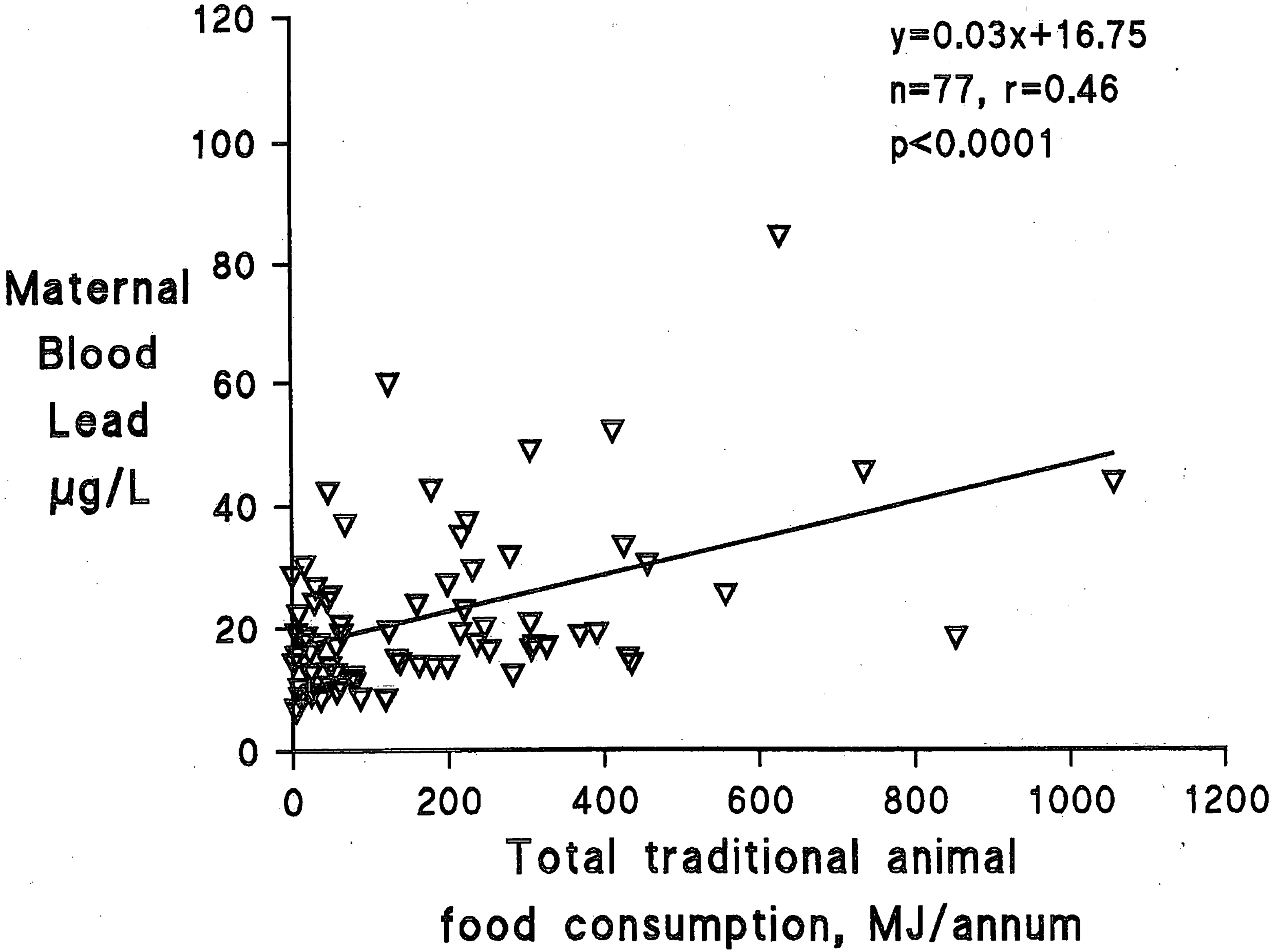
Scatter diagram for lead in cord and maternal blood.

TSUJI



Cord Blood Lead µg/L
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Total traditional animal food consumption, MJ/annum
y=0.05x+11.88
n=73, r=0.61
p<0.00001

TSUJI


y=0.03x+16.75
n=77, r=0.46
p<0.0001
Maternal Blood Lead µg/L
Total traditional animal food consumption, MJ/annum
0
20
40
60
80
100
120
0
200
400
600
800
1000
1200

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CONCLUSIONS

- A small proportion (3%) of cord blood lead levels exceeded 100 μg/L and thus were of medical concern
- Maternal consumption of traditional meats influenced maternal blood, newborn blood and breast milk lead concentrations
- The findings are interpreted to reflect the environmental legacy of the long-term use of lead-containing ammunition

TSUJI

Presentation: 10

Lead poisoning among inuit children : identification of sources of exposure.

Lévesque, B., Centre de santé publique de Québec, Québec, Canada ; Dewailly, E.*, Centre de santé publique de Québec, Québec, Canada ; Dumas, P., Centre de toxicologie du Québec, Québec, Canada ; Rhainds, M., Centre de santé publique de Québec, Québec, Canada.

Since the beginning of the 1980s, lead contamination of the environment has progressively become a major public health preoccupation, mainly as regards to neurobehavioral effects on fetuses and young children. Based on epidemiological evidence, the US Centers for Disease Control (CDC) revised its sanitary intervention threshold to 10 g/dl in 1991. In the province of Québec (Canada), the results of cord blood studies on lead carried out between 1993 and 1995 showed that 7.6% (n=238) of Inuit newborns from Nunavik had blood lead levels of 10 g/dl and more, compared to 0.2% (n=955) of babies from the Southern part of Québec. By reviewing the sources of exposure of Inuit children, it was concluded that nutrition is the most probable source of exposure, especially through two types of food, waterfowl most probably contaminated by lead shots, and caribou contaminated by its lichen-based diet. The isotopic ratio techniques may help to determine distinct sources of lead exposure. We characterized the stable lead isotopes in the blood samples collected from 29 newborns with lead levels equal to or greater than 10 g/dl. Each of these children was paired with a control from the same community and 3 other controls previously sampled from a study carried in the South of Québec. For each blood sample three isotopic ratios (206/204, 206/207, 206/208), are calculated. Means and variances of the three groups will be compared. Results and the discussion of these results will be presented.

Contact:

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Related References:

Dewailly, E. 1995. Cord blood study - Nunavik. Synopsis of Research Conducted Under the 1994/5 Northern Contaminants Program. J.L. Murray, R.G. Shearer and S.L. Han (Editors) Environmental Series No. 73: 283-294.

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SETAC 1998, CHARLOTTE, NC

LEAD POISONING AMONG INUIT CHILDREN:

IDENTIFICATION OF SOURCES OF EXPOSURE

- **Research team:**

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RATIONALE OF THE STUDY

- Health effects of lead
- Newborns exposure
- Potential sources of exposure in Nunavik

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HEALTH EFFECTS OF LEAD

- **Negative results:**
  - **Humans:**
    - **Longitudinal studies:**
      - Sydney (Cooney *et al.* 1989)
      - Cleveland (Ernhart *et al.* 1989)
      - Kosova (Wasserman *et al.* 1992)

No correlations between blood lead levels and cognitive and neurobehavioral alterations in children

HEALTH EFFECTS OF LEAD

- Lead is a neurotoxic:

Most animal and human data suggest a deleterious effect of low-dose exposure to lead on neurobehavioral development of young children

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Intervention threshold $\geq$ 10 μg/dl

Centers for Disease Control (1991)

Canadian Federal-Provincial Committee on Environment and Occupational Health (1994)

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HEALTH EFFECTS OF LEAD

- **Lead is neurotoxic for:**

Humans:

Longitudinal studies:

- Boston (Bellinger *et al.* 1987-1992)
- Port Pirie (McMichael 1988; Wigg 1988; Baghurst 1992)
- Cincinnati (Dietrich *et al.* 1987-1993)

Correlations between blood lead levels (10 μg/dl to 20 μg/dl) and cognitive and neurobehavioral alterations in children

HEALTH EFFECTS OF LEAD

- **Lead is neurotoxic fc**

  Humans:

  Transversal studies:

  - Meta-analysis, 12 studies:

    Alterations to IQ with low doses

    (Needleman and Gastonis 1990)

  - Meta-analysis, 8 studies:

    Neurobehavioral effects

    (WHO-EUROPE, Winneke 1990)

STUDY

- Study objectives
- Methods
- Results and Discussion
- Conclusion
- Recommandations

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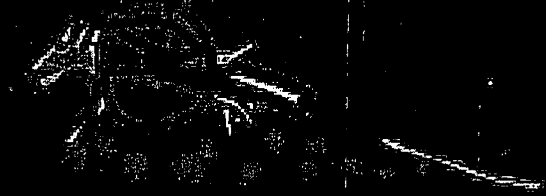
HEALTH EFFECTS OF LEAD

- Lead is neurotoxic for:



  - Animals:
    - Problems of behavioral and learning difficulties for exposed animals (primates)

      (Rice 1993)

    - Neurobehavioral alterations : rats ([Pb] < 20 μg/dl)

      : monkeys ([Pb] < 15 μg/dl)

      (Davis 1990)

POTENTIAL SOURCES OF EXPOSURE IN NUNAVIK

Consumption of traditional country food:

Probably the main source of Pb contamination in Nunavik

DIET (Women 19-40 yrs)	CONSUMPTION	INTAKE (Cons. vs Conta.)
- Canadian goose	24.0 g/d	1.47 µg/d
- Caribou	41.1 g/d	1.03 µg/d
- Willow ptarmigan	16.7 g/d	1.07 µg/d
- Red charr	32.5 g/d	0.16 µg/d

Source : Santé Québec 1992; Dewailly *et al.* 1996 J.F.D.051198 11

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STUDY OBJECTIVES

- Characterize blood lead isotopes in Inuit newborns' cord blood samples.
- Compare results of lead isotopes in two groups of Inuit newborns: 1) ≥10 μg/dl (n=29)
  2) <10 μg/dl (n=31)
- Compare results of lead isotopes in Inuit newborns (n=60) to those of newborns from the southern part of Québec (n=89).

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POTENTIAL SOURCES OF EXPOSURE IN NUNAVIK

- **Air:** Unlikely: elimination of lead in fuel
- **Drinking water:** Unlikely: no use of piping
- **Soil and dust:** Unlikely: no industrial activities
- **Tobacco:** Unlikely: Dose-response relationship but % variance <6%
- **Paint:** Unlikely: paint with Pb banned since 1972

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NEWBORNS EXPOSURE

Pb in blood (µg/dl)	Nunavik (n=475)	Southern Québec (n=955)	North Shore (n=149)	Gaspésie (n=154)
Mean ±SD	4.93±3.66	1.84±2.23	2.44±1.59	1.89±0.89
<10.0	92.6	99.8	99.3	100.0
10-14	5.3	0.1	0.7	0.0
15-19	0.8	0.0	0.0	0.0
20-44	0.8	0.0	0.0	0.0
45-70	0.0	0.1	0.0	0.0

Sources: Dewailly *et al.* (in progress); Rhainds *et al.* 1995; Levallois *et al.* 1995

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LEAD ISOTOPIC RATIO (206/207) IN BIRDS

- Analysis on bones of 123 ducks from Québec:

  Mean Pb isotopic ratio = 1.085
  (Range 0.938-1.212) (Scheuhammer *et al.* CWS database)

- Analysis on muscle of 2 ptarmigans from Northern Québec :

  Mean Pb isotopic ratio = 1.143
  (Scheuhammer *et al.* CWS database)

Mean Pb isotopic ratio in Inuit = 1.195 (n=60)

LEAD ISOTOPIC RATIO (206/207) IN BLOOD

Inuit (≥10 μg/dl) = **1.199**
n=29; range 1.166-1.230

Inuit (<10 μg/dl) = **1.192**
n=31; range 1.174-1.212

Student T-test
p=0.0910

Inuit (all) = **1.195**
n=60; range 1.166-1.123

Southern Québec = **1.167**
n=89; range 1.126-1.230

Student T-test
p<0.0001

RESULTS AND DISCUSSION

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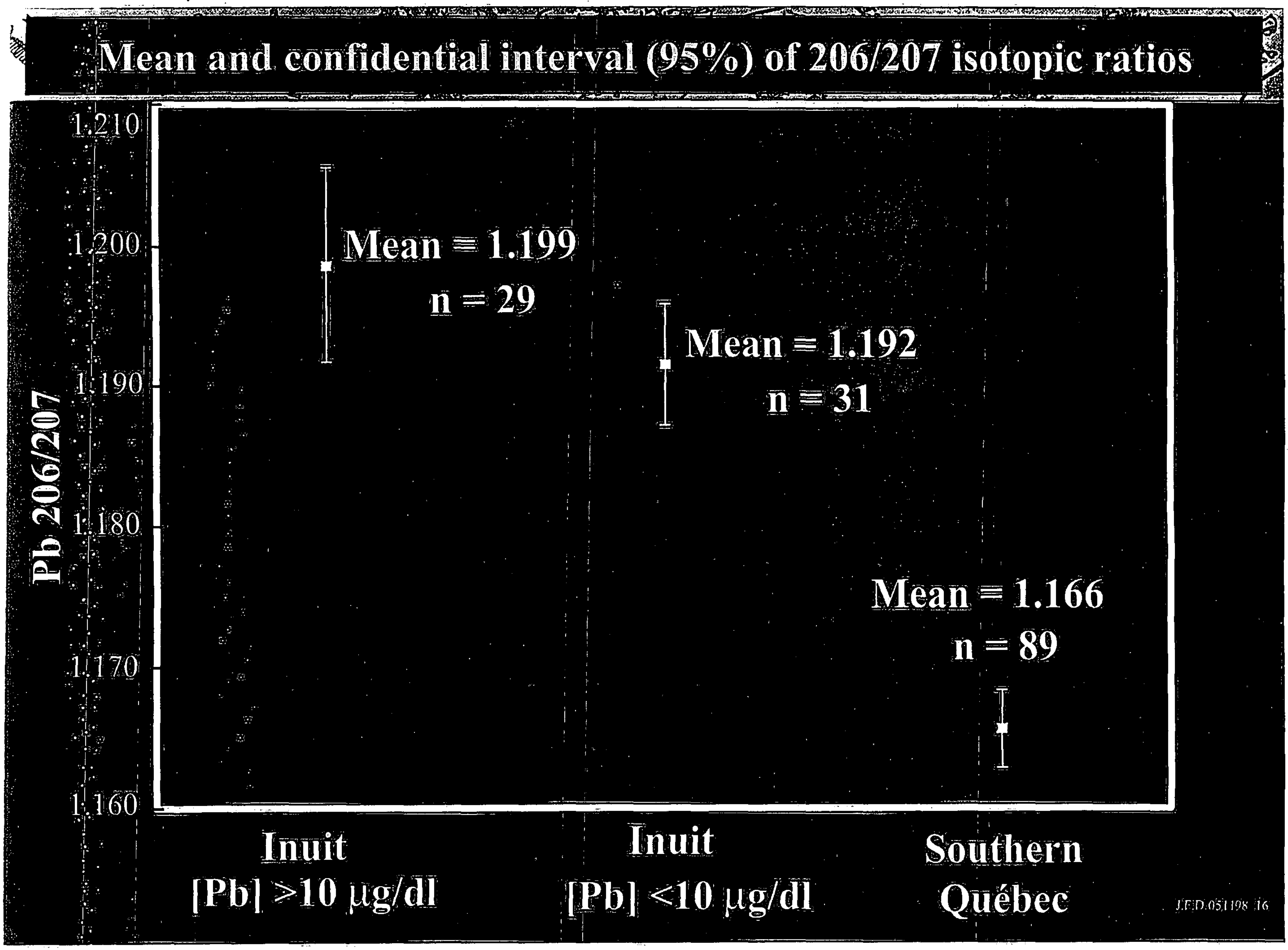
METHODS

- **Umbilical cord blood sample was collected after delivery (frozen at -80°C). We used :**
  - 10 ml and 3 ml lavender cap tubes (EDTA);
  - pre-washed black caps glass vials;
  - flat bottom plastic tube
- **Use of isotopic ratio techniques to determine sources of lead exposure in humans**
  - ICP-MS for the determination of lead ratio 206/204, 206/207, 208/206


Mean and confidential interval (95%) of 206/207 isotopic ratios
Pb 206/207
1.210
1.200
1.190
1.180
1.170
1.160
Mean = 1.199
n = 29
Mean = 1.192
n = 31
Mean = 1.166
n = 89
Inuit
[Pb] >10 μg/dl
Inuit
[Pb] <10 μg/dl
Southern
Québec
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LEAD ISOTOPIC RATIO (206/207) IN CARIBOU AND LICHEN

- No lead isotopic ratio on caribou
  Analysis are in progress
- Caribou is contaminated by lichen
  Mean isotopic ratio in lichen from Nunavik = 1.164
  (n=4; Range: 1.159-1.167)

Mean Pb isotopic ratio in Inuit = 1.195 (n=60)

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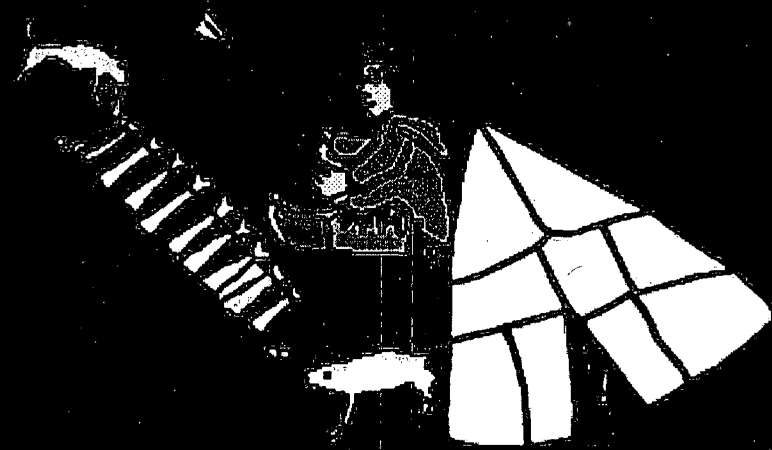
CONCLUSION



It appears that the ingestion of lead shot or lead residues (fragments, dust), found in game that was shot down, is responsable for eleveted lead levels found in Nunavik Inuit

LEAD ISOTOPIC RATIO (206/207) IN AMMUNITION

- Analysis on four brands of lead-containing cartridges used by Inuit: Federal, Winchester, Remington, Imperial

Mean Pb isotopic ratio = 1.193
(n=10; Range : 1.125 - 1.233)
(Scheuhammer *et al.* CWS database)

Mean Pb isotopic ratio in Inuit = 1.195 (n=60)

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RECOMMANDATIONS

- Use non-toxic cartridges like steel shot
- Remove all lead residue from meat before consuming
- Children and women of child-bearing age should receive meat parts free of lead shot