U.S. Fish and Wildlife Service

Environmental Contaminants Program Off-Refuge Investigations

Trumpeter Swan Lead Shot Poisoning Investigation in Northwest Washington and Southwest British Columbia

Project ID: 200310003.1

June 2009

DEPARTMENT OF THE INTERIOR

U.S. FISH AND WILDLIFE SERVICE

REGION 1

ENVIRONMENTAL CONTAMINANTS PROGRAM
OFF-REFUGE INVESTIGATIONS SUB-ACTIVITY

WA -Trumpeter Swan Lead Shot Poisoning Investigation in Northwest Washington and Southwest British Columbia –FINAL REPORT

Project ID: 200310003.1
(filename: EC_TRUSLead Shot Poisoning Final Report.doc)

by

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Abstract

Trumpeter (*Cygnus buccinator*) and tundra swan (*Cygnus columbianus*) populations wintering in northwest Washington State and on the Sumas Prairie, British Columbia, from 1999-2008, lost over 2,574 members, the majority (62%, 1,586) were confirmed as lead poisoned caused by the ingestion of lead pellets. Although mortalities occurred in both trumpeter and tundra swans, over 95% of lead poisoned swans were trumpeter swans.

In 2001, an international effort was initiated to locate the source(s) of the lead. Participants in the investigation include the Washington Department of Fish and Wildlife, U. S. Fish and Wildlife Service, Environment Canada – Canadian Wildlife Service, The Trumpeter Swan Society and the University of Washington (Washington Cooperative Fish and Wildlife Research Unit) with assistance from numerous other government and non-government organizations. The partners took a multi-faceted approach to investigate the swan die-off and potential secondary exposures to other wildlife, including bald eagles.

Wintering swans were captured and blood samples were collected and analyzed for blood lead content. Trumpeter swans were fitted with VHF or satellite transmitters attached to a coded neck collar and tundra swans were fitted with a coded neck collar. Telemetry surveys were conducted each day and night during the winter to document locations of marked individuals. Swan population surveys were conducted to obtain additional detail on population movements and to validate the telemetry data. Sick and dead swans were collected throughout the winter, and carcasses examined to determine cause of death, measure liver lead residues, and recover shot from gizzards.

The locations of collared swans were used to identify forage areas and roost sites, and data for swans that died from lead poisoning after radio-collaring were used to identify and prioritize areas for lead shot density assessment (shot collected from soil/sediment sampling). Lead shot density assessments recovered shot in most crop fields and water bodies sampled. Relatively high densities of lead shot were found on the U.S. side of Judson Lake (a ~100 acre lake spanning U.S./Canada border).

An adaptive management approach was undertaken to determine the extent to which Judson Lake was a contributing source of lead shot causing swan mortalities. Swans were precluded from using Judson Lake for two winters (2006-2007 and 2007-2008) by both passive (windsocks, effigies) and active (noise makers, laser light, airboat) deterrent methods. The number of lead poisoned swans in the study area decreased by at least 50% for each of both years compared to the average of the 5 previous years.

State and Federal Law Enforcement Agents increased waterfowl hunter compliance checks in the area during the 2001 and 2002 waterfowl hunting seasons. Compliance for non-toxic waterfowl loads was reported to be exceptionally good in the area. Environment Canada's Enforcement Officers conducted hunter compliance checks each year of the investigation; very good compliance was reported.

By extrapolating historic growth rates to the present time or by using a simple demographic model, approximately 4,000 (actual and potential) trumpeter swans were estimated to have been lost from the Pacific population from 1999 to 2006. This equates to ~14% loss from the potential 2005 Pacific breeding population and ~23% loss from the potential 2006 SW-B.C. & NW-WA winter population. Despite these losses, both populations are increasing.

A notice was issued to U.S. and Canadian wildlife rehabilitators, State/Provincial veterinarians and biologists, and Federal Law Enforcement agents to request analyses of all bald eagles submitted from northwest Washington for lead exposure through the winter months. From the 1999-2000 winter through the 2006-2007 winter, a total of 62 eagle liver samples from the U.S. side of the border were analyzed for lead residues. Two of the eagles had elevated subclinical lead exposures and ten had lethal lead exposure levels. From 1999-2008, a total of 19 bald eagles from the Canadian side of the border were analyzed for lead residues; 2 of the eagles had lethal lead exposure levels.

In order to provide the general public with information on the project and the status of the swan mortality events, the partners cooperatively developed talking points and media contacts, released annual progress reports, provided information on a USFWS web site, and provided opportunities to attend an annual stakeholders meeting. In addition, two public information sessions were held (one in Whatcom County, Washington and the other in Abbotsford, British Columbia). Two posters promoting the use of non-toxic shot were produced and distributed by Environment Canada-Canadian Wildlife Service (EC-CWS).

Keywords (Project ID: 200310003.1, lead, lead shot, swans, trumpeter swan, *Cygnus buccinator*, tundra swan, *Cygnus columbianus*)

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List of Acronyms/Abbreviations

ATS	Advanced Telemetry Systems
B.C.	British Columbia
BCMAL	B.C. Ministry of Agriculture and Lands
cm	centimeters
EC-CWS	Environment Canada-Canadian Wildlife Service
g	grams
GIS	Geographic Information Systems
GPS	Global Positioning System
ha	hectare
kg	kilograms
m	meters
ml	milliliter
mm	millimeters
NTS	Northwest Treasure Supply
MWS	Monika's Wildlife Shelter
NW-WA	Northwest Washington
Pb	lead
ppb	part per billion
ppm	part per million
PVWRC	Pilchuck Valley Wildlife Rehabilitation Center
RC	Resources Coalition
SW-B.C.	Southwest British Columbia
TTSS	The Trumpeter Swan Society
U.S.	United States of America
USFWS	U.S. Fish and Wildlife Service
VHF	very high frequency
WA	Washington State
WACFWRU	Washington Cooperative Fish and Wildlife Research Unit
WDFW	Washington Department of Fish and Wildlife
wt	weight
WWFWO	U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office

Acknowledgements

All components of this project are a cooperative effort amongst the principal investigators and their agency staff with input from the stakeholders. There are too many participants to mention individually, but we would like to acknowledge key individuals who provided support over the nine years of this investigation.

Agencies with principal investigators:

1. Washington Department of Fish and Wildlife (WDFW): Mike Davison, Jennifer Bohannon, Don Kraege (principal investigators), Lora Leschner;
2. Environment Canada - Canadian Wildlife Service (EC-CWS): Laurie Wilson (principal investigator), Garry Grigg, Barry Smith, Bob Elner, Randy Forsyth, Andre Breault, Communications Branch, Wildlife Enforcement;
3. U.S. Fish and Wildlife Service (USFWS): Western Washington Fish & Wildlife Office (WWFWO) Environmental Contaminants Program, Cindy Schexnider (principal investigator), WWFWO Information and Education, Doug Zimmer; Region 1 Migratory Birds Program, Brad Bortner;
4. The U.S. Geological Survey - Washington Cooperative Fish and Wildlife Research Unit (WACFWRU) from the University of Washington: Dr. Chris Grue, Mike Smith, (principal investigators);
5. The Trumpeter Swan Society (TTSS): Martha Jordon (principal investigator), Ruth Shea, John Cornely.

Additional Government Agencies:

1. USFWS Division of Law Enforcement Redmond Washington Office,
2. USFWS R1 Division of Environmental Contaminants Program;
3. Environment Canada-Science & Technology Branch: Dr. Sean Boyd, Sandi Lee, Dr. John Elliott, Dr. Tony Scheuhammer and lab staff, National Wildlife Research Centre Specimen Bank and Analytical Lab;
4. B.C. Ministry of Agriculture and Lands (BCMAL): Dr. Vicki Bowes, Dr. Stephen Raverty, necropsy and front office staff [post-mortem examination];
5. B.C. Ministry of Environment: Jack Evans, Myke Chutter, Conservation Officer Service [field support, hunter checks]

Additional stakeholders include:

1. North Cascades Audubon Society (Audubon) [population surveys];
2. Pilchuck Valley Wildlife Rehabilitation Center (PVWRC);
3. Northwest Wildlife Rescue and Rehab;
4. Washington Waterfowl Association [funding support and many volunteer hours for

trapping, core sampling and carcass recovery],

5. Ducks Unlimited Canada: Dan Buffett, Kate Hagmier [population surveys, information exchange];
6. Monika's Wildlife Shelter (MWS): Monika Tolksdorf, Gloria Bannister, Lorne Green, Graham [rehabilitation, gizzard examination, core sampling];
7. Central Valley Naturalists & Chilliwack Naturalists,[population surveys]
8. B.C. Institute of Technology [population surveys];
9. EBB Consulting: Oliver Busby [core sampling, population surveys];
10. University of British Columbia: Dr. Kim Cheng [DNA sexing];
11. Associated Wildlife Preserve: [maps of Canadian upland game hunting areas] ;
12. Puget Sound Energy [carcass recovery];
13. Many landowners who permitted agencies access to property and, on occasion, tolerated significant disruption.

This project was funded by principal agencies with additional input by TTSS and the B.C. Waterfowl Society.

1.0 Introduction

The trumpeter swan (*Cygnus buccinator*) is the largest member of the waterfowl family in North America and the largest swan in the world. In the early 1900s, the trumpeter was nearly hunted to extinction. A population assessment conducted in 2005 estimates about 34,800 trumpeter swans reside in North America, 24,928 of those are in the Pacific Coast population (Moser 2006). An estimated 2,500 trumpeter swans winter in the Whatcom County and Sumas Prairie, B.C. Trumpeter and tundra swans are protected under International treaties in the U.S. and Canada. They are protected in the U.S. by the Migratory Bird Treaty Act regulated by the U.S. Fish and Wildlife Service (USFWS) and Washington State regulations through the Washington Department of Fish and Wildlife (WDFW). They are protected in Canada by the Migratory Birds Convention Act and Regulations.

Elemental lead has been recognized as a toxic material for more than 25 centuries and its many modes of toxicological action are well understood (Eisler 1988). Lead is a cumulative metabolic poison affecting a large number of biological functions including survival, reproduction, growth and development, and behavior (Eisler 1988). Lead is a broad spectrum metabolic poison that produces toxic effects in a wide range of organs and tissues. Lead poisoning produces severe degenerative changes in the central nervous system (altered neurophysiological behavior, cerebral necrosis, and death), in the peripheral nervous system (various forms of paralysis), in the blood and blood-forming tissues (anemia and impaired synthesis of hemoglobin), and in the kidney (reversible and irreversible renal dysfunction). Lead toxicity has caused sterility, abortion and both mortality and morbidity in neonates. Immune function also can be impaired by lead as shown both by dysfunction of specific components of the immune system (cell-mediated and antibody-mediated immunity) and increased susceptibility to vital pathogens in animals sub-lethally poisoned with lead (Sanderson et al. 1986). In addition to these specific effects, chronic lead poisoning often induces loss of body weight, proceeding to general emaciation, particularly in birds (Sanderson et al. 1986). This effect probably results from behavioral changes, partial paralyses, and less specific metabolic alterations (Kendall 1996).

Swans are at risk from lead poisoning because of their method of feeding (Blus et al. 1989). Large amounts of plant and sediment material are consumed whole and then passed into the gizzard. Small pebbles (grit) are also swallowed and retained in the gizzard to aid in the grinding of food. Lead pellets may be either intentionally ingested as grit, mistaken as seeds, or inadvertently picked up by swans. The grinding action and acidic environment of the gizzard breaks down the pellets thereby allowing lead to enter the bloodstream (Schillinger et al. 1937; Bellrose 1975; WDFW 2001). Symptoms of lead poisoning (e.g. lethargy, muscular weakness) can appear as early as 4 days after ingestion of as few as 2 to 3 pellets, with death occurring in 17-21 days. Less time may pass before mortality occurs if more pellets are ingested (Bellrose 1975; Pain 1990).

Poisoning of swans from the ingestion of lead pellets has long been known to affect swans wintering in the Pacific Northwest (Munro 1925; Eklund 1946; Cowen 1946; Kendall and Driver. 1982; Blus *et al*. 1989; Lagerquist *et al*. 1994; Wilson *et al*. 1998). The first large scale die-off in this area was in the winter of 1991-92 and involved approximately 100 individuals. There were no reported mortalities between 1992 and 1998. Since 1999, annual mortalities ranging from 100 to 400 individuals per year have been documented in the Whatcom County and Sumas Prairie area.

Whatcom, Skagit, and Snohomish Counties in Washington State and Sumas Prairie, British Columbia, Canada are heavily used migratory waterfowl areas that receive significant hunting pressure. The land-use in these areas is primarily agricultural with the predominant industries being crop farming and dairy operations.

Lead shot use for waterfowl hunting has been banned in northwest Washington State since 1989 (WDFW 2001) and in the Sumas Prairie area of British Columbia since 1992 (Wilson et al. 1998). Lead shot is still permitted for upland bird hunting and target shooting in most of both areas.

In 2001, an international effort was initiated to locate the source(s) of the lead causing swan mortality events. Participants include the U. S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), Environment Canada - Canadian Wildlife Service (EC-CWS), the University of Washington - Washington Cooperative Fish and Wildlife Research Unit (WACFWR), The Trumpeter Swan Society (TTSS), and additional stakeholders from various government and non-government organizations. The scientific objectives of this effort were to: (1) determine where on their wintering grounds, trumpeter swans are picking up lethal doses of lead shot; (2) quantify the extent and level of lead shot contamination at the site(s); and (3) protect swans and other waterfowl from further exposure at these sites. The secondary poisoning of bald eagles from foraging on lead-exposed swans was also monitored.

The final report for this Environmental Contaminants Special Study Investigation was completed with data collected and progress made by this international partnership effort from 2000 through 2007. Continued diligence is necessary to eliminate the annual lead-related mortalities of trumpeter swans and provide a safer wintering environment for waterfowl, raptors, and other wildlife in the area. This Environmental Contaminants Special Study Investigation was completed in FY2008. However, the overall investigation will continue, and the USFWS Washington Fish and Wildlife Office will stay involved to the extent possible.

2.0 Methods and Materials

2.1 Study Area

A study area of ~100,000 ha (58% in Whatcom County, Washington and 42% in the Sumas Prairie, B.C.) was identified based on the daytime forage use areas of swans that died from lead poisoning 1999-2000 (Figure 1).

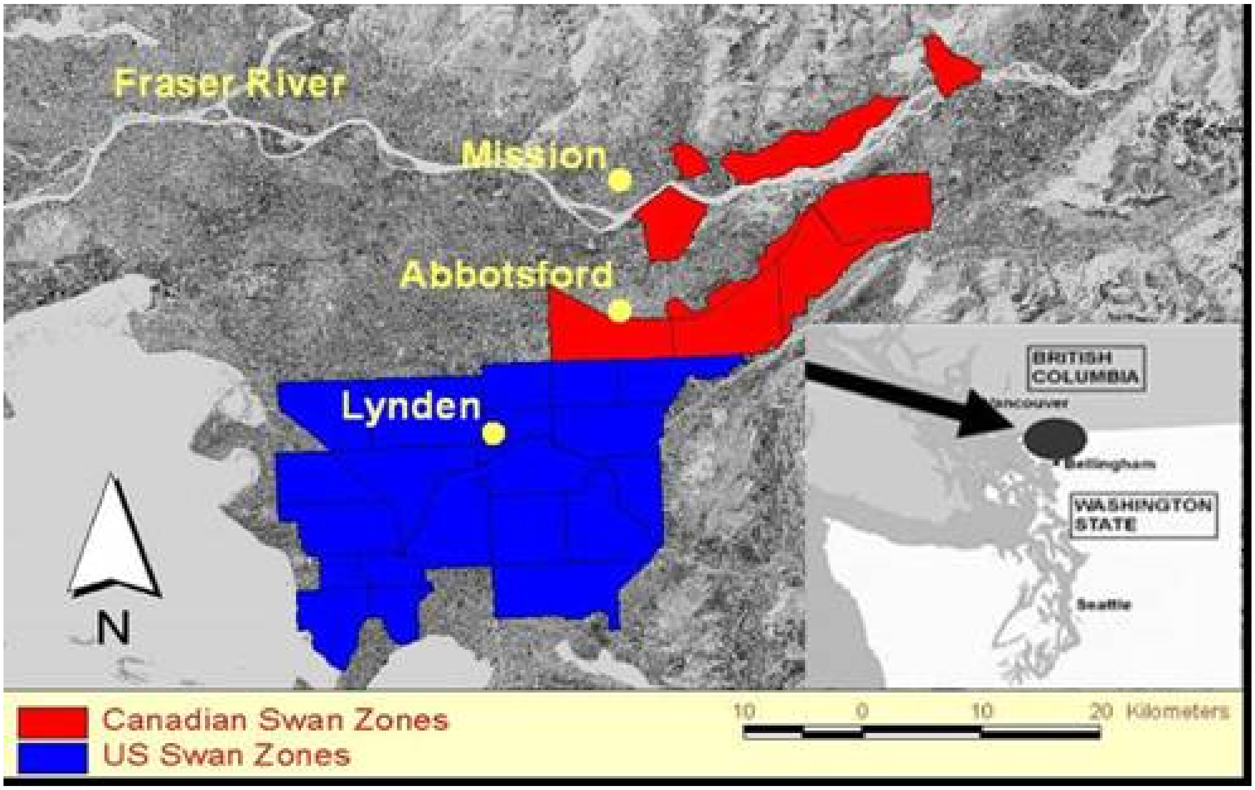


Figure 1. The original study area: Whatcom County U.S. and Sumas Prairie B.C.

The majority of the lead mortalities in Washington State occurred in Whatcom County. However, lead related swan mortalities in Skagit and Snohomish Counties (reported by wildlife rehabilitators and Puget Sound Energy) have also been included in our total, as we believe these individuals may have accessed lead pellets in Whatcom/Sumas prior to moving further south (Figure 2).

Figure 2. Map showing expanded collection area of lead-related swan mortalities in Skagit and Snohomish Counties to the south of Whatcom County.

2.2 Swan Capture and Health Evaluations

Swans were captured over four winters using rocket netting. During the winter of 2001-02, trapping occurred in both the Sumas Prairie and Whatcom County, whereas during the winters of 2002-05, trapping only occurred in Whatcom County. (Trapping effort was discontinued in Canada because there were fewer swans available compared to Whatcom County.) Rocket nets were set up within corn fields where swans were actively foraging. The areas were baited with corn for several days prior to discharging nets. Nets used in the first two years of the study ranged in size from 9 m x 18 m to 6 m x 21 m and were used with 3 to 4 rockets each over the first two years of the study. Nets used in 2003-2005 ranged in size from 9 m x 18 m to 21 m x 30 m; the larger nets required 8 rockets each.

A total of 315 trumpeter and tundra swans were captured. Each bird was weighed, measured (i.e. tarsus, wing chord and culmen), and the age and sex determined. A blood sample (5 ml) was collected from the brachial vein using a heparinized syringe and 22 ½ G needle. Blood samples were analyzed at the BCMAL Animal Health Lab in Abbotsford, B.C. to determine if collared swans had ingested lead prior to capture. Blood lead levels were considered within the normal avian background threshold if less than 200 ppb wet wt., sub-clinically exposed if between 201-999 ppb wet wt., and lethally exposed if greater than 1000 ppb wet wt (Scheuhammer et al., 2008).

Trumpeter swans (n=249) were fitted with either a VHF (n=243) or satellite (n=6) transmitter attached to a coded neck collar. Each bird was marked with a metal tarsus band (size 9C) and a coded (neck-mounted) collar (Protouch Engravings, Saskatchewan, Canada). Trumpeter swans received a red collar with white alphanumeric lettering or a yellow collar with black alphanumeric lettering. Collars were 7.62 cm x 7.62 cm x .635 cm and made of modified acrylic. Trumpeter swan collars had an attached radio-transmitter (Advanced Telemetry Systems (ATS), Isanti, MN). ATS model A3590 transmitters were mounted on swans captured in 2001-2002 and 2002-2003; they had an 18-month life expectancy and the weight of the entire transmitter/collar assembly was 119 g. ATS model A3840 transmitters were mounted on swans captured in 2003-2004 and 2004-2005; they had a 42-month life expectancy and the weight of the entire transmitter/collar assembly was approximately 148 g. Both types of collars had a double mortality signal and transmitter antennas were 10 cm in length and angled away and up from the collar at approximately 45°. Six satellite transmitters were also used in 2003-2004. These transmitters consisted of refurbished Microwave (n=5) and Habit (n=1) technology and were mounted on collars similar to those used for the VHF transmitters.

A total of 60 tundra swans were captured and most (n=42) were fitted with a coded neck collar. Each bird was marked with a metal tarsus band (size 9C) and a coded (neck-mounted) collar (Protouch Engravings, Saskatchewan, Canada). Collars were 7.62 cm x 7.62 cm x .635 cm and made of modified acrylic. Tundra swans received a black collar with white alphanumeric lettering.

2.3 Telemetry on Wintering Grounds

Telemetry monitoring of radio-collared swans was primarily conducted from the ground during roadside surveys in Sumas Prairie and Whatcom County from November through February. During 2001-06, surveys were conducted five to seven days per week; during 2006-07 swans were monitored two to five days per week (weather and personnel availability were limiting factors); and during 2007-08 swans were monitored four days per week. Monitoring occurred between 10:00 and 16:30 to locate daytime forage sites and between 18:00 and 23:00 to record night roosting locations. Telemetry monitoring was primarily conducted from the ground using a hand-held collapsible 173 mHz 3-element Yagi antenna (Telonics, Mesa, AZ) in both Whatcom County and Sumas Prairie. From 2002-05, in Sumas Prairie, preliminary scanning was conducted using an ATS scanning receiver (170-174mHz) attached to dual 4-element economy Yagi antennas extending through the truck cab on a rotating mast. The majority of telemetry points in Sumas Prairie were taken by triangulation with visual confirmation if possible. The majority of telemetry points were visually confirmed in Whatcom County. Collared swan sightings reported by the public were also included if sufficient detail was provided (UTM, specific field at an road intersection).

Weekly aerial surveys of Sumas Prairie and Whatcom County as well as the neighboring Fraser Delta in Canada and Skagit County in the U.S. were conducted (weather dependent) by either the WDFW or EC-CWS, 2001-08.

In Canada, aerial telemetry flights were conducted from a fixed-wing aircraft. Antennas were mounted on the underside of both wings and attached to a 2 mHz scanning-programmable receiver (Advanced Telemetry Systems, Inc. Isanti, MN). Earphones from the aircraft were plugged into the receiver. When a flock of swans was sighted, the aircraft circled the flock until all frequencies had been scanned. If a signal was heard, the location was obtained using a handheld Garmin™ GPS unit (land datum NAD83). Signal strength, location accuracy, air, hydrologic type (slough, residence/lake, sheetwater), field type (corn, winter wheat, pasture, other), number of individuals in a flock, weather (temperature in degrees Celsius), wind speed (Beaufort scale), and survey start and end times were recorded where applicable.

Swan movement, foraging areas, and night roost sites data were incorporated into GIS Software and over-lain with documented swan mortality locations and lead shot detected at sites. At the conclusion of the 2003-04 and 2004-05 field seasons, data from swans that died and were confirmed as being lead poisoned post capture were entered into kernel home range (ArcGIS 3.2) software to produce "activity centers", which encompassed 50% and 90% of all detections of the lead exposed swans. These activity centers were designated as "areas of interest" for subsequent telemetry field seasons. These areas of interest were visited at least twice per day by telemetry personnel in 2005-06 to document individual swan foraging activities.

2.4 Collared Swan Sightings on Migration Routes and Breeding Grounds

We coordinated with USFWS biologists in Alaska and asked them to report all collared swan sightings during routine aerial surveys. EC-CWS biologists in Whitehorse, Canada established a telemetry monitoring station as part of the Celebration of Swans festival and recorded collared swan sightings during their spring migration. Collared swan sightings observed along the migration route were also reported by the public. All data were included in the telemetry database.

2.5 Swan Population Surveys and Observations

Ground surveys were conducted semi-weekly in Whatcom County and Sumas Prairie during the swan wintering season (November to March). Surveys were conducted primarily by WDFW and EC-CWS staff and contractors as well as volunteer naturalists. Surveys were conducted using binoculars and/or spotting scopes and data recorded on standardized data report forms and maps provided by the agencies. For each flock located, the total number of swans was documented in addition to species and age group when possible and the presence of any auxillary markings (bands). Crop types on fields used and amount of flooding were also recorded. All data was entered into GIS map overlay format.

2.6 Mid-winter Population Monitoring

WDFW staff in northwestern Washington State conducted one-day mid-winter ground/road surveys of known swan-use areas for Whatcom, Skagit, and Snohomish Counties in Washington State during January of each year of the study.

2.7 Monitoring Sick and Dead Swans

Roost sites in Whatcom County and Sumas Prairie were visited at least once a week from mid-December through February from 2001-08, to collect all sick and dead swans. Every sick or dead bird reported by volunteer surveyors or the public was also investigated. If possible, sick or injured swans were captured and rehabilitation was attempted. If swans could not be rehabilitated, they were euthanized. A blood sample was also collected from every sick radio-collared swans for lead residue analysis. Intact carcasses were collected. Scavenged remains were noted and spray-painted with a permanent fluorescent dye. In Whatcom County, carcass searching and rehabilitation was conducted by the WDFW, TTSS, Pilchuck Valley Rehabilitation Centre, Western Waterfowl Association and Puget Sound Energy; lead poisoned swans from Skagit and Snohomish admitted to Pilchuck Valley Rehabilitation Centre were included in the total mortality counts. In Canada, carcass searching was conducted by EC-CWS staff and contractors; rehabilitation was conducted by Monika's Wildlife Shelter.

2.8 Post-mortem examinations

All recovered swan carcasses that died from 2002 through 2005 and all recovered collared swan carcasses from 2001 through 2008 were examined post-mortem. From 2005 to 2008 winters, swan carcasses collected in Canada were examined post morten and carcasses from the U.S. were grossly examined (no complete post-mortem) while collecting tissues. Gizzard and liver samples were collected from all swan carcasses for all years of the investigation. Swans that died in the U.S. were examined by the USFWS; TTSS; and Dr. Laurel Degerness and coworkers from North Carolina State University. Swans that died in Canada were examined by the BCMAL Animal Health Lab with assistance by EC-CWS.

Thorough post-mortem examinations determined probable cause of death. Gross presentation of infectious disease (e.g. aspergillosis) was noted when observed. Liver and kidney samples were collected in lead-free containers (acetone-hexane rinsed jars or Ziploc bags) and frozen for future lead analyses. The gizzard (and proventriculus / /esophagus if contents impacted) were collected in Ziploc bags and frozen for future examination.

All gizzards were evaluated for quantity of lead shot and nontoxic shot, as well as grit type and foraging material. Dr. Laurel Degernes and staff examined gizzards obtained from swan carcasses collected in the U.S. in 2001-03; all other gizzards (U.S. and Canada) were examined by Monika Tolksdorf, Surrey, B.C. The contents of each gizzard were placed in a bowl and flushed with a stream of water onto a sieve. Plant material was separated with a fine mesh screen. Pellets were separated from grit by visual examination, and use of a magnet and a Zircon Metal Sensor. Grit was dried and weighed. Steel shot was separated from lead shot using a magnet and enumerated. All grit was re-examined by a second person to ensure no shot was missed; all shot samples were recounted and type of shot was double-checked to ensure accuracy of initial results.

Shot size was determined by EC-CWS Enforcement Officers and trained contractors for a sub-set of gizzard shot samples. Samples determined to be shot were categorized first as magnetic or non-magnetic based on attraction to a magnet. A shot template was created by gluing steel and lead pellets to a section of corrugated plastic board and labeling each shot size. Shot size on the template ranged from large to small and included sizes OO, O, T, F, BBB, BB, B, 1, 2, 3, 4, 5, 6, 71/2, and 8. A table was developed to provide information on magnetic properties of shot types, weight of each shot type within size categories, and shot type in each size class. After determining the magnetic status of the shot, each shot was weighed and sized by comparing it to the shot template. It was then compared with the table to determine the shot type. Shot which did not fit weight or size classes was then crushed between pliers to determine if it was lead or one of the harder non-toxic alternatives like Tungsten matrix. Lead will also leave a mark like a lead pencil on a piece of paper while the other shot types do not. If the shot weight was indicative of lead and fell between shot sizes, the sample was rounded up into the larger size class as it was assumed the shot was worn down in the gizzard to a smaller size. Many shot weighed less than the smallest size noted in the table; these shot were labeled unknown as they were assumed to be worn down by gizzard action and unable to be sized.

Swan livers were analyzed using standard tissue lead residue analyses protocols. Swans with liver lead levels between 8-20 ppm dry wt were considered to have elevated, sub-lethal lead exposure, whereas lead poisoning was assigned as the cause of death if liver lead concentrations were >20 ppm dry wt. (Scheuhammer et al. 2008). Additional criteria used to assign lead status category is summarized in Table 1.

Table 1. Criteria used to assign "Lead Status" Categories for Swan Mortalites

Category	Liver or Kidney Pb	Blood Pb (ppm)	# Pb shot	Green Liver
at trap lead poisoned	-	0.5	-	
at trap lead exposed	-	0.2 - 0.5	-	
Lead poisoned	>20ppm dw = 6.052ppm ww	-	-	
Lead poisoned	-	>0.5	-	
Lead poisoned	-	-	>=10	
Lead exposed	2.42 - 6.052 ppm ww	-	-	
Lead exposed	-	0.2-0.5	-	
Lead exposed	-	-	1 - 9	
Lead exposed	-	-	-	YES
Lead exposed	-	-	0	YES
Not lead	<8ppm dw = 2.42ppm ww	-	0	
Not lead	-	<0.2	0	
Not lead	-	-	0	NO
Not lead	<8ppm dw = 2.42ppm ww	-	0	YES
Inconclusive	no info	no info	0	-
Not tested	no info	no info	no info	NO

2.9 Land Use Investigation

Aerial/satellite photographs of Whatcom County were analyzed at the University of Washington. Suspect fields identified through this process were compared to known use by lead poisoned swans between 2001 and 2005.

2.10 Lead Shot Density Assessment

Lead shot density assessment was conducted in areas used by collared swans that later died from ingestion of lead shot. These potential source areas included day-time forage fields and water-bodies and flooded fields used as night roost sites. The assessment was conducted by collecting core samples and extracting shot.

2.10.1 Core Sampling 2001-2004

Between 2001 and 2004, WDFW and EC-CWS conducted lead shot density assessments of 14 forage fields, 8 permanent water-bodies and 6 temporary roosts (flooded agricultural areas). All forage fields were located in Sumas Prairie; 4 permanent water-bodies were in Sumas Prairie and 4 were in Whatcom County; all 6 temporary roosts were located in Whatcom County (Figure 3). The WDFW collected cores from all but one of the U.S. sites; the EC-CWS collected cores from the Canadian sites and one of the U.S. permanent water-bodies. In Canadian forage fields, core samples were collected in a 5-fingered fan pattern expanding away from active hunting blinds. In Canada, cores were collected throughout the water-bodies in a 20 m grid when water level was less than 3 ft deep. In the U.S., core samples were collected along the shoreline and randomly from select sections of a grid pattern at temporary roosts. At one permanent roost, "pits" measuring approximately 30.48 cm x 30.48 cm x 76.2 cm deep were dug (on the shoreline) and the contents separated into four depth levels and bagged and marked accordingly.

Soil samples were collected using a standard 10.16-cm clam gun to a depth of 15.25 cm. Clam guns were modified with exterior foot pegs to facilitate insertion into the soil and interior plungers to facilitate extracting the sample from the gun. Samples collected by the WDFW were bagged and labeled at the site of collection and transported to the Skagit Wildlife Area for processing. Samples collected by EC-CWS were bagged and labeled at the site of collection and transported to either Environment Canada's Pacific Wildlife Research Centre or Monika's Wildlife Shelter for processing. In total, 605 cores were collected in Canadian agricultural fields and 1179 cores (540 U.S., 639 Canada) were collected from permanent or temporary roost sites.

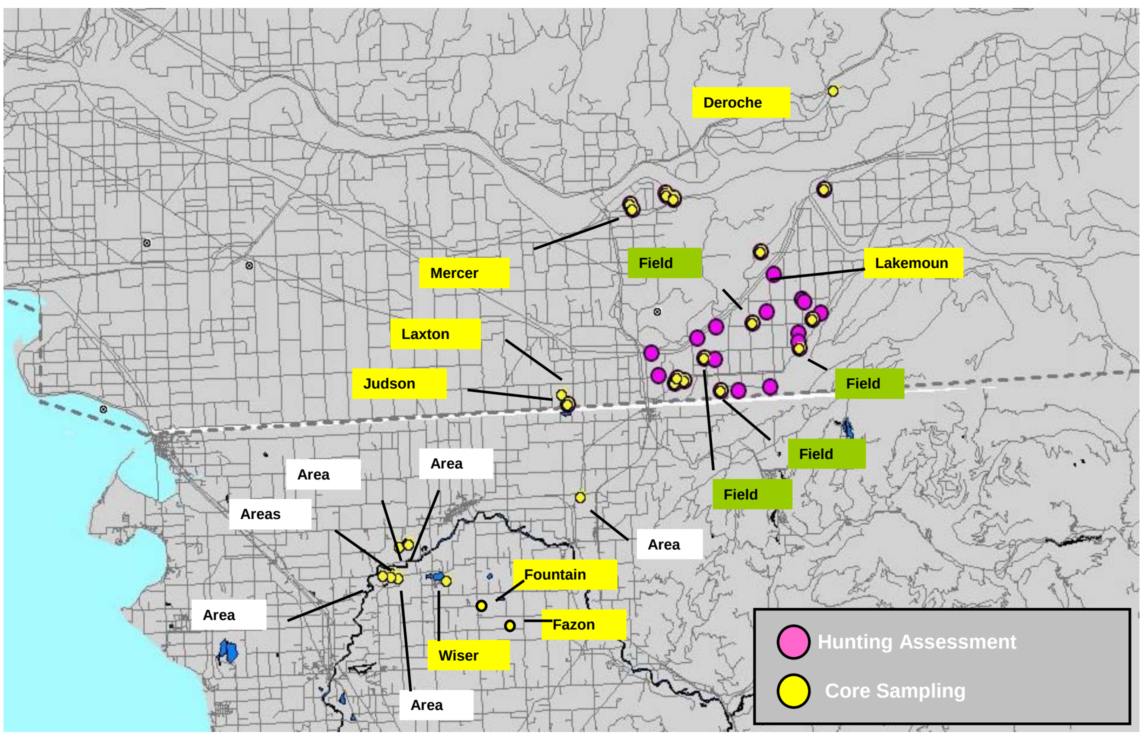


Figure 3. Areas tested for lead shot, 2001-2004. All fields visited by lead-poisoned radio-tagged swans prior to death were assessed for hunting activity (pink). Core samples were collected only from those fields which showed evidence of current hunting activity (yellow) to estimate potential deposits to environment.

2.10.2 Core Sampling 2005-2007

2.10.2.1 Agricultural Fields in Primary Area of Interest

In 2005-06, the University of Washington conducted a lead shot density assessment of a primary area of interest (~243 ha) near the U.S./Canada border (Figure 4). Sampling was limited to corn fields with grass cover crop since these crop types were extensively used by collared swans that died of lead poisoning. Specific forage fields and temporary roost sites (flooded agricultural fields) were selected based on the relative intensity of use by collared swans that died of lead poisoning. Core sampling to assess lead shot density occurred on 11 fields in the U.S. and 4 fields in B.C.

Soil core sampling was accomplished using a 25-m triangular grid. A triangular grid (Gardner 1986) is formed by tiling the plane regularly with equilateral triangles. A Trimble GPS Pathfinder Pro XRS® with the TSC1 data collector® was used to place flags and build grids on the fields (Figure 4.). The samples were then collected at flag placements. Soil samples were collected using equipment also used by wildlife agencies in 2001-04 (described above). Soil samples were bagged and labeled at the site of collection and transported to the University of Washington for processing. In total, 3,429 cores (2,865 U.S., 564 Canada) were collected from the agricultural fields.

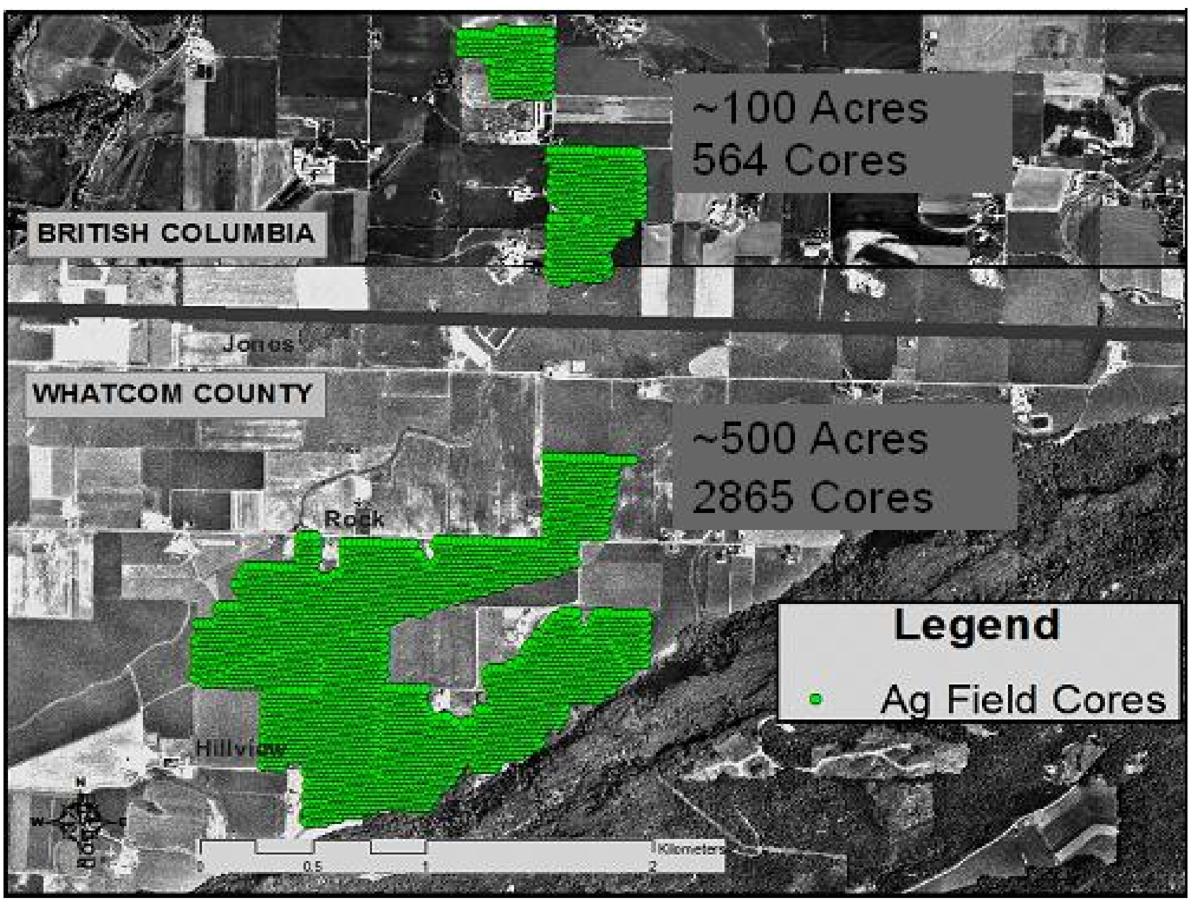


Figure 4. Agricultural fields within the 243 ha (~600 acre) “primary area of interest” where lead shot density assessments were conducted in 2005-06.

Samples collected by the University of Washington in 2005-06 were separated from those collected by wildlife agencies in 2001-05 for analysis. Adaptive kernel estimation (ArcGis 9.1) was used as a means of designating portions of fields that may have elevated pellet densities. A 50% contour was designated (prior to process) as a means of designating the level of significance of pellet densities.

2.10.2.2 Judson Lake

Judson Lake (~40 ha lake spanning the border) was used by more of the marked lead exposed swans (89%) than any other permanent (lakes, ponds, gravel pits, rivers) roost. In addition, these swans roosted at Judson Lake 35% of the time. During 2004, the portion of Judson Lake in Canada had been adequately sampled (EC-CWS, 25 m square grid), but the portion in the U.S. had only been partially sampled (transect lines, also by EC-CWS). For these reasons, the U.S. side of Judson Lake was prioritized as the only permanent roost site for sediment sampling during 2005-2006.

Sediment core sampling was accomplished from a boat using a 25 m triangular grid over the entire U.S. side of the lake. An additional 12.5 m triangular grid was used to sample an area 150 m in length and 50 m in width in front of each of five permanent and two brush blinds (very close together and treated as one) on the U.S. side of the lake. These grids were placed 50 m out from the front of each blind. Where two grids intersected at a sample point, one sample was used for both (Figure 5). A 2.50 cm by 2.54 m bamboo pole was used to mark sample locations with the aid of the above mentioned Trimble unit. Sediment samples were collected using a 10.16 cm aluminum tube to a depth of 15.25 cm. Sediment samples were bagged and tagged immediately upon collection and transported to the University of Washington for processing. A total of 528 samples using the 25 m grid and 549 samples with the 12.5 m grids were collected.

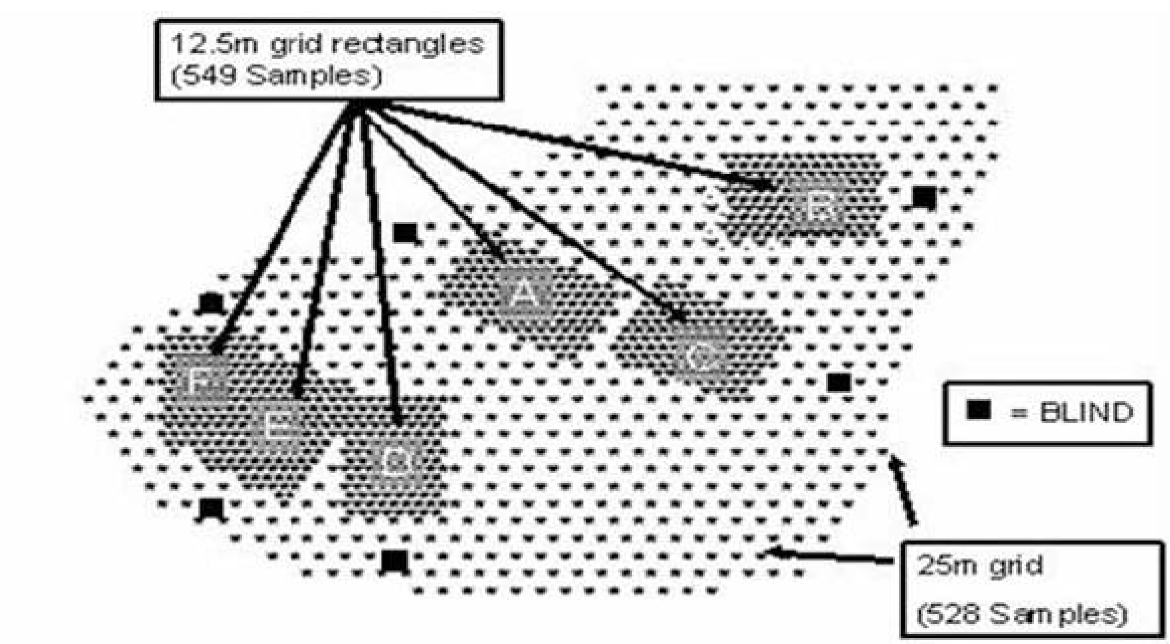


Figure 5. A map of Judson Lake sediment core sampling 25 m grid and 12.5 m grid rectangles collected in 2005-06 (U.S. portion of the lake only).

In this case, core samples collected from the Canadian side of Judson Lake by EC-CWS in 2004 were included with those collected on the U.S. side of Judson Lake by the University of Washington in 2005-06. Adaptive kernel estimation (ArcGis 9.1) was used as a means of designating portions of the lake that may have elevated pellet densities. A 50% contour was designated (prior to process) as the level of significance.

2.10.2.3 Agricultural Fields in the Clearbrook Area

In the spring of 2008, the University of Washington conducted a lead shot density assessment of several corn fields in the Clearbrook area. These fields were used less frequently by swans during 2006-07 and 2007-08 (when mortalities declined) than during previous winters. A total of 550 samples were collected using identical protocols to sampling completed in 2004-05.

2.10.3 Core Sample Processing

All soil and sediment samples were processed by the same protocol. Samples were washed through a 1 mm mesh sieve to remove soil/sediments from pellets, grit/gravels and organic matter. The woody debris remaining in the sieve was floated off by partially submersing the sieve in water. The grit/gravels and any pellets were then rinsed from the sieve into a large aluminum pan. Any remaining pellets were then recovered through visual inspection. Lead and steel pellets were separated with a magnet and stored in a labeled micro-centrifuge tube (2005-08, UW), or Ziploc bag (2001-04, WDFW & EC-CWS) for each pellet type per sample. The remaining grit/gravels were air dried and placed in labeled 50 ml vial (2005-07, UW) or Ziploc bag (2001-04, Canada); grit was not retained from cores collected by WDFW. Due to the possibility of lead contamination, all soils/sediments washed from the samples examined at the University of Washington were trapped and disposed of as hazardous waste (per University of Washington Health and Safety guidelines). During 2001-04, soil and sediment samples were processed by WDFW staff or EC-CWS staff or contractors. In 2005-06, all soil and sediment samples were processed by the same Washington Cooperative Fish and Wildlife Research Unit (WACFWRU) personnel. During 2007-08, samples were processed at the WACFWRU by the some of the same personnel.

2.10.4 Shot Recovery Efficiency

The accuracy of staff and contractors to retrieve shot present in soil cores was estimated by adding shot to a sub-sample of soil cores after their collection, but prior to examination. Staff sorting the samples did not know the cores had been spiked with additional shot. During the 2001-04 lead shot density assessment: A total of 29 shot (14 lead, 25 steel; sizes #2 and #4) were added to 16 cores in Canada, and in the U.S., a total of 13 steel shot were added to 2 cores. During the 2005-06 lead shot density assessment, a total of 40 cores were spiked with 8 to 12 size 7.5 lead pellets. During 2007-08, 9 cores were spiked with 2 to 10 size 7.5 lead pellets.

2.10.5 Pellet Decomposition

During soil and sediment sampling efforts fewer than expected steel (non-toxic) pellets were recovered. One theory to explain this trend is the possibility of the steel pellets degrading in the environment at a rapid rate compared to lead pellets. To investigate this further, WACFWRU used manufactured 0.5 mm mesh Nitex™ comprised of 9 pouches to hold 10 pellets each of 3 different types of shot, in 3 different sizes per type. The shot selected was HEVI●STEEL™

(Environ-Metal inc. Sweethome, OR) in sizes 6, 4 and B; Federal Premium Ultra●Shok™ (Federal Cartridge Co. Anoka, MN) in sizes 4, 2 and BB; and No●Tox™ (The Bismuth Cartridge Co. Dallas, TX) in sizes 4, 2 and BB. The weight of each 10 pellet sample was recorded prior to being deployed.

A site was selected in Whatcom County as representative of common waterfowl hunting locations in the area. The site was prone to flooding at times, similar to many fields in Whatcom County. Each pouch was labeled and filled with shot and soil collected on site, sealed, and placed with the upper surface of the bag level with the surrounding soil. Forty replicates of each bag were placed in the field in January 2006, near the end of the local waterfowl hunting season. Bags were left undisturbed in the field and subjected to drying and submersion as dictated by local weather.

Ten bags were retrieved each month for 4 months. The contents of each pouch were removed and washed through a 1 mm sieve to separate the shot from the soil. Recovered pellets were air dried, weighed, bagged and labeled.

2.10.6 Assessing Reliability of Metal Detectors to Locate Spent Shot

The use of metal detectors to locate areas of elevated lead pellet density, either in fields or lake environments was investigated. Preliminary trials by WDFW, WACFWRU, Northwest Treasure Supply (NTS) and the Resources Coalition (RC) personnel determined that the metal detectors can reliably locate a single pellet in the upper 5 cm of soils, but it was not known how much deeper in the soil they may be able to detect groups of pellets.

Based on the results of initial trials, advice of engineers from manufacturer White's and Garrett combined with the experience of RC and NTS personnel, the White's GMT™ model (White's Electronics, Inc. Sweet Home, OR) was selected as the most appropriate detector for this study. This model encompasses features to aid in lessening interference from ground mineralization and a coil designed to aid in detecting small gold nuggets. It also operates at a comparatively high frequency (48 kHz) which aids in identifying small metals and gold (RC and NTS personnel). Similarities in the ability to detect gold and lead guided the decision towards selecting a machine designed for finding gold.

A pilot study to determine the depth to which groups of lead and steel pellets could be reliably detected using a metal detector was conducted in September to November 2005. The study included an in-field quantification of search efficiencies by placing various numbers of shot and shot sizes at various depths in the fields surveyed and stratifying the effort by 2 habitat types (corn and grass fields). Corn had been harvested from the field, leaving a somewhat sparse grass cover crop and corn stubble up to 46 cm in length. The grass field had fairly thick, tall (approximately 30 cm) grass. The length and thickness of the grass was a concern to metal detector operators as it was unknown if they would be able to consistently keep the detector coil near the ground. Pellet plants were glued to a portion of a wooden tongue depressor to aid in the retrieval of pellets. Pellet sizes were representative of common loads used for hunting and/or target shooting as well as those sizes found in recovered swan carcasses. Lead pellet sizes were numbers 7.5, 6 and 4; steel pellet sizes were numbers 6, 4 and 2. Pellet plants were glued in three different size groups (single, 3 and 9 pellets). The depth of pellet plants were 2.54 cm, 7.62

cm, and 15.24 cm which are depths greater than that available to swans. There were 10 replicates of each pellet type, pellet size, pellet number, and depth for each habitat type for a total of 1080 plants. In addition, there were 120 plants (10% of total plants) consisting of zero pellets to ensure detector operators were not keying on disturbance created by pellet placement.

Three transects (2 m wide by 100 m long; boundaries marked by stakes and flags) were placed in each habitat type. The three transects in each habitat type were considered as one (2m wide by 300 m long) during pellet plant placement designation. These transects were divided into 0.25-m sections and the resulting intersections were numbered from 1 through 10,800. Pellet plants were randomly assigned a number between 1 and 10,800 and placed at the corresponding 0.25-m intersection number. The location of each plant was unknown to detector operators. In addition, transects/plants were in place for 6 days prior to detector sweeps to allow weather to disguise plant placements.

Replicate detector sweeps were completed over 2 days by two Resources Coalition employees and one NTS employee, each person had extensive metal detector operating experience. Operators placed a flag at detection locations. Flag placement was scored by placing a metric tape along the transect length and measuring across to the flag. Coordinates (length by width) of each flag were recorded even if the flag was placed outside the transect boundary. Flag coordinates were adjusted to the nearest 0.25-m intersection to compensate for possible errors introduced during measurement in addition to the lack of pin-pointing by detector operators. This adjustment allowed for a “hit” to be scored if a flag was placed within 12.5 cm along the 0.25-m axes of a plant or up to 17.67 cm on the diagonal from a plant. Operators were instructed to sweep all transects as if they were trying to cover the total area (over 250 ha). This speed was quicker than they would move if recreational metal detecting and did not allow for precise pin-pointing of detection locations. Transects were scored, and flags removed, immediately upon being swept by a detector operator and before another operator was allowed to enter the field.

2.11 Experimental Management Action to Haze Judson Lake (a major roost site)

Lead shot density assessment conducted in 2005-06 found relatively high densities of lead shot on the U.S. side of Judson Lake compared to other sampled permanent roost sites. In addition, this lake was used by a relatively large percentage of the marked swans that subsequently died of lead poisoning. Therefore, it was decided to undertake an experimental management action where swans would be prevented from using Judson Lake. The results of this hazing experiment would be indicative of the lake’s relative contribution to lead-related swan mortalities.

A decision tree for activities and hypotheses tested in an effort to locate the source(s) of lead pellets leading to swan mortality in the Pacific Northwest was developed (Figure 6).

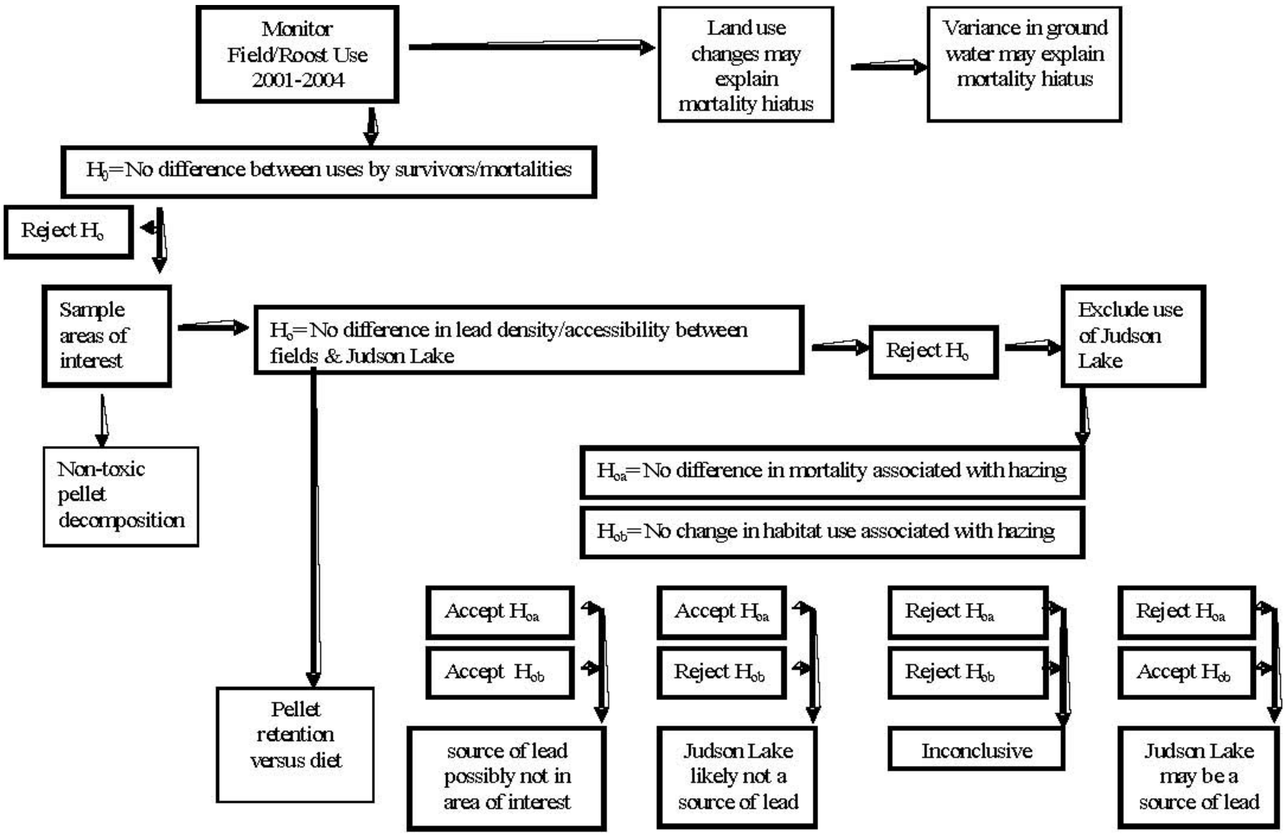


Figure 6. A decision tree depicting the activities and hypotheses tested in an effort to locate the source(s) of lead pellets leading to swan mortality in the Pacific Northwest.

Hazing of swans from Judson Lake was conducted during the winter of 2006-07. Unfortunately, temperatures were unusually cold and many roost sites (temporary and permanent) were frozen, potentially resulting in unexpected movement behavior by the swans. Therefore, the hazing experiment was repeated during the following 2007-08 winter.

During both years, the hazing program began with the first swan arrival and continued without interruption through mid January (well after the estimated lead exposure period of mid November to early December). Hazing activities incorporated a variety of techniques, active and passive. Active forms included the use of an airboat and noise-makers to aggressively alarm the birds and drive them from the area. Passive forms included the use of effigies (scarecrows, coyotes) and lights and lasers in an attempt to keep the birds from choosing the lake as a roost site.

2.12 Bald Eagle Secondary Lead Exposure Monitoring

A notice was issued to U.S. and Canadian wildlife rehabilitators, Federal law enforcement agents, and State veterinarians requesting that all bald eagles obtained from northwestern Washington and Sumas Prairie during the winter months from 1999 to 2008 be analyzed for lead exposure.

2.13 Data Compilation

All data was compiled, and analyzed for each study year using various statistical and GIS tools. This analysis verified suspected contaminated areas, revealed additional suspect areas, and provided necessary information for the project partners to annually evaluate the investigation and pursue the appropriate actions for the upcoming field seasons.

2.14 Public Outreach

To provide the general public with information on the project and the status of the swan mortality events, the partners cooperatively developed talking points and media contacts, released annual reports, and provided opportunities to attend an annual stakeholders meeting. In addition, two public information sessions were held (one in Whatcom County, Washington and the other in Abbotsford, British Columbia) to inform the public on the progress of the investigation as well as solicit public interest in volunteering to assist with the project. Two posters promoting the use of non-toxic shot were produced by EC-CWS and distributed to retail outlets selling lead shot in the Canadian portion of the study area as well as any interest group or stakeholder who requested copies.

3.0 Results

3.1 Swan Capture and Health Evaluations

3.1.1 Capture

Twenty-six swans (25 trumpeters and 1 tundra) were fitted with radio collars for the 2001-2002 winter. Forty-two swans captured in the winter of 2002-2003 were fitted with collars (23 trumpeter and 19 tundra). One additional hatch-year tundra swan was caught and sampled but not fitted with a collar (tarsus band only). In 2003-2004, 101 swans were collared (100 trumpeter and 1 tundra). All trumpeter swans were fitted with radio collars, 1 tundra swan was fitted with a coded collar without a radio and 16 tundra swans received metal tarsus bands only. Ninety-six trumpeter swans were captured and fitted with radio collars in the winter of 2004-2005, 6 with satellite collars and another 3 with standard non-radio collars. In addition, 22 tundra swans were outfitted with standard non-radio collars. Please refer to Table 2.

Table 2. Total numbers of swans, marked and unmarked, captured from 2001-2005.

	Species	2001-2002	2002-2003	2003-2004	2004-2005
Radio Collared	**Trumpeter**	**25**[a]	**23**	**100**[b]	**102**[c]
	Tundra	**1**	**0**	**0**	**0**
Collar no radio	**Trumpeter**	**0**	**0**	**0**	**3**
	Tundra	**0**	**19**	**1**	**22**
Not Collared	**Trumpeter**	**0**	**0**	**0**	**2**[d]
	Tundra	**0**	**1**	**17**	**0**
Total Captured	**Trumpeter**	**25**	**23**	**100**	**107**
	Tundra	**1**	**20**	**18**	**22**

[a] Includes one found injured and rehabbed at PVWRC
[b] Includes two found injured and rehabbed (one at PVWRC and one at MWS)
[c] Includes 6 marked with satellite transmitters
[d] Includes one swan banded elsewhere and one that escaped before collar could be fitted

3.1.2 Blood lead levels at time of capture

Over the years of capture, blood levels tended to be higher for those captured later in the year, and in the northeast portion of the study area (Figure 7).

Of the 25 swans sampled in Whatcom County in 2001-02, 21 (84%) were found to have blood lead levels within the normal range (range 13-122 ppb), 3 (12%) were found to have sub-clinical blood lead levels (range 319-564 ppb) and 1 had blood lead levels considered toxic (1.275 ppb) at the time of capture. The 3 swans with the highest lead levels were caught on the last day of trapping for the season (22 Dec 2001) in Whatcom County in the northeast portion of the study area. Thirty-six swans (84%) sampled in 2002-03 were found to have blood lead levels within the normal range (<25-188 ppb), 6 (14%) had sub-clinical levels (range = 210-848 ppb), and 1 swan had blood lead levels considered toxic (1,972 ppb). Of the 114 swans sampled in 2003-04, 70% (80) had blood lead levels within the normal range (26-195 ppb), 21% (24) had sub-clinical levels (range = 211-908 ppb) and 9% (10) were found to have blood lead levels considered toxic (range = 1,283 -7,244 ppb). All swans with toxic blood lead levels were caught in Whatcom County in the northeast portion of the study area. Of the 127 swans sampled in 2004-05, 80% (102) had blood lead levels within the normal range (4-194 ppb), 14% (18) had sub-clinical levels (range = 216-802 ppb) and 6% (7) had toxic blood lead levels (range = 1,039 -7,610). All of the swans with toxic blood lead levels (Figure 7) were captured in Whatcom County in the northeast portion of the study area.

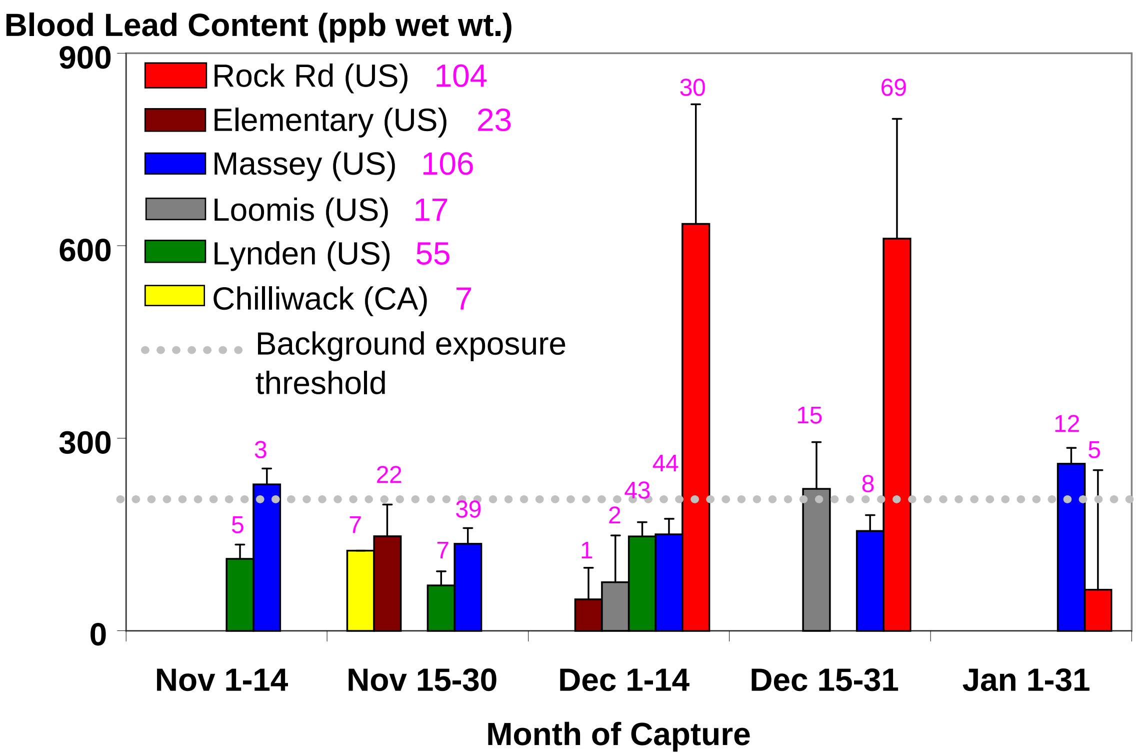


Figure 7. Average blood lead levels ppb wet wt., (± SE) of swans captured between 2001 and 2005.

3.2 Telemetry on Wintering Grounds

Table 3 depicts the total numbers of swans, by species, which were captured and marked each year, in addition to the returning swans from previous years that were available for telemetry monitoring from 2001 to 2005.

Table 3. Total numbers of swans available for telemetry monitoring from 2001-2005

	Species	2001-2002	2002-2003	2003-2004	2004-2005
Radio Collared	Trumpeter	25[a]	23	100[b]	102[e]
	Tundra	1	0	0	0
Returns	Trumpeter	N/A	17	28[c]	82[f]
	Tundra	N/A	1	9[d]	7[g]
Total Monitored	Trumpeter	25	40	128	187
	Tundra	1	20	10	29

[a] Includes one found injured and rehabbed at PVWRC
[b] Includes two found injured and rehabbed (one at PVWRC and one at MWS)
[c] Includes eight returning from capture in 2001-02
[d] Includes one returning from capture in 2001-02
[e] Includes 6 marked with satellite transmitters
[f] Includes six returning from 2001-02 and eleven from 2002-03
[g] Includes one returning from 2001-02 and six from 2002-03

3.2.1 2001-02 Telemetry

All 26 radio-collared swans available over the winter of 2001-02 were detected post capture. Five of the 26 died during the 2001-02 winter. One bird that died of lead poisoning had elevated blood lead levels at the time of capture, one died from unknown causes (heavily scavenged carcass found in February 2002), two succumbed to injuries and one (M52) was confirmed to have acquired lead poisoning post release. Telemetry data from this swan focused the investigation on an area southwest of Lynden, Washington.

3.2.2 2002-03 Telemetry

Forty radio-collared swans were available for tracking over the winter of 2002-03.
Two radio-collared swans died with one (M18) being confirmed as lead poisoned post release; the other died from unknown causes (scavenged carcass, unable to investigate). Telemetry data showed that this bird may have been exposed to lead at least five different locations. Telemetry data from both M18 and M52 focused our investigation on the area (both sides of the international border) near the town of Sumas, Washington.

3.2.3 2003-04 Telemetry

Ninety of the 100 trumpeter swans captured in Whatcom County in 2003-04 were detected in the Sumas Prairie and Whatcom County, 27 used Skagit County and 3 went as far south as Snohomish County. Of the 20 (2002-03) marked birds returning with functional transmitters, 14 were detected in the Sumas Prairie, 14 in Whatcom County, 5 in Skagit County, and none in Snohomish County. Of the 8 marked birds returning from 2001-2002, 6 were detected in the

Sumas Prairie, 6 were detected in Whatcom County, 7 Skagit County, and 3 in Snohomish County.

During the winter of 2003-04, 25 radio-collared swans died. Two were returning swans from capture events in 2002-03 and one was a return from capture in 2001-02. Eight had toxic blood lead levels at the time of capture in 2003-04. Ten carcasses were not recovered and cause of death is not known. Of the seven dead swans that had normal blood lead levels at the time of capture, four were confirmed as succumbing to lead poisoning post-release and three were not lead-exposed (1 aspergillosis, 2 undetermined).

3.2.4 2004- 05 Telemetry

Of the 100 swans marked in 2004-05, 79 were detected in Sumas Prairie and Whatcom County, 21 in Skagit County, and 1 in Snohomish County. Of those returning from capture during the previous 3 years (81 swans), 50 were found in Sumas Prairie, B.C., 62 were found in Whatcom County, 22 were found in Skagit County, and 3 were found in Snohomish County.

Twenty-four of the collared swans died. Nine of the 24 were lead exposed at time of capture. Seven were scavenged before they could be retrieved. Seven swans with normal blood lead levels at time of capture were confirmed as lead poisoned at time of death. One swan died of non-lead means (aspergillosis).

Two of the 6 satellite-marked birds died during the winter of 2004-2005. One (M99) was lead poisoned at the time of capture and the other (M88) suffered a serious wing injury. One (M75) of the 6 satellite transmitters ceased operation early in Jan 2005 and one (M89) ceased operating for a time and then began sending data once per month during the spring migration. The remaining two (M86 & M87) continued functioning through spring migration.

3.2.5 Summary of Telemetry Results for All Years

Considering radio-collared swans that died (n=56) over the 4 years of this portion of the study, 47 were detected in the Sumas Prairie, B.C., 52 in Whatcom County, 8 were detected in Skagit County at one time or another, and only one in Snohomish County. However the telemetry efforts were not equal. More effort was put into conducting telemetry in Whatcom County and the Sumas Prairie since those were the primary areas of focus.

All swan mortalities were trumpeters, with the exception of one tundra that was lead-exposed prior to capture. Thirteen of the swans had low blood lead levels at the time of capture and laboratory tests concluded lead poisoning as the cause of death and therefore were the focus of further intensive analysis of the telemetry data. Of the remaining birds, 18 were exposed prior to capture, 19 were scavenged prior to locating the remains (unable to confirm lead exposure at time of death), and 6 birds died of causes other than lead toxicosis. Two of the satellite marked swans died shortly after release (2004-05), one was lead exposed prior to capture and the other suffered a severe wing injury.

Data indicated that marked swans surviving to spring migration each year were found foraging (during daytime hours) a greater percentage of the time in fields south of Everson, Washington, compared to those marked individuals that succumbed to lead poisoning. The lead poisoned individuals spent a greater percentage of their time foraging in fields east of Sumas, just north and south of the border. All of the 13 marked swans which died of lead exposure post release were located in either Whatcom County or Sumas Prairie one time or another. Those swans that survived to migrate each year spent a greater percentage of their roost time at Wilder gravel pit and Wiser Lake (both in Whatcom County) than those marked individuals that succumbed to lead poisoning. The lead poisoned individuals spent a greater percentage of their time roosting at Judson Lake.

3.2.6 Telemetry – Kernel Home Range Analyses

At the conclusion of the 2003-04 and 2004-05 field seasons, telemetry data (day and night observations) from 13 swans confirmed as being lead poisoned post release were entered into kernel home range (ArcGIS 3.2) software to produce “activity centers” encompassing 50% and 90% of all detections (Figures 8 & 9). These activity centers were ranked based on frequency of use by the lead poisoned birds. The activity centers were designated as “areas of interest” and encompassed forage fields near Lynden, Everson and Sumas in Whatcom County, small portions of the Sumas Prairie in B.C. as well as the Judson Lake and Wilder pit roost areas. Identification of the areas of interest decreased the potential source area for lead pellets by more than 90% (from 100,000 ha to less than 10,000 ha).

Data indicated 12 of the 13 lead poisoned collared swans regularly visited the area of interest near Sumas on both sides of the international border, accounting for 70% of all foraging detections (Figure 8.). The remaining bird (4F0) was sighted only intermittently and was thought to have a malfunctioning transmitter. Eleven of the 13 visited the area near Everson. All 13 lead poisoned collared were located at both Wilder pits and Judson Lake during roost surveys (Figure 9). However, one of these birds (4F0) was located only once at Judson Lake as a weak signal, indicative of the swan actually being at another location or having a faulty transmitter on the collar. Figure 10 combines all activity centers (foraging and roosting).

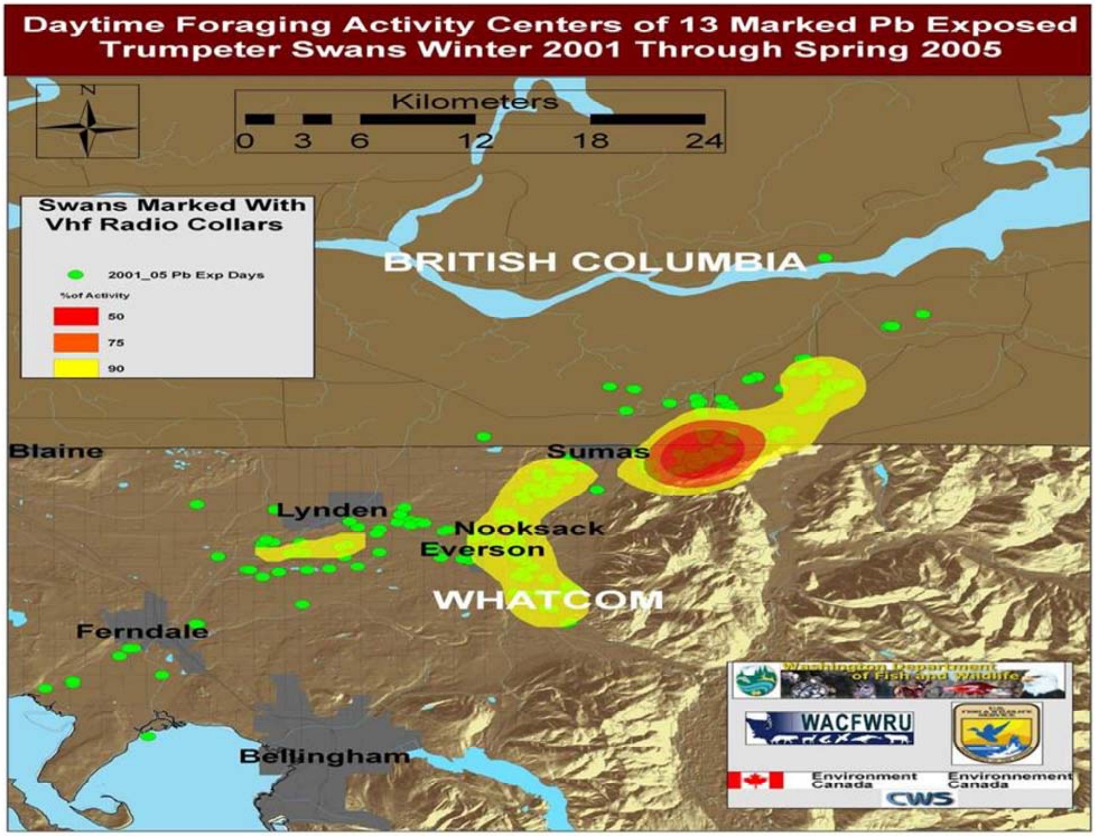


Figure 8. A map of Whatcom County, Washington and Sumas Prairie, B.C. showing the daytime foraging locations used by 13 lead poisoned collared swans between 2001 and 2005. The areas highlighted in yellow, orange, and red encompass 90%, 75% and 50% of the total sightings, respectively.

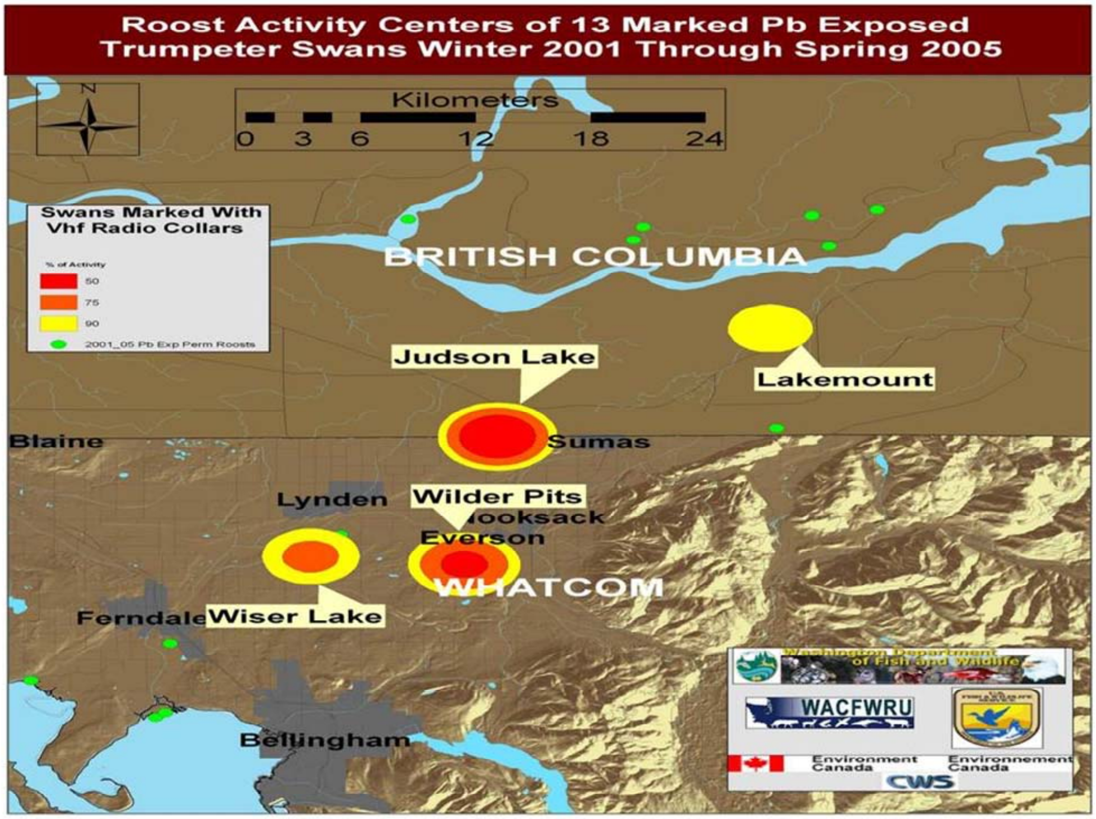


Figure 9. A map of Whatcom County, Washington and Sumas Prairie, B.C. showing kernel home range estimates for roosting activities of 13 lead poisoned collared that died between 2001 and 2005. The areas highlighted in yellow, orange, and red encompass 90%, 75%, and 50% of the total sightings, respectively.

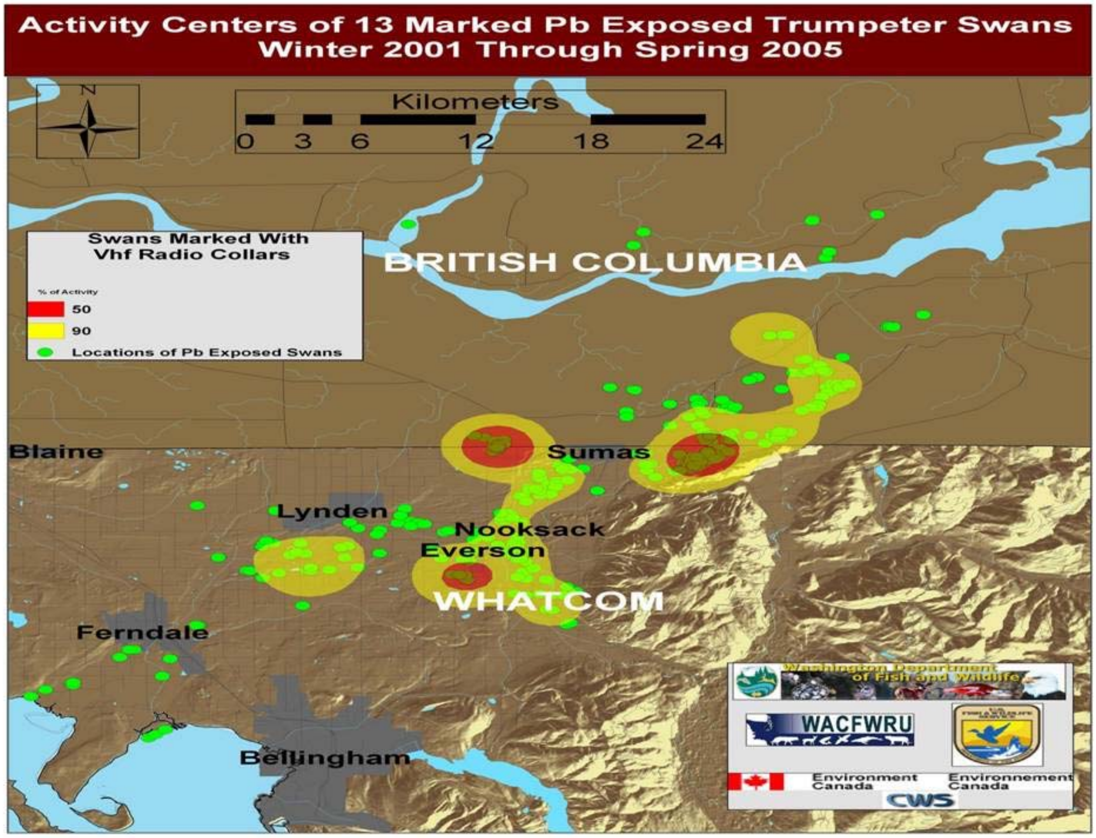


Figure 10. A map of Whatcom County, Washington and Sumas Prairie, B.C. showing kernel home range estimates for foraging and roosting activities of 13 lead poisoned collared swans that died between 2001 and 2005. The areas highlighted in yellow and red encompass 90% and 50% of the total sightings, respectively.

3.2.7 Telemetry of Swans Migrating Back to Breeding Grounds

As of July 2005, two of the satellite collared swans migrated to Alaska and one was found in Yukon (Figure 11).

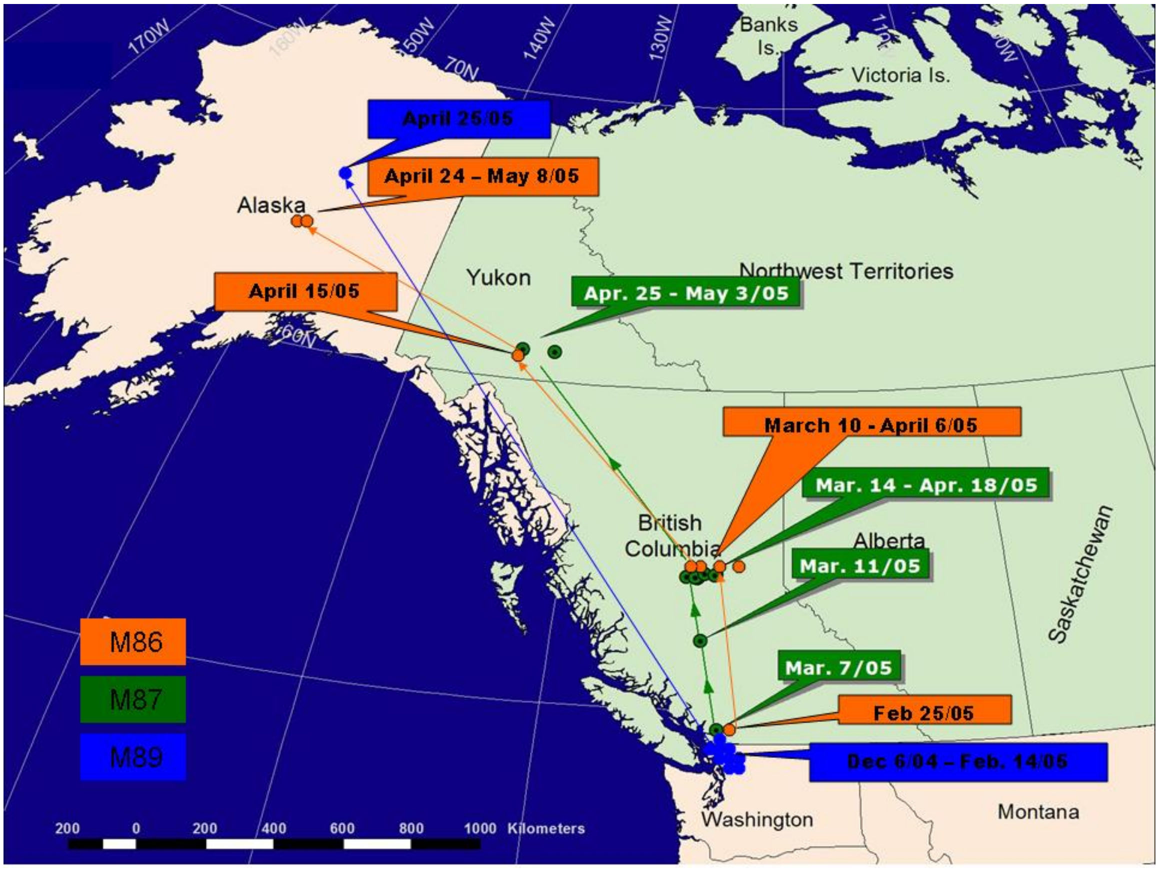
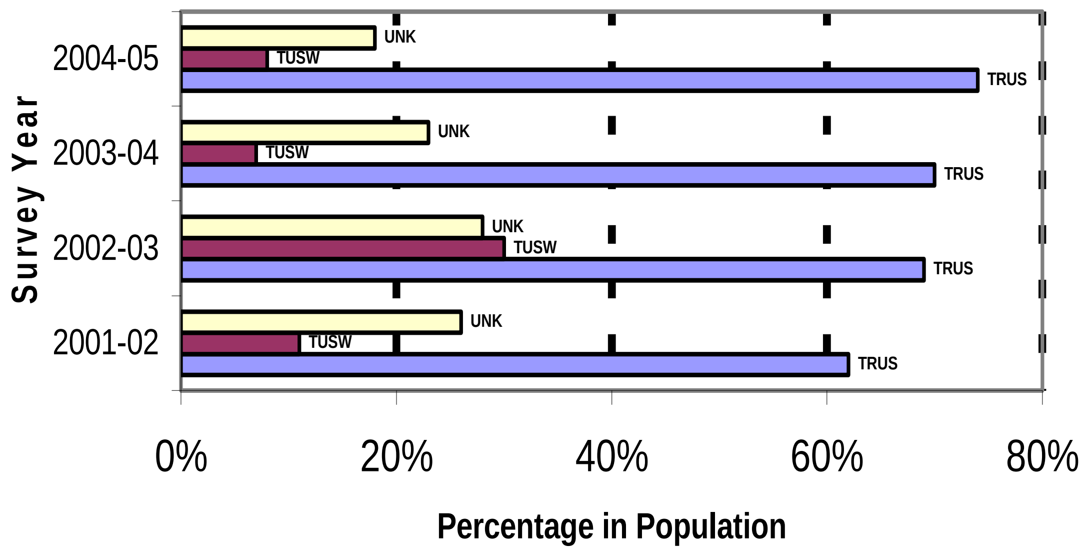


Figure 11. A map of the locations of 3 satellite marked trumpeter swans during the spring and early summer of 2005.

3.3 Swan Population Surveys and Observations 2001 - 2005

The first flock of swans observed in the winter of 2001-02 was at Harrison Bay B.C. on 27 October, possibly migrating south through Canada to winter in Whatcom County. Swans continued to arrive gradually, with a large influx of approximately 800 swans on 5 December, until reaching a maximum of approximately 2,500 to 2,700 in Whatcom County and Sumas Prairie when surveys ended on 19 December. In the winter of 2002-03 the first flock was observed in early November. Total numbers did not reach those of the previous year, reaching a maximum of approximately 1,400 in Whatcom County and Sumas Prairie during the survey period. In addition, there was no apparent large influx of swans. In the winter of 2003-04, 220 swans were counted on 13 November with a maximum of 2,746 in Whatcom County and Sumas Prairie on 13 December. An influx of over 1,100 swans was observed on 8 November. In the winter of 2004-05, 456 swans were counted on 3 November with a maximum in Whatcom County and Sumas Prairie of 2,581 on 9 December. There was an influx of approximately 780 swans on 20 November and approximately 1,230 on 22 January.

The relative proportion (Figure 12) of swan species observed during the surveys was 62%-74% trumpeter, 3%-11% tundra and 18%-28% of unknown species. The category of unknown is high largely due to swans grouping in sizeable flocks and survey time constraints limiting abilities to separate individuals by species.



UNK = Unknown; TUSW = tundra swan; TRUS = trumpeter swan

Figure 12. Total counts of swans, by species, recorded during roadside surveys in Whatcom County and Sumas Prairie for 2001-02 and 2002-03 and Whatcom County only for 2003-04 and 2004-05.

3.4 Mid-winter Population Monitoring

The results of WDFW one-day counts from 2002-2008 (Figure 13) indicate the swan population in northwest Washington State (Whatcom, Skagit and Snohomish Counties) is growing by approximately 15% per year in spite of the die-offs. In these instances, large numbers of swans recorded as unknown species are due to very large flocks being located late during the survey day and in at least one instance a large flock was flushed by a dog before species composition could be recorded.

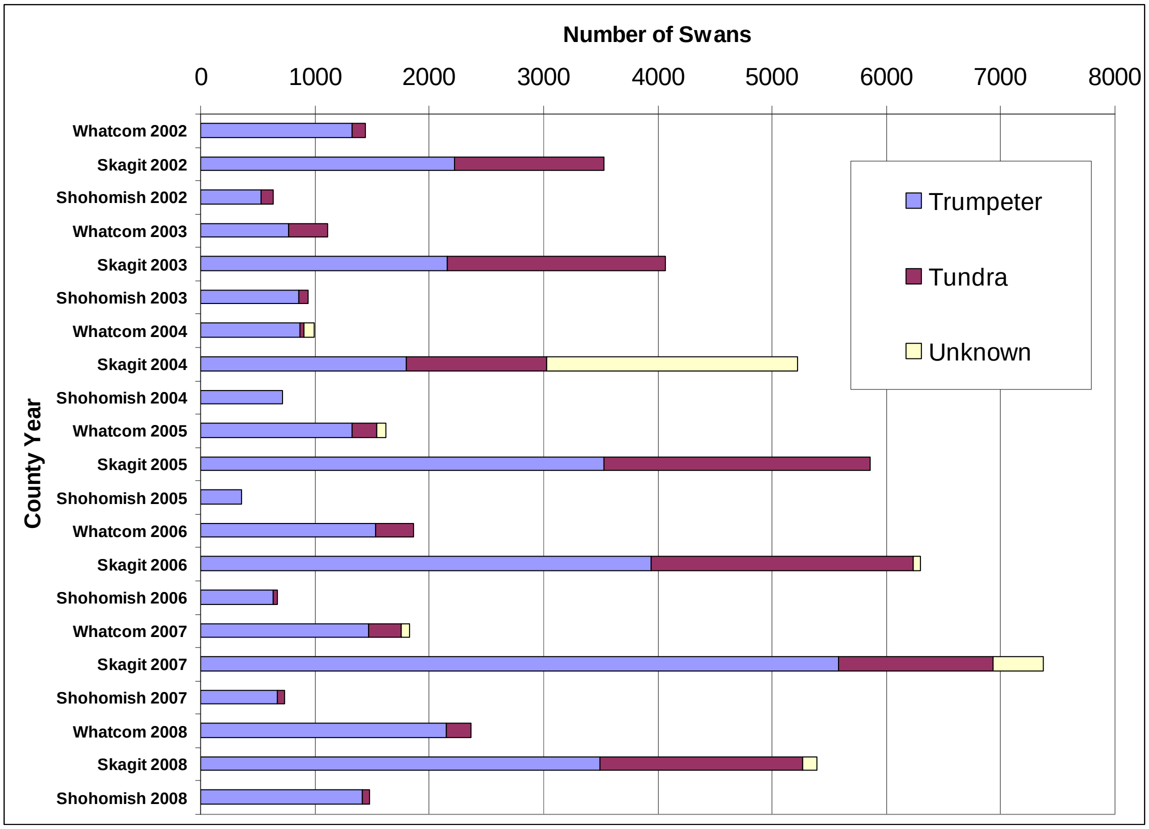


Figure 13. Total swan counts, by species and county, recorded during WDFW annual mid-winter swan surveys.

3.5 Monitoring sick and dead swans

3.5.1 Carcass collections

Carcass collections and post-mortem examinations have been routinely performed since 1999. To date, over 2,500 swan mortalities have been reported in Sumas Prairie and Whatcom, Skagit and Snohomish Counties (Table 4).

Table 4. Annual swan mortalities, 1999-2008 (N=2,574)

Year	Sumas Prairie	Whatcom County	Skagit County	Snohomish County	Total
1999-2000	16	67	26	0	109
2000-2001	57	198	44	11	310
2001-2002	90	250	20	4	364
2002-2003	44	130	33	30	235
2003-2004	124	222	34	16	396
2004-2005	41	212	66	10	329
2005-2006	112	217	49	24	401
2006-2007	44	79	93	16	232
2007-2008	25	64	47	59	195
Total	**553**	**1439**	**412**	**170**	**2574**
Average	61	160	46	19	286

From 1999 to 2006 (prior to the hazing of Judson Lake), the majority of swans died in Whatcom County with very few lead-related swan mortalities occurring outside of the study area (Figure 14).

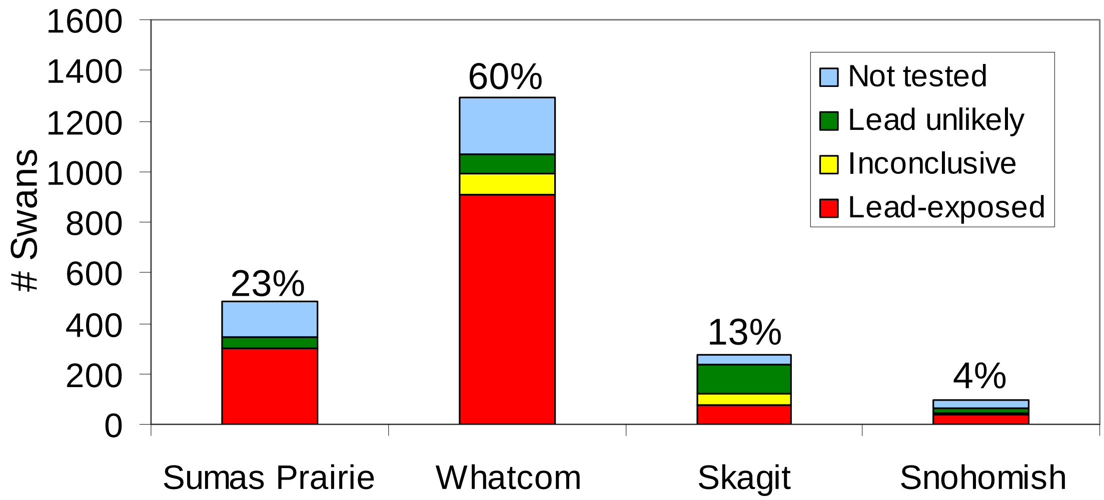


Figure 14. Swan mortalities by county (1999-2006, n=2,147)

The majority (55%) of lead poisoned swans were collected from 4 roosts (Figure 15) but as sick swans seek shelter of safe waterbodies as roost sites, this finding does not necessarily reflect where swans ingested shot.

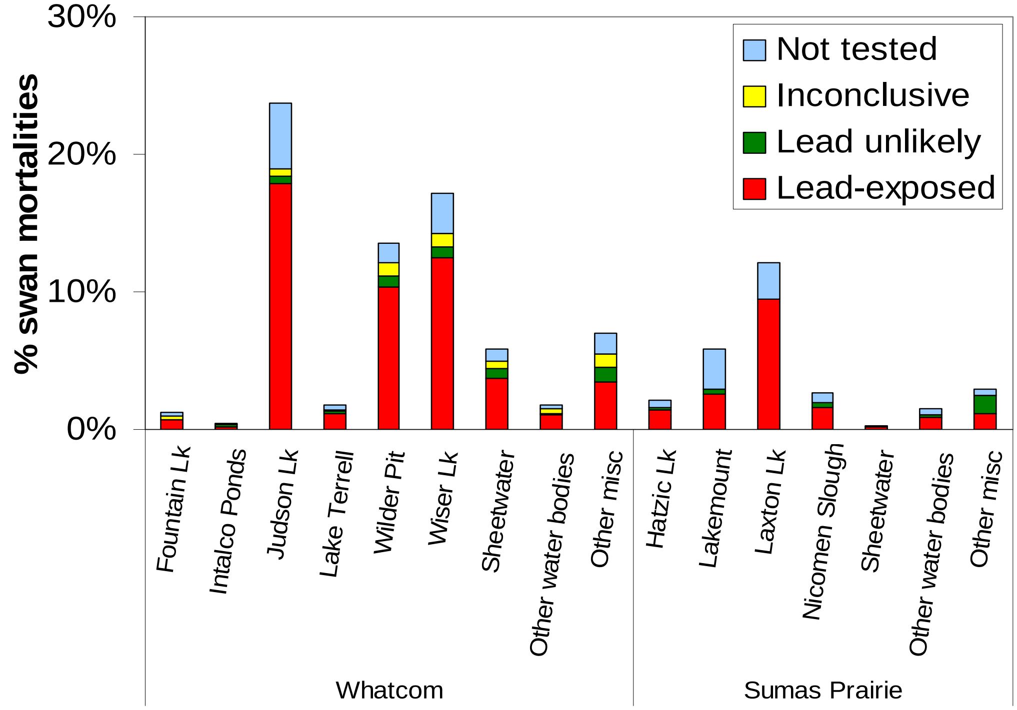


Figure 15. Swan mortalities by location (1999-2006, n=2,123)

Results indicate that mortalities commence shortly after swans arrive on the wintering grounds; mortalities increase sharply about a month after swans arrive (mid-December), peak around the beginning of the New Year and decline again sharply in February prior to their leaving on spring migration (Figure 16).

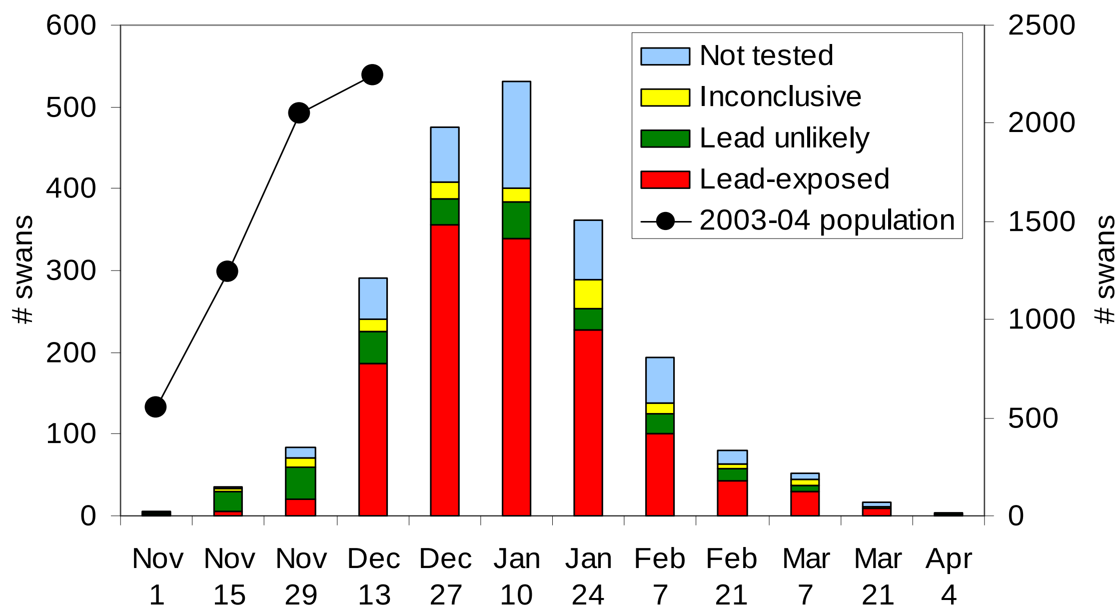


Figure 16. Swan mortalities summed in two-week intervals (1999-2006, n=2,130; bars) and swan population in Sumas Prairie & Whatcom County (2003-2004; line).

It has been estimated that swans may succumb to lead poisoning within 21 days of exposure (USGS 1999). Carcass collection dates were offset 28 days (conservative estimate) to establish an "exposure window" for when swans may have been exposed to lead (Figure 17). These exposure windows indicate that swans are accessing pellets soon after arriving on the wintering grounds.

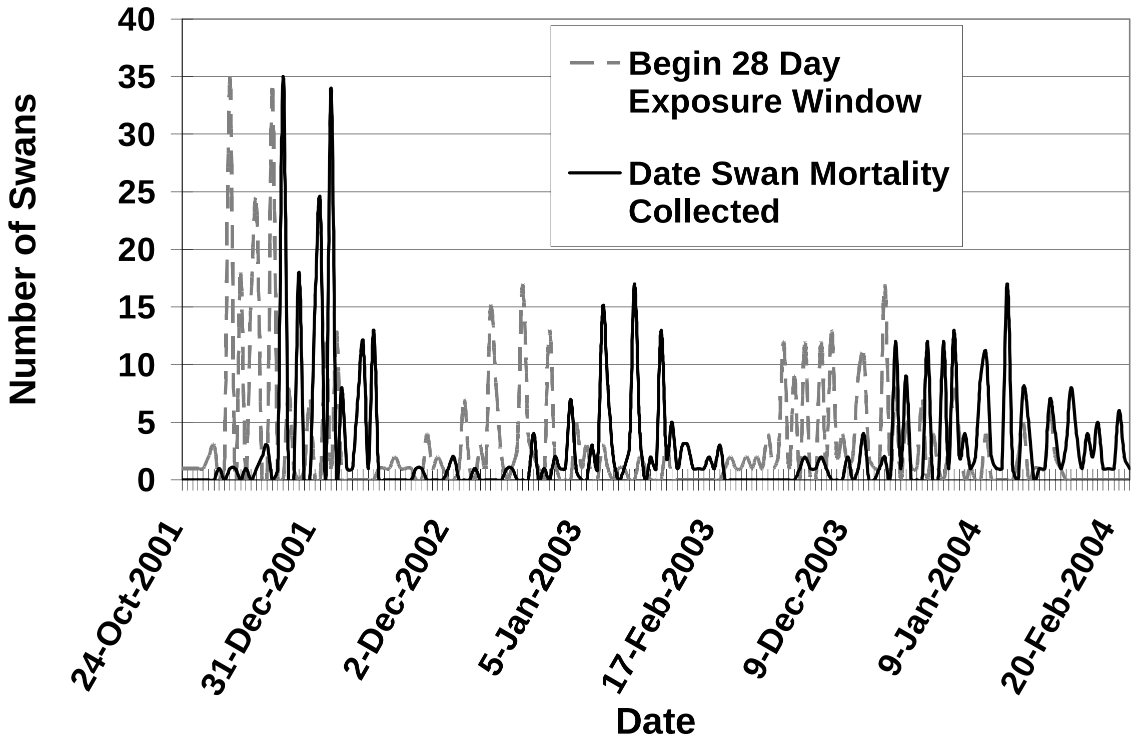


Figure 17. Dates of swan carcass collection in Whatcom County, WA during 2001 through 2004 were back-dated 28 days to estimate a window of possible lead exposure.

3.5.2 Radio-tagged swan mortalities

Details of marked swans that died between 2001 and 2005 were discussed earlier (Sections 3.2.1 - 3.2.5). In 2005-2006, 8 marked swans died, of which 4 were confirmed lead exposed post-release, 3 did not have elevated lead and died from other causes (aspergillosis, powerline collision, gunshot), one was scavenged so unable to further investigate.

Approximately 25% (64 of the 250) of radio-tagged trumpeter swans died from 2001-2006. Seventeen swans were confirmed as lead poisoned after the time of capture (2001-02 n=1, 2002-03 n=1, 2003-04 n=4, 2004-05 n=7, 2005-06 n=4), 20 were scavenged (only collars located and cause of death could not be ascertained), 9 were not lead poisoned and 18 had elevated lead burdens at time of capture for radio-tagging.

Only 3% (2 of 61) of collared tundra swans were determined to have died. However, it was more difficult to recover these individuals as they did not have transmitters and the population of tundra swans in Whatcom County is much lower than that of trumpeter swans.

The majority (65%, 40 of 64) of the radio-collared trumpeter swans were recovered from roosts (Figure 18); 32% (20 of 62) from the four major roosts (Judson Lk., Laxton Lk., Wiser Lk., Wilder Pit).

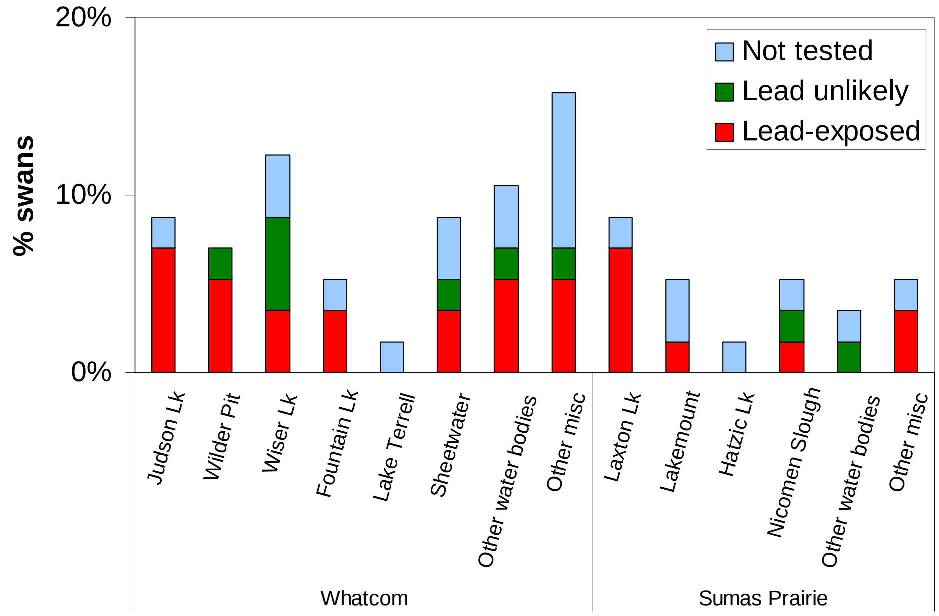


Figure 18. Recovered radio-collared swan locations and lead status.

3.6 Post-Mortem Examinations

From 1999 to 2006, prior to the hazing of Judson Lake, at least 62% of the 2,148 mortalities (total mortalities includes feather piles) were confirmed lead-exposed (Table 5). Of the 1,719 carcasses examined, 77% were confirmed as lead-exposed.

Table 5. Lead status category of swan mortalities, 1999-2006 (n=2148)

Lead Status Category	**# Swans**	
Lead-exposed	1326	62%
Lead unlikely	260	12%
Inconclusive	133	6%
Not tested	429	20%
	2148	

The majority of dead swans examined between 1999-2006 were lead poisoned (Figure 19). Of the 1,326 swans classified as lead-exposed, 1,143 swans were confirmed to have died from lead poisoning. Aspergillosis was detected in 230 swans but was the primary cause of death in only 103 swans.

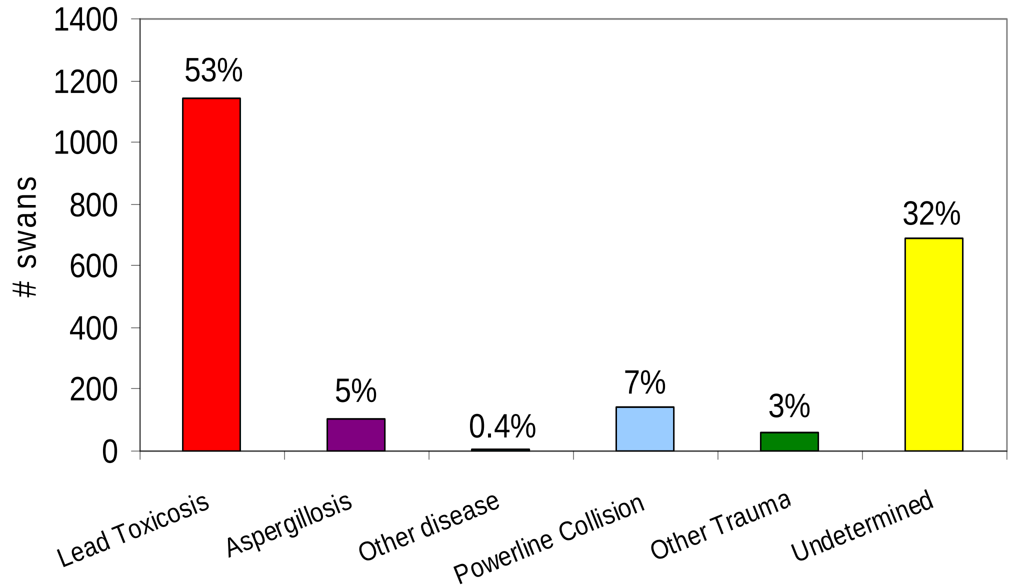


Figure 19. Causes of death of swans, 1999-2006 (n=2,148*)*.

From 1999-2006, prior to the hazing of Judson Lake, 92% of lead-exposed swans had shot in their gizzard (Figure 20). Lead-exposed swans had an average of 22 lead and 9 non-lead shot.

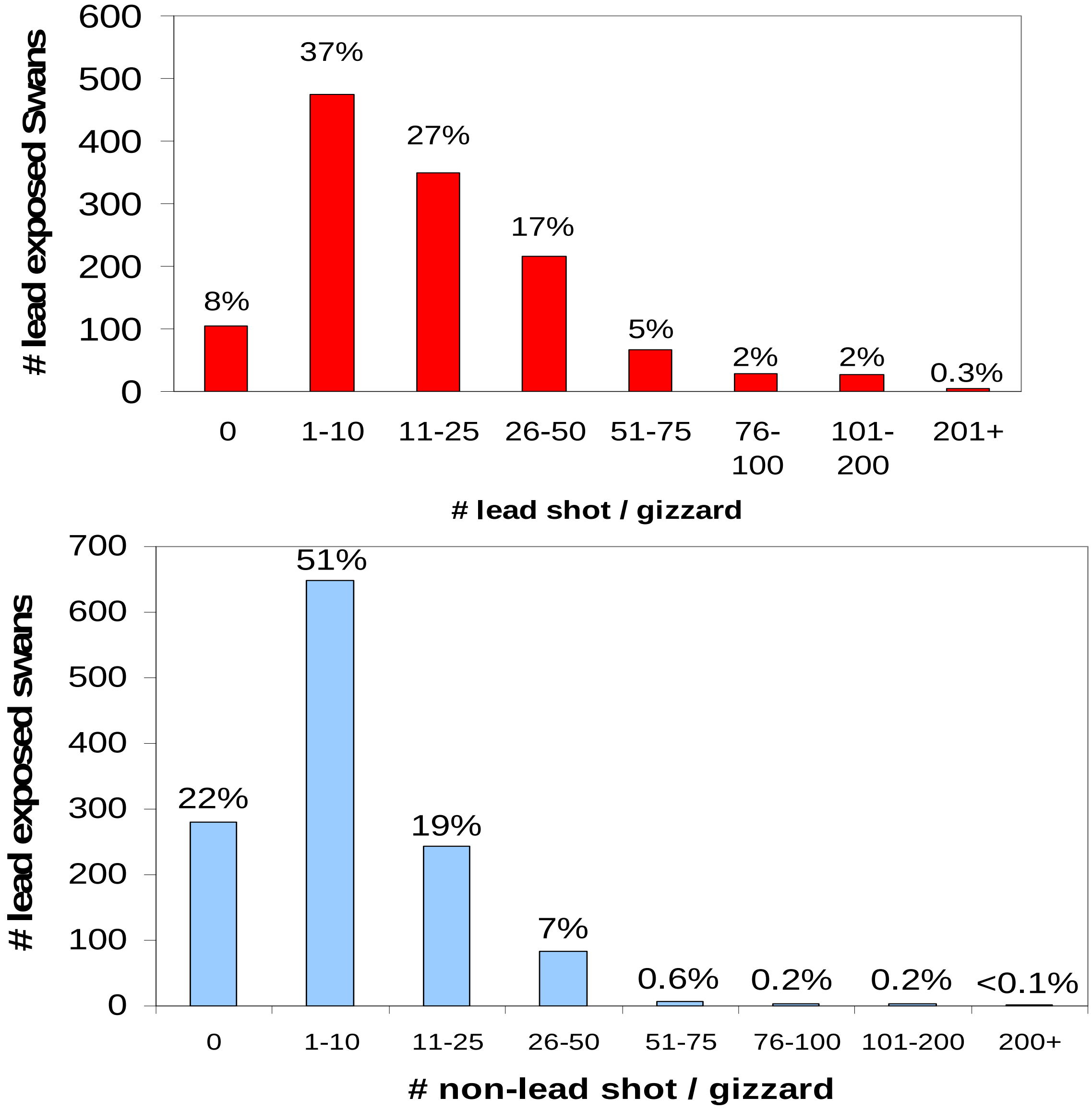


Figure 20. Lead and non-toxic shot frequency distribution from the gizzards of 1,270 swans found dead in the study area from 1999-2006 (lead shot n=27,380; non-lead shot n=11,315).

Lead shot and non-lead shot collected from gizzards of dead swans were of sizes used in waterfowl hunting, upland game hunting and trap shooting, however there is the potential for shot to break-down in the environment and gizzard, so diameter of recovered shot is likely smaller than original size.

From 1999-2006, the number of trumpeter and tundra swan mortalities was proportional of the two species in the local population (Figure 21). The sex rations were similar – 37% males, 32% females, 31% unknown. Age classes were: 21% juveniles, 22% sub-adults, 44% adults, and 13% unknown.

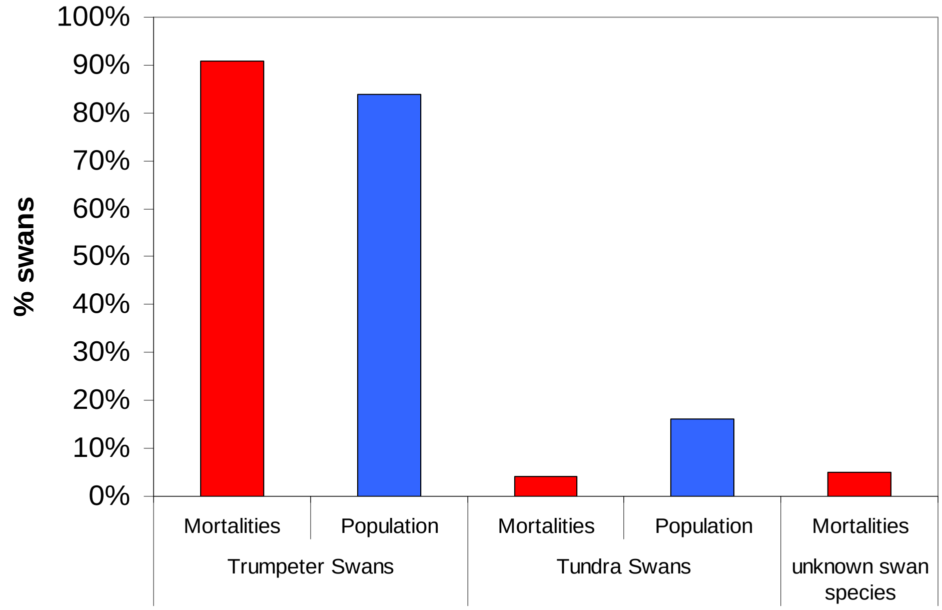


Figure 21. Comparative relationship – percent of trumpeter compared to tundra swans that died (n=2,148, 1999-2006) compared to the relative proportion of each species in the study area (n=3,406, 2005-2006).

3.7 Land Use Investigation

Aerial photographs taken in a subset of years that swan mortality occurred (1991 and 2003) were compared to photographs taken in a year without swan mortality (1995). The intent was to identify fields that may have been used to grow crops attractive to swans during 1991 and 2003 that were also planted with crops unattractive to swans in 1995. Unfortunately, the photographs in some years were taken early in the growing season (May). Crops in these photographs had not sufficiently emerged to allow for their identification from these aerial photographs.

3.8 Lead Shot Density Assessment

3.8.1 Core Sampling 2001-2004

From 2001 to 2004, the EC-CWS and WDFW conducted core sampling in both forage fields and roost sites identified early in the study effort as possible lead sources. Results showed that 3 forage fields had the highest lead shot densities, followed, generally by permanent roosts and then temporary roosts (Figure 22).

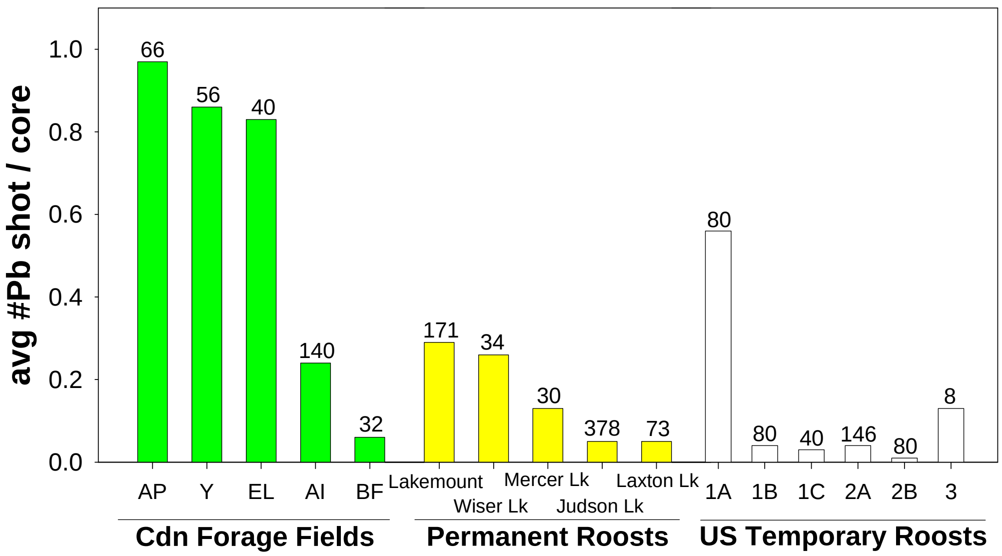


Figure 22. Lead shot density assessment of areas of interest, as identified by telemetry data from 2001 to 2004.

Shot was recovered from throughout core columns which were from 6-12 inches deep (all cores were 6 inches deep except 28 cores taken from Wiser Lake and 227 cores taken from Judson Lake). This suggests historic and possibly current lead shot deposition. In addition, the size of shot recovered from these cores suggested waterfowl and upland game bird hunting as well as trap shooting could all be contributing sources of lead shot responsible for the lead-related swan mortalities.

3.8.2 Core Sampling 2005-06

3.8.2.1 Agricultural Fields in the Primary Area of Interest

A comprehensive soil core sampling effort was undertaken during the winter of 2005-2006 by the University of Washington to determine the lead pellet density in the primary agricultural areas of interest. From 3,429 soil samples processed in the laboratory at the University of Washington, a total of 62 pellets (60 Pb, 2 steel) were recovered. There were 0.0119 lead and 0.0003 steel pellets per core from the U.S. portion of the study and 0.0461 lead and 0.0018 steel pellets per core from samples collected in the fields (Table 6).

Table 6. A breakdown of the pellets recovered from core samples taken in agricultural fields in the U.S. and B.C.

Pellets	U.S. Fields	CA Fields
Number of Cores	2865	564
Pb/Core	0.0119	0.0461
Steel/Core	0.0003	0.0018
# Cores with Pb & Steel	0	0
# Cores with 1 Pb	27	19
# Cores with 2 Pb	2	2
# Cores with 3 Pb	0	1
# Cores with 4 Pb	0	0
# Cores with 8 Pb	0	0
# Cores with 1 Steel	1	1
# Cores with 2 Steel	0	0
# Cores with 3 Steel	0	0

The fields in the U.S. had relatively few pellets scattered over a large area (Figure 23). The average number of lead pellets per core inside the 50% kernel range contour was 0.030. The fields in Canada (Figure 23) had nearly as many pellets as the much larger U.S. area. The resultant lead pellet per core average inside the 50% kernel range contour was 0.381. Therefore, the portions of the fields in Canada that fell within the 50% kernel range contour may pose a greater risk to waterfowl compared to areas sampled in the U.S.

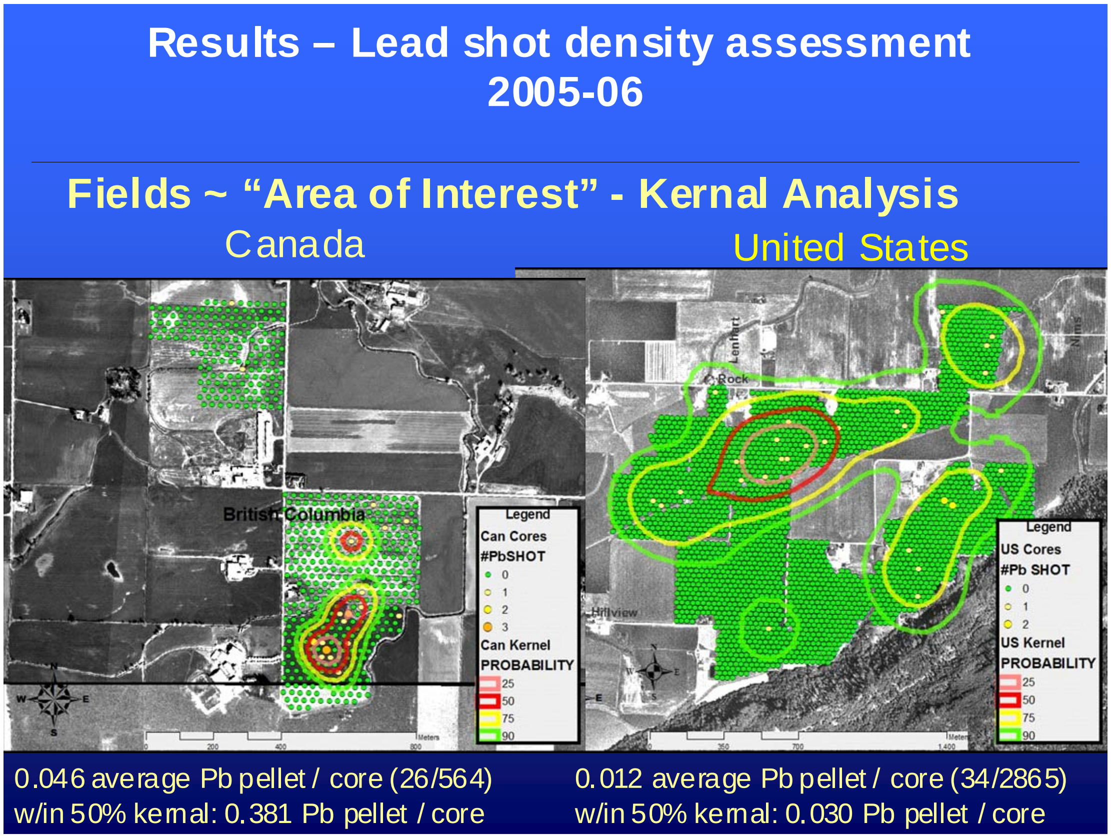


Figure 23. Results of soil coring in Canadian and U.S. forage fields.

3.8.2.2 Judson Lake

A comprehensive assessment of lead shot density on Judson Lake was undertaken in 2005 and 2006 by the University of Washington. Including cores collected on the Canadian side of Judson Lake by CWS in 2004, a total of 1,521 sediment core samples were collected (528 using 25-m and 227 using 20-m triangular grids and 766 using a 12.5-m triangular grid) from the U.S. portion of Judson Lake. An average of 0.22 lead and 0.06 steel pellets per core were recovered (Table 7).

Table 7. A breakdown of the pellets recovered from sediment core samples taken from Judson Lake.

Cores	CA Judson (20-m Grid)	U.S. Judson (25-m Grid)	U.S. Judson (12.5-m Grid)	Average
Number of Cores	227	527	766	
Pb/Core	0.0176	0.3220	0.3169	0.218
Steel/Core	0.0220	0.0436	0.1002	0.0552
# Cores with Pb & Steel	0	7	14	
# Cores with 1 Pb	4	103	111	
# Cores with 2 Pb	0	23	22	
# Cores with 3 Pb	0	3	5	
# Cores with 4 Pb	0	1	1	
# Cores with 8 Pb	0	1	0	
# Cores with 1 Steel	5	17	43	
# Cores with 2 Steel	0	3	3	
# Cores with 3 Steel	0	0	2	

The 50% contour of the adaptive kernel estimation was used to evaluate pellet densities from sampling done on the Canadian side of Judson Lake in 2004 (CWS) and the sampling completed on the U.S. side in 2006. The portion of Judson Lake in Canada had a very low pellet density (Figure 24). Within the 50% contour the lead pellets per core average was 0.028. The U.S. side of Judson Lake (25-m grid) had a higher lead pellet density (0.322 average) than any of the other swan roost sites (in our study area) that have been sampled to date (Lakemount roost site nearly as high at 0.29). Moreover, within the 50% contour, the average lead pellet per core was 0.505. Therefore, the lead shot density on the U.S. side of Judson Lake was the highest of all roosts sampled in our study area to date (but only slightly higher than the Lakemount Canadian roost).

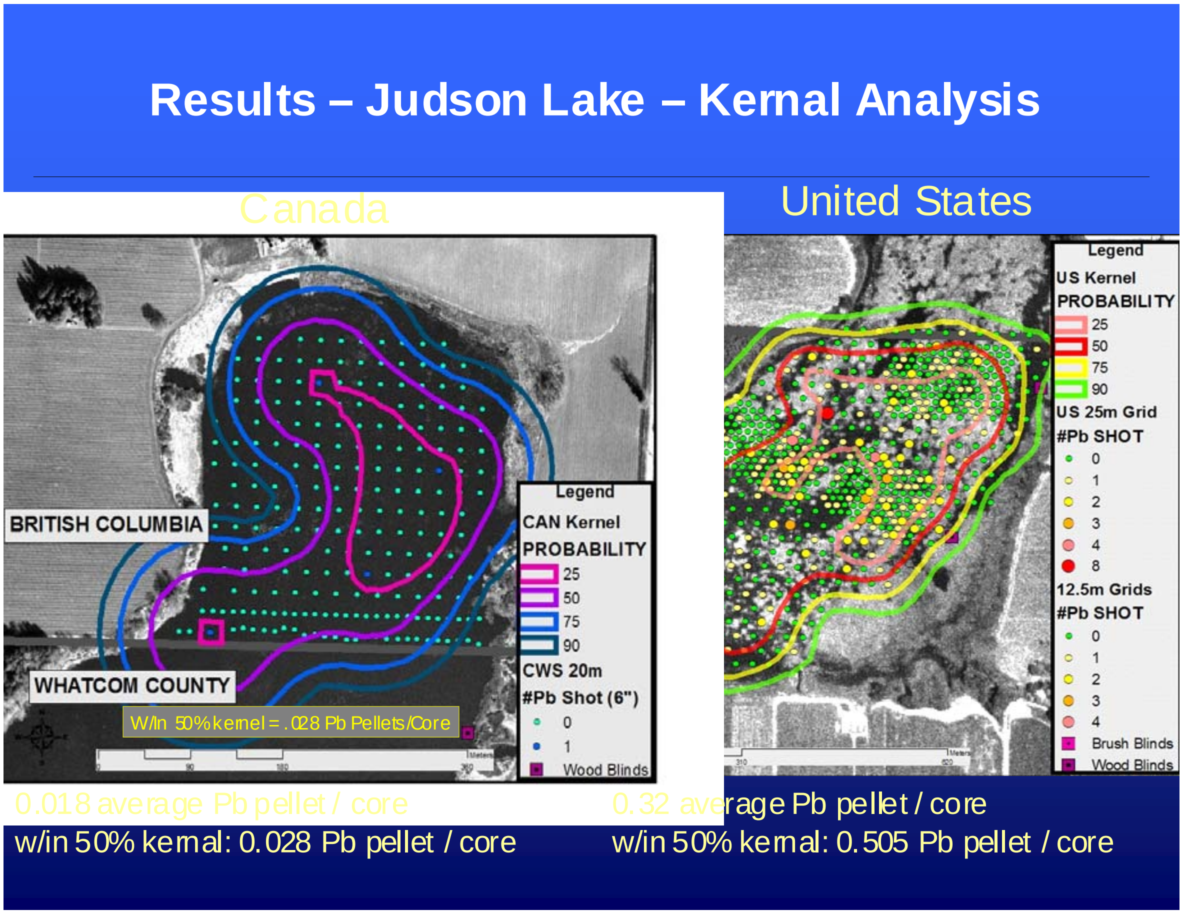


Figure 24. Results of sediment coring in Judson Lake

3.8.2.3 Agricultural fields in Clearbrook Area

The shot density assessment of corn fields in the Clearbrook area conducted in early spring 2008 determined that this area was unlikely to be a significant source of lead shot responsible for swan mortalities. The average 0.0042 lead pellets per surface core (top ~1 cm) and 0.0167 lead pellets per entire core clarified that the observed reduction in swan mortalities in 2007 and 2008 was likely from the reduction in swan use of Judson Lake, and not the Clearbrook area.

3.8.3 Shot Recovery Efficiency

Investigators were 100% successful in recovering shot from the spiked core samples both in Canada and the U.S. (2002). During 2005-2006 in the U.S. over 98% of spiked shot were recovered. During 2007-2008 in the U.S. over 98% of spiked shot were recovered.

3.8.4 Pellet Decomposition

Decomposition of pellets occurred in the two types of steel shot (Federal Premium Ultra●Shok™ and HEVI●STEEL™) during the initial month. Some of the pellets became nearly encased by rust during that initial month. However, the rate of decomposition declined during the remainder of the test. Decomposition never occurred in the bismuth shot type (No●Tox™) throughout the test.

3.8.5 Metal Detecting

A total of 232 flags were placed by RC1 and 366 flags were placed by RC2 during sweeps of the corn-field transects. RC1 and RC2 scored hits (placed a flag within the predetermined adjustment distance) on 15 (2.8%) and 27 (5.0%) of the 540 available plants, respectively. This corresponds to a total of 44 (4.1%) of the 1,080 plants available over two passes. In addition, RC1 placed 2 flags near dummy plants and RC2 placed 3.

A total of 349 flags were placed by RC1, and 259 flags were placed by RC2, during sweeps of the grass-field transects. NTS placed 82 flags during the sweep of one 100-m long segment of the grass transect.

There were no significant differences ($P > 0.05$) between the size of shot detected or the depth at which the shot was found. There was a significant difference ($P < 0.05$) with respect to the number of shot per detection (higher) in the grass-field habitat, but no significant difference ($P > 0.05$) in the corn-field.

There was no significant difference ($P > 0.05$) between the detections of RC1 or RC2 in either the corn-field or grass-field habitats. However, the number of detections by RC1 and RC2 in the grass-field habitat were significantly greater ($P < 0.05$) than the number in the corn-field. The percentage of steel plants detected by all operators was greater than that of lead plants. However, there was only a significant difference ($P < 0.05$) between the steel and lead plants detected by RC2 and NTS in the grass-field habitat.

RC1 and RC2 scored hits on 57 (10.56%) and 44 (8.15%) of the 1080 available plants, respectively. This corresponds to a total of 101 (9.4%) of the 1080 plants available over 2 passes. In addition, RC1 placed 2 flags near dummy plants and RC2 placed 1. NTS scored hits on 8 (4.19%) of the 191 plants available over the transects swept. NTS placed no flags near any dummy plants.

3.9 Experimental Management Action to Haze Judson Lake

An adaptive management approach was undertaken from October 2006 to January 2007 to test the hypothesis that Judson Lake is a source of lead shot causing swan mortalities. Hazing activities were successful in keeping trumpeter swans off of Judson Lake during the winter of 2006-2007. It appeared that there were approximately 50% fewer mortalities (n= 114) compared to average over the previous 5 years (n= 209) (Figure 25). However, this could have been due to the snow/ice cover in 2006-2007 that resulted in the majority of swans leaving the study area altogether. Population surveys showed fewer swans foraged in an agricultural area (Clearbrook) near Judson Lake. This could have been a contributing factor to the reduced mortality, if the area had a relatively high density of lead shot. (Refer to Section 3.8.2.3).

Hazing of Judson Lake from October 2007 to January 2008 resulted in a >50% decrease in mortalities (n=103) compared to the average of the 5 years previous to the hazing activity (Figure 25). During the winter of 2007-08, there were no weather events forcing swans to depart the study area. As in 2006-07, population surveys showed that fewer swans foraged in the Clearbrook area.

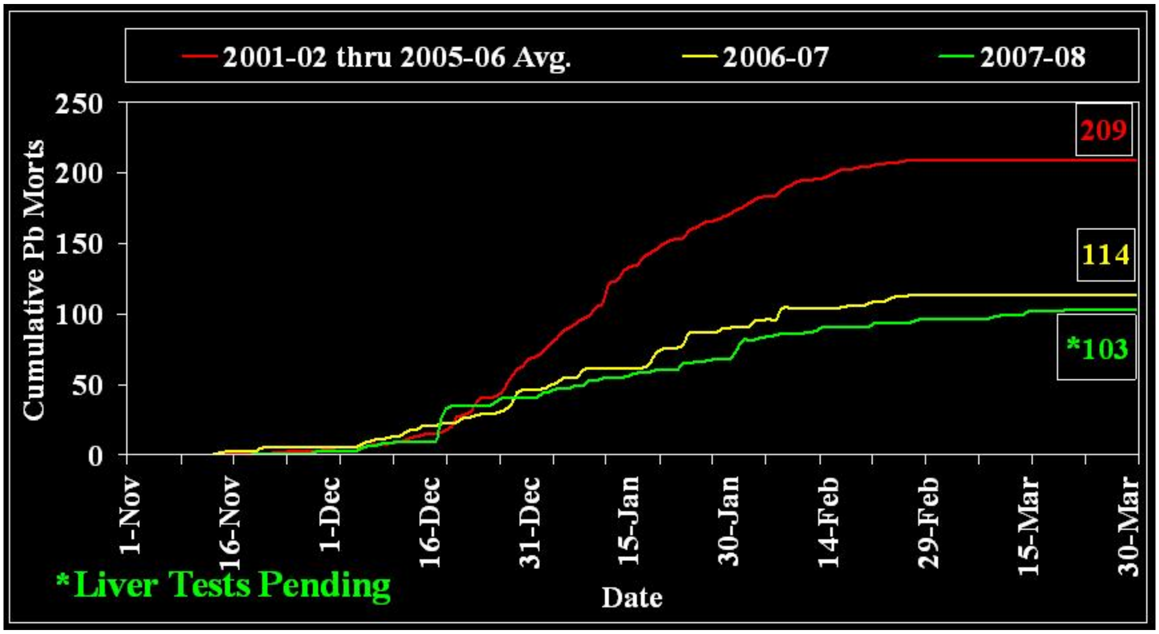


Figure 25. Cumulative lead-exposed swan mortalities.

In addition to the overall decline in lead-exposed swan mortalities following the hazing of Judson Lake, Figure 26 depicts that the lead exposures from Whatcom/Sumas becomes more comparable to the U.S. Counties of Skagit and Snohomish.

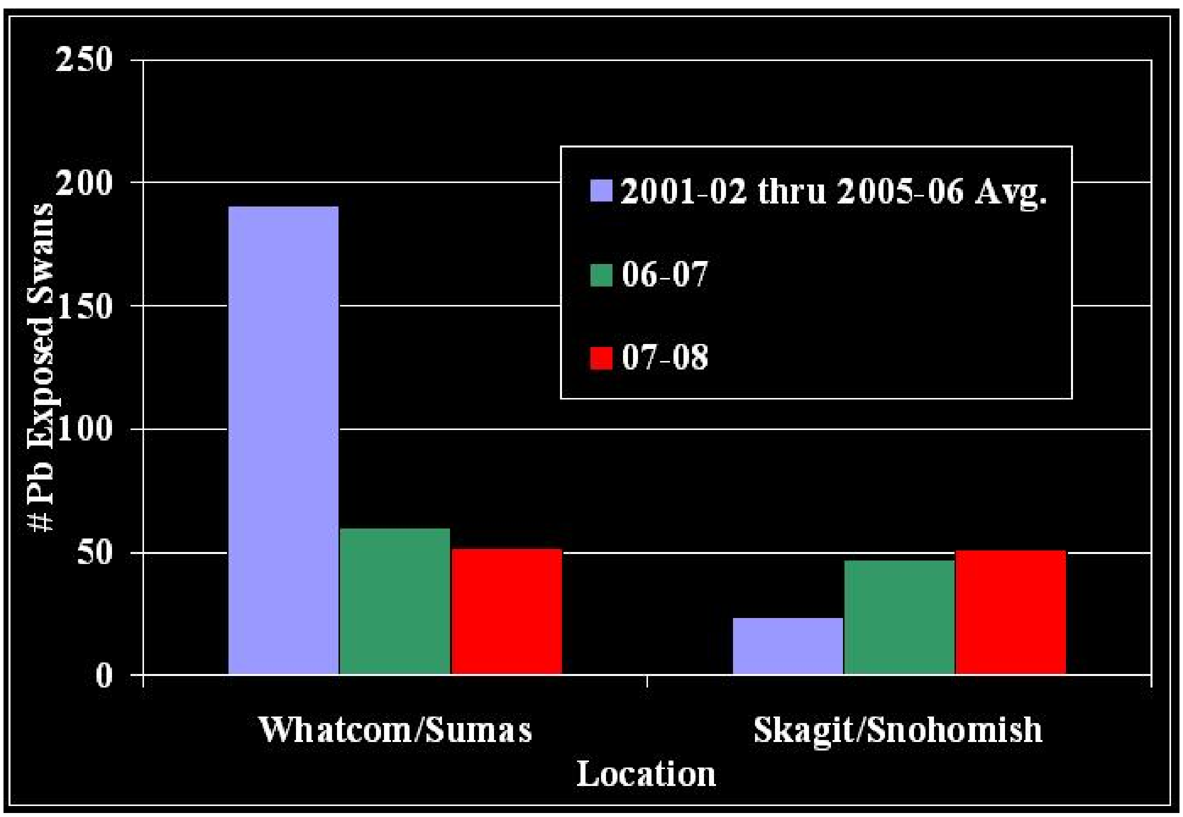


Figure 26. Lead exposed swans by location and year.

Carcasses recovered from 2001 through 2006 averaged over 20 lead pellets per gizzard (Figure 27). Most of the carcasses collected with over 100 pellets were found at Judson Lake. The dramatic reduction in number of pellets recovered from gizzards of lead poisoned swans beginning in 2006-2007 is likely due to the elimination of swan use at Judson Lake.

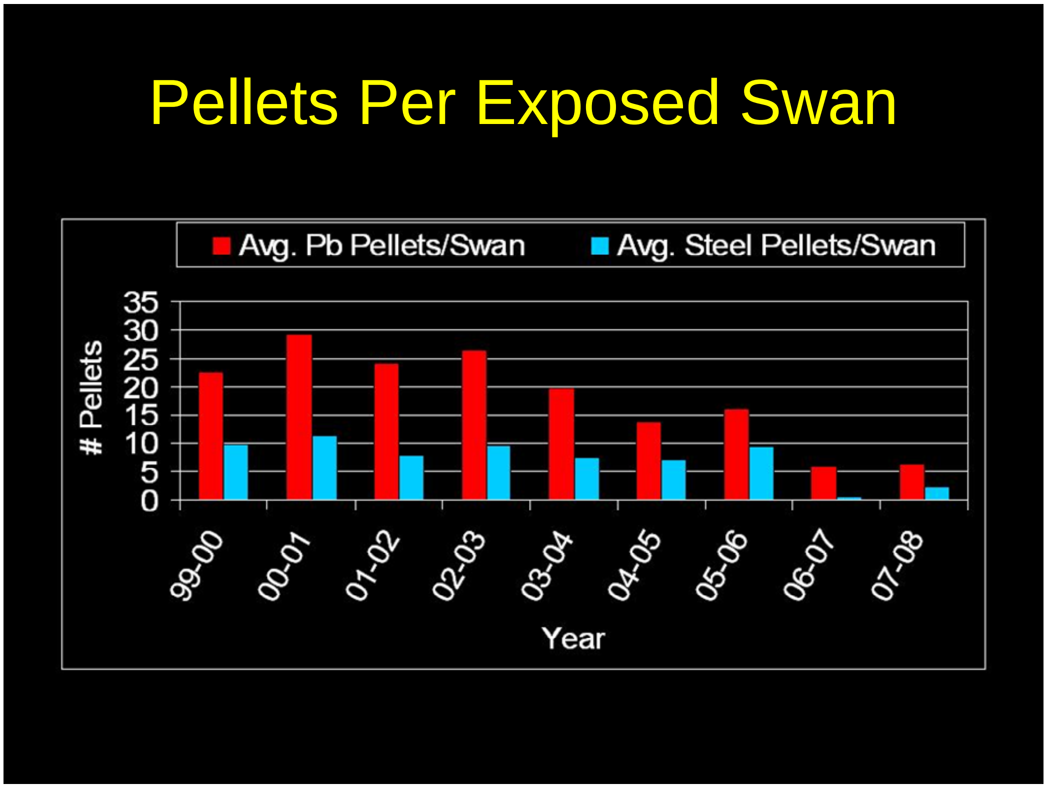


Figure 27. Average pellets per gizzard of lead poisoned swans

3.10 Bald Eagle Secondary Lead Exposure Monitoring

From the 1999-2000 winter through the 2006-07 winter, a total of 63 liver or blood samples from 63 bald eagles either sick, injured, or dead, in northwest Washington were analyzed for lead content. Two of the eagles had elevated subclinical lead exposures and ten (16%) had lethal lead exposure levels (see Table 8). Lead-exposed eagles were documented for most years; the 10 lethal lead-exposed eagles were recovered late in the spring (March/April/May). Four of the 10 lethal lead-exposed eagles were collected in Whatcom County, 2 were from Skagit County, 1was from Snohomish County, 2 were from Island County, and 1 county location was unknown. See Figure 2 for County locations**.**

From 1999 to 2007, a total of 39 injured or dead bald eagles were collected from the Upper Fraser Valley (which includes Sumas Prairie and Abbotsford but does not include the Fraser Delta) (see Table 9.). Of the 39 eagles, 19 were analyzed for lead residues, of which 2 (11%) had died of lead poisoning. Both lethal lead-exposed eagles were recovered in winter/spring.

Table 8 Bald Eagle Exposure Data in the U.S.

Date	Juv/Adult	Male/Female	Cause of Death	Liver Lead	Blood Lead	County
2-Mar-2000	Adult	Male	Power Line Strike	unknown	0.06 ppm	Skagit
26-May-2000	Adult	Male	Head trauma	unknown	0.17 ppm	Skagit
24-Mar-2001	Adult	Male	Lead-Poisoned	unknown	8.50 ppm	Whatcom
7-May-2001	unknown	Unknown	Undetermined	unknown	0.10 ppm	Skagit
19-Mar-2002	Adult	Unknown	Lead Poisoned	unknown	29 ppm	Whatcom
27-Apr-2002	Adult	Male	Lead Poisoned	unknown	8.7 ppm	Skagit
5-May-2003	Adult	Male	undetermined	BDL	unknown	Snohomish
10-Jan-2004	Adult	Male	Electrocution	BDL	unknown	Skagit
9-Feb-2004	Juvenile	Male	Head Injury	BDL	.02 ppm	Snohomish
13-Feb-2004	Adult	Unknown	Undetermined	BDL	unknown	Island
2-Mar-2004	2 Year old	Male	Power Line Strike	BDL	unknown	Whatcom
5-Mar-2004	Juvenile	Female	Power Line Strike	BDL	unknown	Whatcom
25-Mar-2004	Adult	Male	Power Line Strike	BDL	unknown	Skagit
25-Mar-2004	Adult	Male	Power Line Strike	BDL	unknown	Whatcom
25-Mar-2004	3 Year old	Male	DOA	BDL	unknown	Whatcom
8-Apr-2004	Adult	Male	Undetermined	unknown	0.65 ppm	unkown
30-Apr-2004	Unknown	Unknown	Undetermined	unknown	0.57 ppm	unknown
22-Aug-2004	HY	Female	Possible shooting	BDL	unknown	Skagit
23-Oct-2004	Adult	Female	dead on beach	BDL	unknown	Whatcom
8-Nov-2004	Adult	Male	Undetermined	BDL	unknown	unknown
29-Dec-2004	Adult	Male	Vehicle Strike	BDL	BDL	Skagit
27-Jan-2005	Adult	Female	DOA	BDL	unknown	Pierce
9-Feb-2005	Adult	Male	DOA	BDL	unknown	Whatcom
10-Feb-2005	Adult	Female	DOA	BDL	unknown	Whatcom
23-Feb-2005	Sub Adult	Male	Live/Euthanized	unknown	0.47 ppm	Skagit
25-Feb-2005	Adult	Male	Power Line Strike	BDL	unknown	Whatcom
3-Mar-2005	Adult	Female	Vehicle Strike	BDL	unknown	Snohomish
2-Mar-2005	Adult	Male	undetermined	47 ppm	unknown	Whatcom
15-Mar-2005	Adult	Female	Shooting	38.0 ppm	unknown	Snohomish
15-Mar-2005	Unknown	Female	Undetermined	BDL	unknown	Skagit
18-Mar-2005	Adult	Female	Undetermined	BDL	unknown	Whatcom
22-Mar-2005	Adult	Female	Power Line Strike	BDL	unknown	Whatcom
25-Mar-2005	Adult	Female	Undetermined	BDL	unknown	Island
26-Apr-2005	Adult	Female	DOA	BDL	unknown	Snohomish
1-May-2005	Adult	Male	Euthanized	BDL	0.05 ppm	Island
27-Jan-2006	Juvenile	Female	Undetermined	BDL	unknown	Snohomish
28-Jan-2006	Juvenile	Male	Power Line Strike	BDL	unknown	Whatcom
29-Jan-2006	Adult	Female	Power Line Strike	BDL	unknown	Whatcom
31-Jan-2006	Juvenile	Female	Power Line Strike	BDL	unknown	Whatcom
12-Feb-2006	Adult	Female	Power Line Strike	BDL	unknown	Skagit
6-Mar-2006	Adult	Male	Undetermined	unknown	0.65 ppm	Island
25-Mar-2006	Adult	Female	Electrocution	28 ppm	unknown	Island
13-Apr-2006	Adult	Male	Undetermined	34 ppm	unknown	Whatcom
1-May-2006	Adult	Female	Undetermined	34 ppm	unknown	Skagit
14-Nov-2006	Adult	Female	Powerline Strike	BDL	unknown	Skagit
17-Nov-2006	Adult	Male	Powerline Strike	1.0 ppm	unknown	unknown
25-Nov-2006	Adult	Male	Power Line Strike	BDL	unknown	Skagit
12-Dec-2006	Adult	Male	Undetermined	BDL	unknown	Island
19-Dec-2006	Adult	Male	Power Line Strike	BDL	unknown	Whatcom
23-Jan-2007	Juvenile	Female	Power Line Strike	BDL	unknown	Whatcom
27-Jan-2007	Adult	Male	Power Line Strike	BDL	unknown	Snohomish
6-Feb-2007	Adult	Female	Euthanized	BDL	unknown	Island
6-Feb-2007	Sub Adult	Female	Undetermined	BDL	unknown	Whatcom
9-Feb-2007	Adult	Female	Vehicle Strike	BDL	unknown	Island
14-Feb-2007	Adult	Female	Undetermined	BDL	unknown	Whatcom
16-Feb-2007	Adult	Female	Undetermined	BDL	unknown	Skagit
21-Feb-2007	Adult	Unknown	Live/Euthanized	unknown	BDL	Skagit
2-Mar-2007	Adult	Male	Power Line Strike	BDL	unknown	Whatcom
6-Apr-2007	Adult	Male	Undetermined	< 1 ppm	unknown	Whatcom
12-Jun-2007	Adult	Female	Undetermined	BDL	unknown	Island
*All analyses in wet weight. ** BDL = Below Detection Limit *** MDL ~1 ppm in liver and 0.01 ppm in blood ****Elevated subclinical level =>2 ppm in liver and/or between 0.20-0.59 ppm in blood. ***** Lethal exposure level = >16 ppm in liver and/or >0.60 ppm in blood.						

Table 9. Probable cause of injury or mortality of Bald Eagles collected from the Upper Fraser Valley, BC, 1999-2008.

EC-CWS #	Death Date	Age	Sex	Location	Probable Cause of Death	Pb liver wet wt	Note
L99-996	15-Jan-99	Adult	Male	Maple Ridge	Aspergillosis	NT	
L99-987	26-Apr-99	Adult	Female	Pitt Polder	Powerline strike	NT	
L03-550	8-Nov-99	Juvenile	Female	Abbotsford	Powerline strike	NT	
L00-695	31-Jan-00	Juvenile	Female	Langley	Powerline strike	<2 ppm	
L00-694	released	Adult	Male	Abbotsford	Undetermined	NT	admitted 16-Feb-00
L00-696	released	Juvenile	Male	Abbotsford	Undetermined	NT	admitted 23-Dec-00
L01-742	30-Dec-00	Adult	Unknown	Mission	Powerline strike	NT	
L03-551	22-Jan-01	Adult	Female	Hope	Trauma	NT	
L03-853	15-Feb-03	Immature	Male	Abbotsford	Powerline strike	NT	
L03-701	released	Adult	Male	Chilliwack	Undetermined	NT	admitted 5-Jun-03
L03-616	released	Adult	Male	Langley	Interspecies fighting	NT	admitted 20-Nov-03
L04-579	10-Feb-04	Adult	Male	Abbotsford	Gun shot	<2 ppm	
L04-730	6-Aug-04	Juvenile	Female	Harrison Lake	Undetermined	NT	
L05-732	released	Adult	Male	Matsqui Flats	Undetermined	NT	admitted 25-Jan05
L05-619	17-Feb-05	Adult	Male	Langley	Aspergillosis	<2 ppm	
L05-743	8-Apr-05	Juvenile	Female	Abbotsford	Vehicle strike	<2 ppm	
L05-756	20-Apr-05	Adult	Male	Mission	Powerline strike	<2 ppm	
L05-751	9-May-05	Adult	Male	Abbotsford	Powerline strike	<2 ppm	
L05-764	released	Sub-adult	Unknown	Abbotsford	Starvation	NT	admitted 13-Jul-05
L06-500	16-Jan-06	Juvenile	Unknown	Abbotsford	Powerline strike	NT	
L06-808	6-May-06	Adult	Male	Abbotsford	Pesticide poison (Carbofuran)	<2 ppm	4.6 ppm stomach
L06-508	7-Jun-06	Sub-adult	Unknown	Langley	Powerline strike	<2 ppm	
L06-817	18-Jun-06	Adult	Female	Abbotsford	Entrapment?	<2 ppm	
L06-861	released	Adult	Male	Langley	Interspecies fighting	NT	admitted 10-Dec-06
L06-858	11-Dec-06	Adult	Male	Harrison Mills	Lead poisoned	23 ppm	
L07-579	27-Nov-07	Juvenile	Unknown	Pitt Meadows	Powerline strike	<2 ppm	
L07-583	30-Dec-07	Juvenile	Male	Abbotsford	Powerline strike	<2 ppm	
L08-719	9-Jan-08	Juvenile	Male	Langley	Trauma	<2 ppm	
L08-597	25-Feb-08	Adult	Male	Aldergrove	Trauma	<2 ppm	
L08-598	26-Feb-08	Juvenile	Unknown	Abbotsford	Powerline strike	<2 ppm	
L08-781	3-Mar-08	Juvenile	Male	Deroche	Undetermined	TBA	
L08-501	5-Mar-08	Juvenile	Female	Abbotsford	Interspecies fighting	<2 ppm	
L08-742	11-Mar-08	Juvenile	Female	Chilliwack	Lead poisoned	32 ppm	
L08-743	13-Mar-08	Adult	Female	Aldergrove	Trauma	<2 ppm	
L08-756	18-Mar-08	Sub-adult	Male	Langley	Trauma	<2 ppm	
L08-775	9-Apr-08	Adult	Male	Langley	Trauma	TBA	
L08-787	12-Jun-08	Adult	Female	Abbotsford	Vehicle Strike	TBA	

NT – Not tested

4.0 Discussion

4.1 Telemetry on Swan Wintering Grounds

Through the winter of 2005-2006, a total of 64 (62 trumpeter and 2 tundra) of the marked individuals were documented as mortalities. Eighteen of those were identified as accessing lead pellets post release. Survey data for these 18 individuals were used to identify primary areas of interest as possible sources of lead pellets. These areas of interest consisted of approximately 243 ha of agricultural fields (predominantly corn with a grass cover crop) near the U.S./Canada border and Judson Lake which was used by swans as a roost throughout the winter.

The kernel home range analysis indicated that there were differences in both the field and roost site use between the marked lead exposed and the marked not lead exposed swans, when viewed as percentage of detections at various fields or roosts. The marked swans that succumbed to lead poisoning were located a greater percentage of the time in the fields east of Sumas, both north and south of the international border. These lead-poisoned birds were also located a greater percentage of the time roosting at Judson Lake.

4.2 Telemetry of Swans Migrating Back to Breeding Grounds

The transmitters provided general information on the migration of these swans and where they chose to breed. Some monitoring was conducted, however, only limited data were collected on three individuals. M86 migrated through the interior of B.C. to breed in central Alaska; M87 also migrated through the interior of B.C. and stopped in the Yukon; M89 migrated along a more coastal path and bred in Alaska. More birds would need to be monitored to gain potentially valuable information on the variety of routes that may be used by swans in the Pacific population.

4.3 Swan Surveys and Observations

Volunteer population surveys have validated our telemetry results as both marked and unmarked swans have been found using the same locations. These surveys indicate swans begin to arrive on the wintering grounds in the Pacific Northwest during the end of October or early November, usually reaching peak numbers around the middle of December. Swans wintering in agricultural areas like those along the B.C.-WA border, tend to forage in agricultural fields (predominantly corn and pasture), and roost on small lakes, ponds, or flooded fields. During most years, the study area realizes a fairly sudden increase in swan numbers (nearly 1000) during some point of the winter. There are consistently at least 500 more swans in Whatcom County than in the Sumas Prairie area of B.C.

Swans prefer to forage in agricultural fields during the day but some birds have been observed foraging at roost sites. It is not known what percentage of forage intake consists of material from fields and what percentage is collected from night roosts. A roost site foraging observation study conducted in January-March 2002 found that although loafing, swimming, alert, and sleeping activities constituted the bulk of observed behaviors on select roost sites (Hatzic Lake, Judson Lake, Lakemount, Nicomen Slough), the incidence of foraging and the number of swans foraging on night roosts indicated that feeding at roost sites was not an uncommon behavior.

4.4 Population Monitoring

Annual, one-day counts performed by WDFW indicate the population in Whatcom County is made up of approximately 75% trumpeter and 25% tundra swans and is growing in spite of the lead shot ingestion mortalities. However, it is unclear if Whatcom County/Sumas Prairie swans are experiencing an intrinsic population increase or if birds are immigrating into the area from other more densely populated wintering areas such as the Fraser Delta and Skagit County.

4.4.1 Estimating Population Level Effects

Environment Canada (Dr. Sean Boyd) estimated population level effects of lead shot mortalities on the winter (Southwest -B.C. and Northwest-WA) and summer Pacific coastal trumpeter swan population by using: 1) historical count data to estimate population growth rates from the 1960s/70s to 1999/2000 and extrapolating numbers to the present time, and; 2) a simple demographic model that estimates the cumulative number of potential recruits lost over the period 1999-2006.

Approximately 2,100 swan carcasses were collected during the winters from 1999-2006 in the study area. This is a minimum number as not all carcasses would have been found, due to the large size of the area, or would have been removed by scavengers before discovery. Of these 2,100 carcasses, a minimum of 1895 were trumpeter swans and the majority of these died from lead poisoning. Therefore, trumpeter swan mortalities average 270 per year or roughly 1.1% and 1.5% of the Pacific fall population estimated in 2000 and 2005, respectively. At first glance, this would not appear to have a significant population-level effect. However, these numbers do not take into account the full number of birds lost or the number of potential recruits not realized during the years 1999-2006.

Although the SW-B.C. and NW-WA winter and the summer Pacific coastal trumpeter swan populations have been growing exponentially, the most recent counts for each population are off-set from, and lower than, the trend line describing the previous years. Environment Canada converted raw numbers to natural logs and applied a linear model to the data for the years up to 1999, the first year the investigation began into the swan mortality events. The amount of variation explained by the model was very high (R^2 = 99%) suggesting a good fit to the data. Using the model, and assuming that the same growth rate occurred after 1999, the predicted population in 2006 should have been ~17,790 birds. However, the actual number of trumpeter swans counted was ~ 13,860 birds or ~ 4,000 less than the predicted number (Figure 28). The same procedure was repeated for the Pacific summer trumpeter swan population data set for the years up to 2000 (1 year after lead poisoning began on the winter grounds; these counts are done only every 5 years). The predicted population in 2005 should have been ~28,970 birds or ~4,000 more than the actual number (24,900) (Figure 29). This result is similar to that determined for the B.C.-WA winter population.

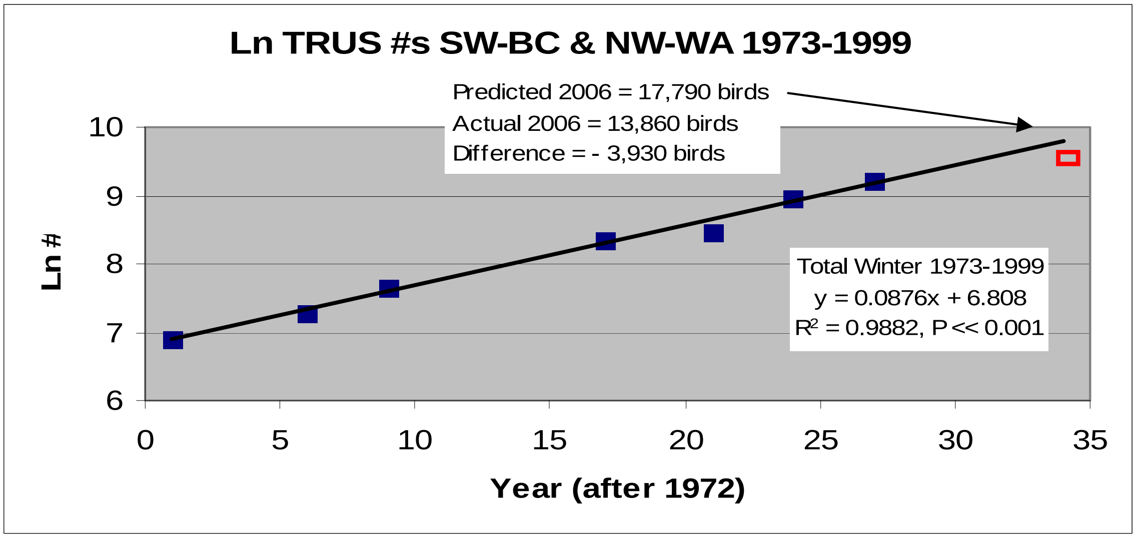


Figure 28. Growth trends and estimated total loss of trumpeter swans from B.C.-WA wintering population.

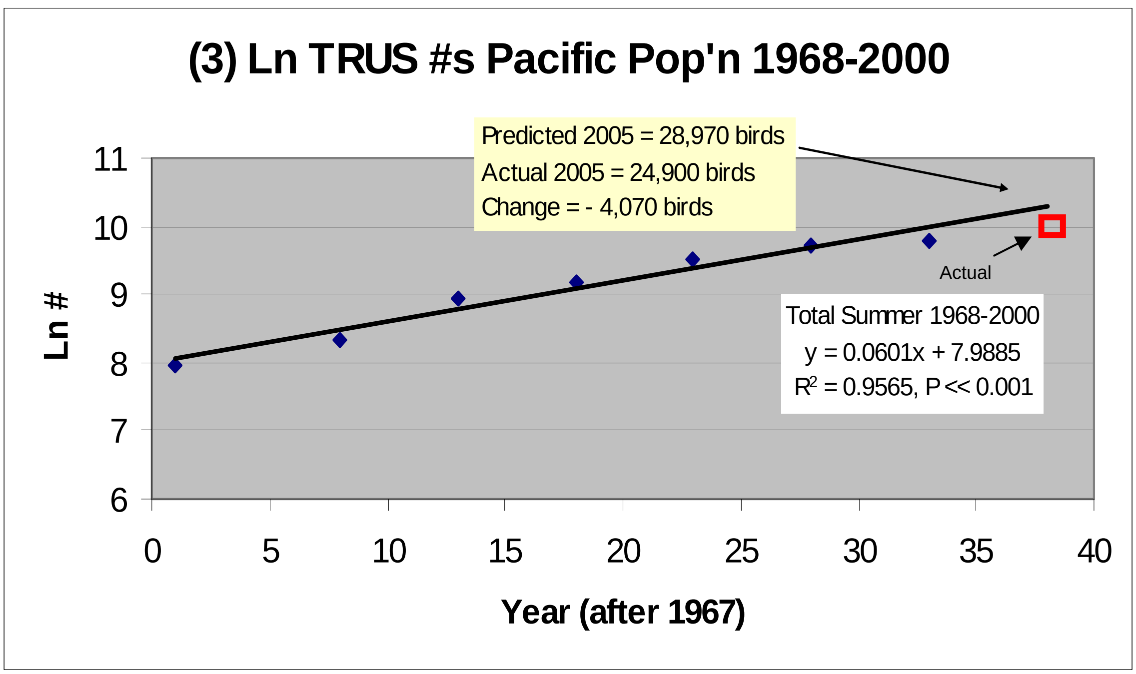


Figure 29. Growth trend and estimated total loss of trumpeter swans from the Pacific summer population.

In summary, by extrapolating historic growth rates to the present time or by using a simple demographic model, approximately 4,000 (actual and potential) trumpeter swans were estimated to have been lost from the Pacific population from 1999 to 2006. This equates to ~14% loss from the potential 2005 Pacific breeding population and ~23% loss from the potential 2006 SW-B.C. and NW-WA winter population. Despite these losses, both populations are increasing exponentially, albeit at lower rates. The growth rate of the Pacific trumpeter swan breeding population declined slightly (by 0.23% per year), from 6.01% to 5.78% per year (comparing data from 1968-2000 and 1968-2005, respectively) (Boyd 2006). The growth rate of the study area winter population declined by 1.77% per year, from 8.76% to 6.99% (comparing data from 1973-1999 and 1973-2006, respectively). (Boyd, 2006).

4.5 Carcass Recovery

Results indicate that most swans (~80%) arrive on the wintering grounds with low blood lead levels; mortalities increase sharply about a month after swans arrive (mid-December), peak around the beginning of the year, and decline again sharply in February. These results suggest that swans are lead-exposed after ingesting lead shot in their wintering area.

Trumpeter swan and other waterfowl mortality rates in northwest Washington are likely to be considerably higher than the number of carcasses collected by the monitoring program because of the difficulties associated with recovering all carcasses. Large, localized mortality events of hundreds and thousands of waterfowl have been documented in the U.S. since the late 1800s. However, most losses of waterfowl to lead poisoning go undetected as sick birds often seek dense cover and die there or are consumed by predators (Bellrose 1959). Swan carcasses may be more easily found than other avian species as they are large white birds which are highly visible on the landscape and they are often found at discrete roost sites rather than scattered throughout their entire range. However, carcasses are still difficult to see among the dense thick reeds and they can be quickly scavenged by predators. Therefore, the actual rate of acute swan mortalities is unknown. We have documented lead poisoning in other waterfowl species (Canada Geese) which use the same fields and roost areas within our study area. The extent of lead exposure of these species is also unclear.

The majority of swan carcasses were recovered from roost sites. Although swans usually die at a roost site, there is a considerable amount of time (days to weeks) between ingestion of lead shot and death. The individual becomes progressively weaker from the effects of lead poisoning and seeks the protection of a roost site. One possible scenario is that the swans ingest the shot while foraging or obtaining grit on agricultural fields during the day and then succumb to the effects of lead at their roost site. Another hypothesis is that the swans ingest shot while foraging or obtaining grit at their roost sites, where they become exposed to lead and die on site.

4.6 Post-Mortem Examinations

The majority (~70%) of all examined carcasses were determined to have been lead exposed. Over 92% of all mortalities have been trumpeter swans. The proportion of lead-exposed trumpeter swans and tundra swans is roughly proportional to their mix in local wintering flocks in our study area (mortalities from 1999-2006 is ~92% trumpeters; ~3% tundras, ~5% unknown).

This NW-WA and SW-B.C. die-off is affecting breeding age adult swans, as well as sub-adults. The potential chronic effects to breeding trumpeter swans that may have been exposed to the lead shot contamination, but were healthy enough to migrate to the breeding grounds, are unknown. We have tentatively documented lead poisoning of a trumpeter swan at a spring migration staging area (Bella Bella B.C.).

There is evidence that waterfowl in general may succumb to lead poisoning 21 days after ingesting as few as 1 or 2 pellets. The exact timeline with respect to wild swans with variable doses and states of body condition is unknown. In addition, it is unknown if lead absorption rates may differ when swans are foraging on aquatic vegetation in their northern summer range as opposed to feeding on a predominantly corn diet soon after arriving on the wintering grounds. For this investigation, we assume a conservative 28-day exposure window.

Lead shot can be retained as grit in the gizzards of birds that ingest them, where enzymes and the grinding action of the gizzard act to breakdown shot and make it available for absorption in the digestive tract. The released lead is absorbed, resulting in weakened birds whose reproductive abilities are reduced and that may starve or fall prey to predators (Clemens *et al*. 1975). As noted previously, absorbed lead causes a variety of effects including damage to the nervous system, muscular paralysis, inhibition of heme synthesis, damage to kidneys and liver, and may ultimately lead to death (Mudge 1983). In wildlife, acute lead poisoning (where exposure to lead occurs at relatively high levels) can be a quick, direct cause of mortality (USFWS 1986).

The toxicity of lead shot to birds is broadly predictable but is also highly variable among individuals of a given species. This variability results, partially or entirely, from a combination of: (1) chance events associated with the retention of lead shot in the digestive system; (2) species-specific factors that affect the dose actually absorbed from a shot pellet; (3) components in the diet that may affect lead dissolution and absorption; and (4) environmental conditions to which the bird must respond (Kendall *et al.* 1996).

Diet can have a pronounced effect on the toxicity of ingested lead shot. In particular, high levels of protein and calcium have been shown to reduce lead toxicity, although the exact mechanism for each is not known (Sanderson 1986). More generally, diets composed of whole or cracked cereal grains, particularly corn, enhance the toxicity of lead shot compared to more balanced, nutritionally complete diets (Kendall *et al.*1996).

Swans may consume up to 9 kg of aquatic vegetation in a 24-hour period (James 2000). In our study, lead poisoned swans had proportionately little vegetation compared to grit in their gizzards. The relatively delicate nature of aquatic vegetation could allow for it to be ground in the gizzard and quickly become unidentifiable. However, more likely, there was a lag between the shot ingestion and mortality during which the swan became progressively ill and unable to forage or digest food properly.

Environmental factors other than diet also must be considered when evaluating the toxic effects of ingested lead shot. Studies of birds orally administered lead and then exposed to warm versus cold environmental temperatures have demonstrated a greater susceptibility and mortality among those birds exposed to cold (Buerger *et al*. 1986). There may be additional implicating factors for birds just arriving from their winter migration.

There was a dramatic reduction in number of steel pellets recovered from gizzards of lead poisoned swans in 2006-07 and 2007-08 compare to 2002 to 2005 (Figure 27). The change in lead/steel ratio may be due to elimination of Judson Lake swan use.

4.7 Land Use Investigation

The absence of documented swan mortalities between 1991 and 1999 suggested land use activities in the area, specifically crop rotations, may play a role in exposure of swans to lead shot. Analysis of agricultural practices has the potential to shed light on this phenomenon. In this study area, swans forage predominantly in corn, potato, and grass fields, but do not use berry crops. The lifespan of a raspberry crop, for example, may fit the timeline associated with the decrease in mortalities. Identification of fields converted from corn/grass to other crops during this time may explain the lapse in swan mortality from 1992 through 1998.

Aerial photographs available for the timeframe in question were not adequate to identify fields converted from corn/grass to other crops. Satellite photographs have been obtained and land use analyses are ongoing.

4.8 Lead Shot Density Assessment

4.8.1 Core Sampling

Telemetry and mortality data have identified areas of interest as possible sources of lead shot contributing to the mortality of swans. Lead shot density assessments (soil/sediment core sampling) have indicated lead pellets are present, in varying densities, at multiple locations within these areas of interest. Shot was recovered from throughout the cores (soil cores to 6 inches depth; sediment cores to 12 inches depth) suggesting deposition from historic and also possibly current hunting and shooting use. Shot sizes recovered from fields and roosts reflected all types of hunting (waterfowl, upland game bird, trap, and recreational shooting) as possible contributing sources.

4.8.1.1 Soil Cores

The results of the soil sampling effort indicate the lead pellet densities within the U.S. portion of the focus area may be too low to be a point source contributing to the considerable swan mortality events. The portions of the fields in Canada that fall within the 50% kernel range contour may pose a greater risk to waterfowl than U.S. fields (Figure 23). A small portion of one field (within our 50% contour) was sampled by EC-CWS (using a fan sampling pattern) in 2003. The fan pattern was located adjacent to pit blinds that were dug into the bank of a ditch dissecting the field. That sampling effort collected 30 samples and recovered 24 lead pellets (0.8 lead pellets/core). During sampling in 2000-05, little evidence of hunting and no pit blinds were noticed in the Canadian fields. Presumably, the higher pellet density observed during the earlier sampling effort had been tilled further down into the soil column, or dispersed through the field, over subsequent years.

4.8.1.2 Sediment Cores

The density of lead shot at Judson Lake (0.32 average Pb pellets/core) is higher than any of the other sampled permanent roost sites (Lakemount nearly as high at 0.29 average Pb pellets/core). In addition, particular portions of Judson Lake appear to have much higher lead shot densities than the lake as a whole, possibly even approaching densities in some fields. The relevance of these different lead shot densities is unclear as the gritting behaviour of swans at roost sites compared to forage fields is poorly understood. However, during processing of sediment samples collected at Judson Lake, lead pellets were frequently discovered entangled in the root mats of yellow pond lily (*Nuphar polysepala*), a known food source for swans. The sediments at Judson Lake are much less dense and possibly more easily displaced by swans than the high clay content soils in the fields.

The results of the sediment sampling efforts at Judson Lake indicate lead pellet densities (0.322 average Pb pellets/core) on the U.S. side are nearly 18 times higher than on the Canadian portion (0.018 average Pb pellets/core). Waterfowl hunting has not been allowed on the Canadian portion for many years, but that portion of the lake was heavily hunted between 1950 and 1970. The U.S. side of the lake was heavily hunted in past decades, as well as in recent years. As lead pellets may remain in the environment for more than 100 years (Kendall et al. 1996) and the use of lead shot for waterfowl hunting has been banned in the U.S. and Sumas Prairie of B.C. since the early 1990s, we assume the majority of the lead pellets present were deposited prior to that time. The division of lead pellet densities along the international border may be a result of (landowner) hunting restrictions on the Canadian side being instituted much earlier compared to U.S. landowners and possibly lower total hunting pressure in Canada compared to U.S. portions of the lake.

The lead pellet per core average (0.32 Pb pellets/core) on the U.S. side of Judson Lake is nearly 8 times higher than that of the steel pellet average (0.04 steel pellets/core). One reason for this may be that the steel pellets deteriorate in the environment very quickly. More investigation is needed to verify or discount this hypothesis. It is also possible that the frequency of hunting was much greater at Judson Lake prior to the ban on lead shot for waterfowl hunting. Another possible explanation is hunter noncompliance with current regulations.

Densities of 0.7 lead shot per m^2 have been reported as sufficient to cause mortalities in Canada Geese in Colorado (Szymczak and Adrian 1978). Densities of 16,000 lead shot per ha (1.6 lead shot per m^2; Kingsford et al 1989) have resulted in the ingestion of shot by a relatively low (1.5%) number of ducks collected from a lake in Australia. The density of lead shot on the U.S. side of Judson Lake averages 0.32 pellets per core; a crude extrapolation estimate equates this density to 37 lead shot per m^2 in the upper 6 inches of sediment (123.4 cores possible per m2 multiplied by the average of 0.3 pellets per core). This extrapolates to as many as 370,000 pellets per ha. Inside the 50% kernel range contour the density was 0.505 pellets per core. Inside the 25% contour the density was nearly 0.7 pellets per core. It is likely that portions of Judson Lake contain sufficient density to be a major source of lead pellets for some, if not many, of the poisoned swans recovered over the past few years.

4.8.2 Shot Recovery Efficiency

In 2005-06, U.S. investigators processed over 3,000 cores collected from fields and roosts. During that time, it was necessary to hire additional staff to ensure examination of the samples was completed in a short time span. Although shot recovery was lower in the very early stage of this investigation, the staff quickly gained experience and their efficiency improved prior to the examination of the majority of the cores (overall efficiency = 98%).

4.8.3 Pellet Decomposition

Decomposition of pellets during the initial stages of the investigation is significant enough to warrant re-examination of grit retained from the soil/sediment sampling efforts. It is possible that steel pellets remain in the grit samples and are eroded enough to not appear as pellets during visual examination. Ten percent of grit samples collected during 2005-06 were randomly selected and scanned with a magnet to check for pellets fragments that may be present. No pellet fragments were found.

4.8.4 Metal Detecting

The lead shot plants detected were of all shot sizes, shot numbers and depths. Larger numbers of pellets were detected more readily in the grass-field habitat, but the depth of these plants tended to be random. It is unclear at this time why the detectors were more successful in the grass than the corn fields. One may have expected to achieve less success in the grass field due to the length and thickness of the grass.

None of the scores by the detector operators were high enough to warrant use of metal detectors as a means of locating pellets in groups $\geq$2.54 cm below the surface. The best score detected less than 11% of the available plants. In addition, the greatest numbers of detections were of steel pellets rather than lead.

It is possible that ground mineralization in the specific area of the pilot study may have hindered the ability of the detectors to locate the majority of available pellets. The weather at the time of the study; approximately 4.5 $^{\circ}$C, rain and 30–60 kph winds may not have affected the machines, but likely hindered the efforts of the operators. The detector was not actually at ground level in the grass field due to the grass height, effectively increasing the depth of the shot plants. The corn stubble obstructed the swing of the detector in the corn field. As these machines require constant motion to function properly, this may have lowered their effectiveness in the corn field. In addition, the targets were recently planted. In the experience of the detector operators, "targets that have been in the ground for longer period of time leech into the ground and set up a more distinct magnetic field." These magnetic fields may increase detection of the target.

4.9 Experimental Management Action to Haze Judson Lake

In conjunction with the Judson Lake hazing effort, population and telemetry surveys were conducted (TTSS & EC-CWS) to document areas used by swans throughout the winter. It was essential to the experiment that swans excluded from using Judson Lake continued to forage in fields and roost in alternate areas within the area of interest. This allowed for the inference to Judson Lake as a lead pellet source, should swan mortalities significantly decline over the winter (in relation to the previous 5 years). If swans excluded from Judson Lake avoided using the surrounding area as well, the source(s) underlying the mortality would have been difficult to ascertain.

There are alternate swan roost sites (Laxton Lake, Lakemount, Wiser Lake.) near Judson Lake that also offer easy access to the forage fields within the area of interest. It appears that the availability of alternate roost sites, combined with the preference of the swans to feed in the surrounding area, allowed the swans hazed from Judson Lake to continue using areas of interest during at least parts of the winter.

In 2005-06, hazing activities to keep swans off the lake from their arrival in early November through January, coincided with at least, and likely greater than, 50% reduction in lead-caused swan mortalities when compared to the previous 5-year average (2001 to 2006). Interpretation of these data was complicated by both early flooding, which potentially shifted swan habitat use within the study area, and heavy snow storms which forced swans out of the study area during the window of exposure. Hazing, therefore, was repeated in 2007-08 and this again resulted in at least a, and likely greater than, 50% reduction in lead-caused swan mortalities.

Population surveys conducted in 2006-07 and 2007-08 showed that fewer swans foraged in an agricultural area of particular interest to the investigative team (Clearbrook). It was possible that some of the decrease in lead-caused mortalities observed in those years may have been related to the decreased use of this area. However, core sampling conducted in 2007-08 determined that the area was unlikely to be a significant source of lead shot.

In 2006-07 and 2007-08, we observed a higher number of lead-related swan mortalities on roost lakes further to the south, in Skagit and Snohomish Counties of Washington State, compared to past years (annual average, 1999-2006: 19 swans; annual average, 2006-2008: 49 swans). It is possible that some of the increase in lead-related swan mortalities in the Skagit and Snohomish Counties may be attributable to increasing swan populations in those counties.

Because mortalities have continued to occur during experimental hazing, we conclude that Judson Lake is a major contributor to the lead-related swan mortality but it is not the only source of lead shot. It is apparent however, that swans should be temporarily discouraged from using Judson Lake until a more permanent solution can be found. Project partners are currently working on solution to reduce lead exposure in swans using Judson Lake.

4.10 Bald Eagle Secondary Lead Exposure Monitoring

Birds of prey and scavengers can succumb to lead poisoning after ingesting lead shot embedded in the tissues of wounded birds or in the digestive tracts of birds that consumed lead shot; a process called secondary poisoning (Scheuhammer and Norris 1995). Lead-poisoned waterfowl tend to seek seclusion and often die in areas of heavy cover; these carcasses are rapidly removed by predators and scavengers, and may result in secondary lead poisoning, especially among raptors such as the bald eagle (Feierabend and Myers 1984; Reichel *et al*. 1984). The highest incidences of lead shot mortality in raptors is reported for bald eagles (Scheuhammer and Norris 1995, Kramer and Redig 1997, Wayland et al 2003).

Between November and March, large numbers of bald eagles arrive annually in Sumas Prairie, and Whatcom and Skagit Counties. These are very popular bald eagle viewing areas which have been promoted by the State of Washington and The Nature Conservancy as one of the highest wintering concentrations in the contiguous U.S. Unfortunately, the highest mortality rates for trumpeter swans, and possibly other waterfowl, occur from mid-December to mid-January, correlating with the maximum numbers of wintering eagles. All reported lead-exposed eagles occurred during the winter or spring (December-May) confirming possibility of secondary poisoning.

Approximately 19% of the bald eagles tested from northwest Washington and 11% from southwest B.C. had at least subclinical exposure to lead. Data from Northwestern Washington eagles reveal excessive blood lead concentration levels in over 57% of eagles sampled (8 of 14).

A dead bald eagle from Whatcom County collected in March 2001 had the highest blood lead concentration (8.5 ppm) ever measured by the Analytical Sciences Laboratory at the University of Idaho Holm Research Center, that number was greatly exceeded a year later with another eagle from Whatcom County (refer to Table 8).

Pattee et. al. 1981 reported up to 70% of eagle castings contained lead pellets, suggesting that lead exposure is limited by the regurgitation mechanisms that evacuates shot with other indigestible materials (Pattee, *et a.l* 1981). Further investigation of the extent of lead exposure in predatory birds is warranted, especially as during the majority of this study, the bald eagle was listed as federally threatened and remains listed as threatened in the State of Washington.

4.11 Project Summary

Through this investigation, the partnership effort has determined that Judson Lake (a border lake serving as a major swan roost site) is a major source, though not the only source, for swan poisoning from ingestion of lead shot in this wintering area.

- Necropsies have confirmed that the majority of swans have died from lead poisoning through ingestion of lead shot.
- Blood samples from swans trapped in the wintering area strongly indicate that the swans are picking up the lethal doses of lead shot in the local wintering area.
- Telemetry and population surveys narrowed the area of interest by more than 90% (from 100,000 hectares to less than 10,000 hectares).
- Lead shot density assessments from soil and sediment core sampling indicated that lead pellets are present, in varying densities, at multiple locations within the area of interest. Lead shot at Judson Lake was higher than any other sampled permanent roost site.
- Because Judson Lake is a high swan use area and it has a relatively high density of lead shot, experimental management was conducted to prevent swans from using Judson Lake during the 2006-07 and 2007-08 winters, reducing the overall morality rate by more than 50%.
- Population surveys have determined that trumpeter swan populations are increasing despite these mortality events, although likely at a lower rate.
- The next phase of this project will be to prevent swans from continued exposure at Judson Lake through the development of interim and long-term strategies to make the lead there inaccessible to swans.

5.0 Management Recommendations

Judson Lake was determined by this investigation to be a major source of lead shot. Therefore, it should either be remediated or swan use of the lake should be precluded as a means to protect wintering swans and other birds managed under the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Canada Migratory Birds Convention Act.

The use of lead shot for waterfowl hunting has been banned in Whatcom County, Washington, U.S. since 1989 and in the Sumas Prairie, B.C. since 1992, although lead shot continues to be permitted for upland game bird hunting and trap and other target shooting. It is unclear if swans in this investigation are ingesting spent lead shot pellets from historical waterfowl hunting, non-compliance of current waterfowl hunting, upland game bird hunting, or trap and recreational shooting. Regardless, there are benefits to reducing the current deposition of persistent and toxic lead shot from hunting and sport shooting and replacing them with non-toxic alternatives.

Over the last decade, numerous regulatory steps were enacted to reduce the deposition of lead in the environment (e.g., restricting the utilization of leaded fuels, reducing the allowed lead emissions, restrictions of lead-based products, and banning the use of lead shot for the hunting of waterfowl. However, migratory and resident birds protected under a number of existing laws are still under increasing threat from a variety of anthropogenic stressors. Considerations of cost-benefit issues to identify economic efficiencies while seeking to reduce ecological risks associated with lead shot in the environment should be pursued.

It appears possible that failure to address the risks from lead shot associated with upland hunting and target shooting could result in later regulatory action, placing significant cost burdens on landowners, states, and government (Kendall *et al*. 1996). In Canada, a regulatory approach could include restrictions on the import, manufacture, and sale of lead shot and bullets using the Canadian Environmental Protection Act.

One approach to address the current risks of spent lead shot is to engage potentially effected parties in devising solutions (regulatory and/or non regulatory) to reduce or eliminate the risks associated with lead shot. It may be beneficial to bring all stakeholders (hunters, environmentalists, firearm and munitions manufacturers, state and Federal wildlife agencies) together to design compatible solutions that sustain healthy avian populations. A good strategy may be to begin in key local areas of interest, such as the study area, to increase success of achieving target goals.

Please see Appendix A for a letter dated July 29, 2008 from the Wildlife Society addressed to the USFWS Region 1 Director for their recommendations for future research and possible paths for new policies and/or regulations regarding the use of lead ammunition and fishing tackle and its potential exposure to health and biota in various ecosystems.

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Appendix A.

The Wildlife Society letter to the USFWS regarding recommendations for research and policies on lead shot and fishing tackle.

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X NWRS
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29 July 2008

Mr. Ren Lohoefener
U.S. Fish and Wildlife Service
911 NE 11th Avenue
Portland, OR 97232-4181

Dear Mr. Lohoefener:

The Wildlife Society just completed its latest technical review, *Sources and Implications of Lead-Based Ammunition and Fishing Tackle on Natural Resources*, which is now available for purchase at www.wildlife.org. I've included herein a summary of the report

Topics covered in this report include the chemical properties of lead, sources and estimated quantities of lead originating from hunting, shooting and fishing, as well as the pathways of exposure and the effects of lead on plants, animals, and humans. Current regulations on lead ammunition and fishing tackle, along with alternative materials, are also evaluated.

The review also contains suggestions for future research and possible paths for new policies and/or regulations. Those of highest priority include:

- Broad scale monitoring on the incidence of lead poisoning in wildlife in countries where the extent of the problem is poorly documented or unknown;
- Data on the prevalence of lead poisoning related to fishing tackle in reptiles and aquatic birds;
- Information on the weathering, dissolution, and long-term fate of lead fragments, and bioavailability of lead in various ecosystems;
- The hazards of spent ammunition and mobilized lead to wildlife at or near shooting ranges; and
- Evaluation of regulations restricting the use of lead ammunition and fishing tackle on exposure and health of biota in various ecosystems.

The full technical review, *Sources and Implications of Lead-Based Ammunition and Fishing Tackle on Natural Resources*, is available for purchase at www.wildlife.org. If you have any questions about the report, please don't hesitate to get in touch.

Sincerely,

Laura M Bies

Laura Bies, Associate Director of Government Affairs

Excellence in Wildlife Stewardship Through Science and Education