SPECIAL PROJECT REPORT **FY09-MEFO-2-EC**

Maine Field Office – Ecological Services **March 2011**

Screening-Level Assessment of Organochlorine Compounds in Raccoons (*Procyon lotor*) at Aroostook National Wildlife Refuge

Fish and Wildlife Service

U.S. Department of the Interior

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Suggested citation: Mierzykowski S.E., D. Washington, F. Corey and D. Macek. 2011. Screening-Level Assessment of Organochlorine Compounds in Raccoons (*Procyon lotor*) at Aroostook National Wildlife Refuge. USFWS. Spec. Proj. Rep. FY09-MEFO-2-EC. Maine Field Office. Orono, ME. 31 pp.

U.S. FISH AND WILDLIFE SERVICE
MAINE FIELD OFFICE
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Screening-Level Assessment of Organochlorine Compounds in Raccoons (*Procyon lotor*) at Aroostook National Wildlife Refuge

DEQ Project ID: 200750001.1
Region 5 ID: 1261-5N43
(Filename: 1261-5N43 Final Report_2011.pdf)

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March 2011

Executive Summary

The Aroostook National Wildlife Refuge (ARONWR) was established in 1998 on the site of the former Loring Air Force Base (LAFB), a cold-war era Strategic Air Command facility. Throughout the course of its 40+ year operational history, Department of Defense activities at LAFB resulted in widespread contamination of soil, sediment, surface water, groundwater and biotic resources of the former base and present-day wildlife refuge. In addition to the release of large volumes of petroleum products, cleaning solvents, heavy metals, and other toxic chemicals to the environment; leaking underground transformers contributed to a chronic release of polychlorinated biphenyls (PCBs) that contaminated sediments along several miles of the East Branch of Greenlaw Brook. Air Force remedial activities included a massive PCB-contaminated sediment removal project in Greenlaw Brook that resulted in the excavation and disposal of over 100,000 cubic yards of surficial sediments and floodplain soils. Subsequent sediment sampling by the Aroostook Band of Micmacs, however, located several pockets of un-remediated, contaminated sediments in Greenlaw Brook. Moreover, long-term contaminant monitoring of brook trout in Greenlaw Brook indicates only modest declines in body burdens of organochlorines since the large-scale sediment remediation.

Greenlaw Brook divides refuge and tribal lands. The USFWS and the Micmac tribe both had concerns regarding residual contaminant uptake by resident wildlife using the brook, and the tribe was also concerned about sustenance consumption of wildlife. In this screening level contaminant assessment, the raccoon was selected for study. Raccoons are an important animal to the Micmacs and to other Native American tribes providing fur and food. Fat from the animal is also used by tribes for medicinal purposes. We enlisted local trappers to collect raccoons from the Greenlaw Brook riparian area. Adipose (fat) and liver tissue were extracted to determine if raccoons are accumulating PCBs and other organochlorine pesticides. For comparative purposes, trappers also collected raccoons from off-refuge reference sites. Between 2006 and 2007, nine raccoons were collected and analyzed for organochlorine compounds; four from the refuge and five from reference areas. The analytical results were:

● ΣPCB, or total PCB, was 25-fold higher in raccoon adipose tissue from the refuge than the reference areas. ΣPCB in raccoon adipose tissue, while considerably higher at the refuge (mean 898.3 ng/g wet weight) than at the reference areas (34.8 ng/g), was well below the suggested wildlife threshold effect level of 10,000 ng/g.

● Raccoon livers contained 10-fold lower concentrations of ΣPCB than adipose tissue. ΣPCB was 9-fold higher in raccoon livers from the refuge (mean 83.0 ng/g) than the reference areas (mean 9.1 ng/g). On a lipid weight basis, ΣPCB in refuge raccoon livers (mean 1.64 µg ΣPCB/g lipid) was well below the suggested tissue effect threshold (41 µg ΣPCBs/g lipid).

● Similar to ΣPCB, but less pronounced, ΣDDT was 3.6-fold higher in refuge raccoon adipose tissue (mean 103.2 ng/g) than in animals from the reference areas (mean 28.6 ng/g).

● Raccoon livers contained 35-fold lower concentrations of ΣDDT than adipose tissue. ΣDDT was 1.5-fold higher in raccoon livers from the refuge (mean 2.9 ng/g) than the reference areas (mean 1.9 ng/g).

● Oxychlordane was the only other organochlorine compound consistently detected in both raccoon adipose and liver tissue. Concentrations were 3-fold higher in adipose tissue of raccoons from the refuge (mean 14.0 ng/g) than animals from the reference areas (mean 4.6 ng/g). Oxychlordane concentrations in raccoon livers were 20-fold higher at the refuge (mean 10.1 ng/g) than at the reference areas (mean 0.5 ng/g).

Although considerably higher organochlorine contaminant concentrations were detected in raccoons from the refuge compared to the reference areas, the levels in raccoon adipose tissue and livers were well below threshold ranges associated with adverse effects for mammals.

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List of Acronyms and Abbreviations

ACF	Analytical Control Facility (USFWS)
AFCEE	Armed Forces Center for Environmental Excellence
ARONWR	Aroostook National Wildlife Refuge
ATSDR	Agency for Toxic Substances and Disease Registry
BHC	benzene hexachloride
BIA	Bureau of Indian Affairs
CCP	Comprehensive Conservation Plan
DDD	dichloro diphenyl dichloroethane
DDE	dichloro diphenyl dichloroethylene
DDT	dichloro diphenyl trichloroethane
DEQ	Division of Environmental Quality (USFWS)
DOI	Department of the Interior
dw	dry weight
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
HCB	hexachlorobenzene
LAFB	Loring Air Force Base
LC_{50}	lethal concentration that kills 50% of a sample population
ME	Maine
MEDEP	Maine Department of Environmental Protection
MEFO	Maine Field Office – Ecological Services (USFWS)
µg/g	micrograms per gram (ppm)
ng/g	nanograms per gram (ppb)
NWR	National Wildlife Refuge
PCB	polychlorinated biphenyl
PPE	personal protective equipment
ppb	parts-per-billion (ng/g)
ppm	parts-per-million (µg/g)
USFWS	U.S. Fish and Wildlife Service
ww	wet weight

PREFACE

This report provides information on organochlorine compounds in adipose tissue and livers collected from raccoons in northeast Maine. Analytical work was completed under three U.S. Fish and Wildlife Service (USFWS) catalogs:

Catalog 5100024, Purchase Order # 94420-07-Y837 Mississippi State Chemical Lab
Catalog 5100031, Purchase Order # 94420-08-Y883 TDI – Brooks International, Inc.
Catalog 5100034, Purchase Order # 94420-08-Y941 TDI – Brooks International, Inc.

Questions, comments, and suggestions related to this report are encouraged. Written inquiries should refer to Report Number FY09-MEFO-2-EC and be directed to:

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This report complies with the peer review and certification provisions of the Information Quality Act (Public Law 106-554, Section 515).

ACKNOWLEDGEMENTS

Funding for this project was provided by the U.S. Fish and Wildlife Service's Division of Environmental Quality. In-kind support was provided by the Aroostook National Wildlife Refuge and the Aroostook Band of Micmacs. James Libby and Jerry McLaughlin altered their trapping schedules and locations to assist in this study. Kirk Cote, engineer equipment operator at Aroostook NWR, was instrumental in coordinating with trappers, storing carcasses, and providing other logistical assistance. Peer review of the report was provided by F. Timothy Prior, U.S. Fish and Wildlife Service (retired). Final editorial review was provided by Wende Mahaney, USFWS.

KEYWORDS

raccoon, *Procyon lotor*, organochlorine compounds, PCB, Maine

1. Background

The Aroostook National Wildlife Refuge (ARONWR) was established in 1998 on the site of the former Loring Air Force Base (LAFB), a cold-war era Strategic Air Command facility. Throughout the course of its 40+ year operational history, Department of Defense activities at LAFB resulted in widespread contamination of soil, sediment, surface water, groundwater and biotic resources of the former base and present-day wildlife refuge. In addition to the release of large volumes of petroleum products, cleaning solvents, heavy metals, and other toxic chemicals to the environment; leaking underground transformers contributed to a chronic release of polychlorinated biphenyls (PCBs) that contaminated sediments along several miles of the East Branch of Greenlaw Brook. Use and disposal of organochlorine pesticides (i.e., DDT and chlordane) in the course of military support activities resulted in additional contamination to the base's watershed resources, which as previously mentioned, are now located on ARONWR.

Intensive remedial and restoration activities occurred at LAFB throughout much of the 1990s. These actions resulted in the removal and mitigation of the most serious environmental contamination issues at the installation. Remedial activities included a massive PCB-contaminated sediment removal project in Greenlaw Brook that resulted in the excavation and disposal of over 100,000 cubic yards of surficial sediments and floodplain soils. PCB-contaminated sediments located at depths greater than two feet were not excavated, but were covered with a geo-textile fabric and a clean sediment cover to prevent mobilization of contaminants at depth. Pesticide contamination in the remediated area was determined to be co-located with PCB-contaminated sediment. Subsequent sediment sampling by the Aroostook Band of Micmacs, however, located several pockets of residual or un-remediated pesticide-contaminated sediments.

Following a 1994 fish tissue investigation conducted as part of the LAFB Superfund remedial investigation, the Maine Bureau of Health issued a fish consumption advisory in 1996 for several LAFB surface waters based on PCB contamination. Despite extensive remedial actions and removal activities in 1998, elevated levels of PCBs persist in fish tissue and the consumption advisory remains in place. Follow-up biota monitoring conducted in 2001, 2003, and 2008 by the Air Force indicates that PCB concentrations in fish tissue and dragonfly nymphs remain elevated at some sampling locations (AFCEE 2004, Stantec Consulting 2009). The Air Force, Environmental Protection Agency, and Maine Department of Environmental Protection had predicted that subsequent to the removal or containment of PCB-contaminated sediments, PCB concentrations in fish would steadily decrease and that the consumption advisory would likely be rescinded within five to ten years (ATSDR 1999). The expected decrease in biota PCB concentrations has not occurred.

ARONWR provides habitat for a variety of plants, animals, and birds. The refuge is an important resting and feeding area for migratory waterfowl, wading birds, and other trust resources of the Department of the Interior (DOI). A bald eagle nest territory (BE 337A) is located within seven miles of the refuge and eagles have been observed foraging along the affected watercourses of the refuge. In bald eagle populations feeding on PCB-contaminated prey at other contaminated sites, a negative correlation was found between bald eagle productivity and PCB concentrations in eggs (Bowerman *et al*. 1995)

Along with PCB threats to eagle populations, previous studies have determined that PCBs readily accumulate in waterfowl and significantly affect their health and reproductive success (Rathke and McRae 1989, Foley 1992). In an Ontario study, breast muscle geometric mean concentrations of PCBs in mallards collected 10 days after release to a PCB contaminated site contained concentrations 5,300 times greater than residues measured in ducks on the day of release, and exceeded FDA guidelines for edible poultry (Gebauer and Weseloh 1993). Although potential threats to waterfowl or other animals who consume waterfowl may exist at ARONWR, the migratory behavior of waterfowl presents difficulties in assessing the impact of environmental contaminants on them and definitively identifying the source of the contaminants.

Unlike difficulties associated with monitoring waterfowl for the presence of toxics, the raccoon (*Procyon lotor*) provides an excellent local surrogate to evaluate organic contaminant (PCBs and pesticides) concentrations to assess ecological risks to higher trophic level species such as piscivorous birds and mammals (Layher *et. al*. 1987). The usefulness of raccoons as a sentinel of environmental conditions as influenced by the presence of anthropogenic contaminants has been demonstrated through numerous studies conducted across the United States (Layher *et al*. 1987, Valentine *et al*., 1988, Ford and Hill 1990, Herbert and Peterle 1990, Lord *et al*. 2002). The raccoon's omnivorous diet, its opportunistic feeding habits, its preference for aquatic habitats that often serve as contaminant sinks, its relatively limited home range, and its tolerance to toxic contaminants all support use of this species as an environmental indicator of ecological health (Smith *et al*. 2003).

Raccoon are typically trapped for fur, but some hunters and trappers may also consume parts of the animal. Raccoons are an important animal to the Aroostook Band of Micmacs and to other Native American tribes. In an ethnographic assessment of the Wabanki people (Prins and McBride 2007), medicinal, food, and cultural uses of the raccoon were described. Medicinal uses included rubbing the fat on the skin to treat rheumatism or boiling the fat and providing it to children for a physic[a] (Wallis 1922). Raccoon fat was kept in bark vessels to be eaten at any time or mixed with maple sap. The raccoon baculum or penis bone was used as a toothpick. Animal fat such as raccoon fat was used by Maine's Native American tribes during canoe making (Kusnierz D. 2011. Water Quality Specialist - Penobscot Indian Nation. Personal communication.). The fat was mixed with pine pitch to seal stems and gores[b] (Hennessey 2007).

In this screening-level contaminant assessment, we enlisted local trappers to collect raccoons from PCB-contaminated locations at ARONWR and an adjoining Bureau of Indian Affairs (BIA) property that are bisected by the East Branch of Greenlaw Brook. Adipose tissue and livers were extracted to determine if raccoons using the former military installation are accumulating PCBs and organochlorine pesticides. For comparative purposes, trappers also collected raccoons from off-refuge reference sites in Perham and Woodland.

2. Assessment Objectives

Determine organochlorine contaminants levels in raccoon adipose tissue and livers from Aroostook NWR and reference areas.

Compare organochlorine contaminants levels in raccoon adipose tissue and livers to other raccoon or mammal studies and to suggested toxicity threshold effect levels.

3. Study Areas

The assessment occurred in northeast Aroostook County, Maine (Figure 1). Reference collections areas were in the townships of Perham and Woodland, approximately 10 to 15 miles west of the refuge (Figure 2). Aroostook National Wildlife Refuge is located within the townships of Limestone, Caswell, Connor, and Caribou (Figure 3).

4. Methods

4.1 Raccoon Trapping. In 2006 and 2007, during the State of Maine trapping season - October 30 to December 31 when raccoons were in prime condition - animals were trapped from ARONWR and from reference areas near Caribou, ME. Trappers in the study possessed Maine Department of Inland Fisheries and Wildlife trapping licenses and were issued a USFWS Refuge Special Use Permit. Raccoons were trapped with baited, box traps and

[a] physic is an earlier term for a laxative

[b] gores are triangular pieces of material to provide greater width

dispatched with a .22 caliber firearm. Cooperating trappers recorded date of collection, total body weight, and trap coordinates.

4.2 Carcass Processing. Skinned carcasses were received from trappers by refuge personnel and frozen until processing. Prior to processing, each carcass was removed from freezers and allowed to partially thaw. Animals were processed approximately 24 hours after removal from freezers. Although rabies has not been reported in the study area, additional safety and personal protective equipment (PPE) precautions were instituted for this study (i.e., rabies titer check, face shields, double-gloves, aprons, etc.). All trays and processing equipment were decontaminated with a wash of biodegradable soap and tap water, followed by a de-ionized water rinse. All processing equipment was decontaminated between each animal.

Carcasses were weighed with a spring scale. A scalpel was used to enter and expose the body cavity. Qualitative estimates of subcutaneous, intra-abdominal, and mesentery adipose tissue were made on a 0 to 5 scale (0 = Emaciated, 1 = Thin, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent). Adipose tissue was removed from the abdominal cavity, placed in labeled chemical clean jars, and weighed on an electronic scale. Livers were then extracted, placed in labeled chemical clean jars, and weighed on an electronic scale. If male, bacula were excised and placed in zip-loc plastic bags. Shears were used to cut the rear of the jaw so the lower mandible could be used for aging.

4.3 Organochlorine Analyses. Adipose tissue and liver samples were shipped to USFWS Analytical Control Facility (ACF) contract laboratories for an organochlorine scan with PCB quantification of individual Aroclors. [Note: Aroclor 1260 is the PCB formulation closely associated with LAFB contamination.] The first catalog for the study, 5100024, was analyzed by the Mississippi State Chemical Laboratory at Mississippi State, MS. The second and third study catalogs, 5100031 and 5100034, were analyzed by TDI – Brooks International, Inc. at College Station, TX.

The organochlorine analytical scan included the following compounds: Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260, ΣPCB or Total PCB (the sum of four PCB Aroclors); alpha, beta, gamma, and delta benzene hexachloride (BHC, also known as hexachlorocyclohexanes); chlordane compounds (*alpha* chlordane, *gamma* chlordane, *cis*-nonachlor, *trans*-nonachlor, heptachlor epoxide, oxychlordane), and DDT metabolites and isomers (*o,p*'-DDD, *o,p*'-DDE, *o,p*'-DDT, *p,p*'-DDD, *p,p*'-DDE, and *p,p*'-DDT). ΣDDT or Total DDT was determined by summing metabolites and isomers. Other organochlorine compounds in the scan included dieldrin, endrin, hexachlorobenzene (HCB), mirex, and toxaphene. Quantification of residues was determined by electron capture gas chromatography.

Adipose tissue and liver analytical data are presented in ng/g (nanograms per gram or parts-per-billion) on a wet weight (ww) basis in the text of this report and in Table 3 (adipose tissue) and Table 4 (liver). Sample detection limits are noted in the tables. Additional tables are provided with the data expressed on a dry weight basis (Tables 5 and 6) and lipid weight basis (Tables 7 and 8).

4.4 Quality Assurance/Quality Control (QA/QC). Quality assurance and quality control procedures included duplicates, spikes, and certified reference material in accordance with ACF contract specifications. All QA/QC criteria in the three catalogs were deemed acceptable by USFWS analytical chemists.

5. Results

5.1 Trapping. Although considerable effort was expended by two experienced volunteer trappers for this assessment, raccoon trapping success on the refuge was limited. Raccoons are frequently observed in the developed portions of the former Loring Air Force Base such as near the Job Corps dormitories, Defense Finance and Accounting Service building, and other buildings. For this screening-level assessment, however, trapping was

focused on the East Branch of Greenlaw Brook where extensive remediation of PCB-contaminated sediment occurred and where residual contamination was suspected (Figure 3). Animals that had been feeding from dumpsters or in areas with commercial or industrial refuse were avoided. Similarly, remote reference areas were selected for trapping to avoid animals that had been feeding on refuse associated with urban/suburban areas (Figure 2).

Five raccoons were collected in 2006 and four were collected in 2007. The volunteer trapper was unable to trap any raccoons from the refuge in 2006; all animals in 2006 were collected from the reference area. Snowfall in early November significantly limited the number of trap nights, particularly in 2007. Raccoons in northeast Aroostook County went into winter dens much earlier than usual and were not available for collection (McLaughlin J. 2007. Personal communication.). Although 14 baited live traps were run continuously over two weeks in 2007, only four animals were collected – all from the refuge. By mid-November, raccoon tracks were completely absent at three refuge trap sites and the reference trap site, indicating the animals had entered winter dens.

5.2 Sample Metrics. Nine raccoons were collected for the screening-level assessment. Five males were collected from reference sites in Perham and Woodland in 2006 and four females were collected from Aroostook NWR in 2007 (Table 1). Sex was determined by the presence of bacula. Baculum weight and length (Table 2) indicated that all male raccoons from the reference area were sexually mature (Kramer *et al*. 1999). Relative age of animals was determined by tooth wear (Grau *et al*. 1970), and all were classified as adults. Qualitative estimates of body fat for animals trapped in the assessment ranged from good to excellent (Table 2).

5.3 Organochlorine Analyses. Organochlorine analytical results on a wet weight basis are listed in Table 3 (Adipose tissue) and Table 4 (Liver). The text of this report discusses organochlorine concentrations on a wet weight basis unless otherwise noted. Since other raccoon studies in the scientific literature may report organochlorine results on a dry weight basis or on a lipid weight basis, additional data tables are provided (Table 5 Adipose tissue and Table 6 Liver on a dry weight basis, Table 7 Adipose tissue and Table 8 Liver on a lipid weight basis).

5.3.1 Aroclors. Aroclor 1242 and 1248 were below detection limits (< 17.6 ng/g) in all adipose tissue samples. Aroclor 1254 was detected in all adipose tissue samples from the refuge (mean 587.8 ng/g) and in none of the animals from the reference area (< 10.0 ng/g). Aroclor 1260 was detected in all adipose tissue samples. The mean Aroclor 1260 concentration at the refuge was 309.5 ng/g (range: 152.0 – 492.0 ng/g) and the mean in the reference areas was 34.8 ng/g (range: 12.0 – 90.0 ng/g).

Aroclors were detected in lower concentrations in raccoon liver samples than in adipose tissue. Aroclor 1242, 1248, and 1254 were below detection limits (< 4 ng/g) in all liver samples. Aroclor 1260 was detected in all liver samples. Mean Aroclor 1260 concentrations in liver tissue were 9.1 ng/g (range: 3.2 – 29.6 ng/g) and 83.0 ng/g (range: 30.2 – 162.0 ng/g) at the reference areas and refuge, respectively.

5.3.2 ΣPCB. ΣPCB or Total PCB was determined by the sum of four Aroclors – 1242, 1248, 1254 and 1260. ΣPCB in adipose tissue samples from the refuge was comprised of Aroclor 1254 and Aroclor 1260. ΣPCB in adipose tissue samples from the refuge averaged 898.3 ng/g with a range of 380.0 to 1390.0 ng/g. At the reference sites, ΣPCB in adipose tissue was comprised entirely of Aroclor 1260 with a mean of 34.8 ng/g and a range of 12.0 ng/g to 90.0 ng/g.

ΣPCB in raccoon livers was comprised entirely of Aroclor 1260 since the other Aroclors were below detection limits (< 4.0 ng/g) in all samples. Mean ΣPCB in liver was 9.1 ng/g (range: 3.2 – 29.6 ng/g) at the reference areas and 83.0 ng/g (range: 30.2 – 162.0 ng/g) at the refuge.

5.3.3 Benzene hexachloride (BHC). Four benzene hexachloride (BHC) compounds in the analytical scan – *alpha*, *beta*, *gamma* (lindane), *delta* - were below detection limits (< 2.0 ng/g) in all raccoon adipose tissue and liver samples.

5.3.4 Chlordane Compounds. *Alpha* chlordane, *gamma* chlordane, and *cis*-nonachlor were below detection in all adipose tissue samples from the reference areas and the refuge (< 2.0 ng/g). *Trans*-nonachlor was detected at the detection limit in one adipose tissue sample from the reference areas (2.0 ng/g). All adipose tissue samples from the refuge contained *trans*-nonachlor (mean 1.9 ng/g, range: 0.9 – 3.2 ng/g). Heptachlor-epoxide was below detection (< 2.0 ng/g) in all adipose tissue samples from the reference areas and was detected in three of four adipose tissue samples from the refuge (range: 0.6 – 0.9 ng/g). Oxychlordane was found in all adipose tissue samples. Mean oxychlordane was 4.6 ng/g (range: 3.0 – 8.0 ng/g) at the reference areas and 14.0 ng/g (range: 5.8 – 19.7 ng/g) at the refuge.

Chlordane compounds were detected more frequently in liver samples than in adipose tissue. *Alpha*-chlordane was detected in all liver samples. Mean *alpha*-chlordane in liver was identical at the reference and refuge at 0.7 ng/g. *Gamma*-chlordane was detected in all livers from the reference areas (mean 0.3 ng/g, range: 0.1 – 0.6 ng/g) and in three of four livers at the refuge (range: 0.3 – 1.8 ng/g). *Cis*-nonachlor was below detection (< 0.2 ng/g) in all liver samples. *Trans*-nonachlor was detected in two of five liver samples from the reference areas (0.1 ng/g, 0.3 ng/g) and in three of four liver samples from the refuge (range 0.2 – 0.6 ng/g). Heptachlor-epoxide was below detection in all liver samples from the reference areas (< 0.3 ng/g). All liver samples from the refuge had detectable concentrations of heptachlor-epoxide (mean 0.4 ng/g, range: 0.3 – 0.6 ng/g). Oxychlordane was detected in all liver samples with means of 0.5 ng/g (range: 0.3 – 0.9 ng/g) and 10.1 ng/g (range: 5.4 – 18.4 ng/g) at the reference areas and refuge, respectively.

5.3.5 DDT Metabolites, Isomers, and ΣDDT. *o*,*p*'-DDD and *o*,*p*'-DDE, and *o*,*p*'-DDT were below detection limits (< 2.0 ng/g) in all adipose tissue samples from the reference areas. *o*,*p*'-DDD was detected in one adipose tissue sample at 0.6 ng/g at the refuge. *o*,*p*'-DDE was below detection in all adipose tissue samples from the refuge (< 0.4 ng/g). *o*,*p*'-DDT was detected in all adipose tissue samples from the refuge (mean 5.9 ng/g, range: 2.2 – 8.7 ng/g). *p*,*p*'-DDD was detected in two adipose tissue samples from the reference areas (5.0 ng/g, 6.0 ng/g) and in all raccoon adipose tissue samples from the refuge (mean 3.5 µg/g, range: 1.9 – 5.6 ng/g). *p*,*p*'-DDE was found in all adipose tissue samples with means of 19.8 ng/g and 71.0 ng/g at the reference and refuge sites, respectively. *p*,*p*'-DDT was detected in four of five reference area adipose tissue samples (range: 6.0 – 12.0 ng/g) and in all the refuge adipose tissue samples (mean 22.7 ng/g, range: 12.9 – 37.5 ng/g). ΣDDT was determined by summing detectable concentrations of the DDT metabolites and isomers. Mean ΣDDT in raccoon adipose tissue samples was 28.6 ng/g at the reference areas and 103.2 ng/g at the refuge.

DDT metabolites were detected less frequently in raccoon liver samples than adipose tissue samples. *o*,*p*'-DDD and *o*,*p*'-DDE were below detection in all liver samples (< 0.2 ng/g). *o*,*p*'-DDT was below detection in liver samples from the reference areas (< 0.2 ng/g) and found in three of four liver samples from the refuge (range: 0.1 – 0.4 ng/g). *p*,*p*'-DDD was detected in three of five liver samples from the reference area (range: 0.2 – 0.4 ng/g) and in two of four samples from the refuge (0.3 ng/g, 0.4 ng/g). *p*,*p*'-DDE was detected in all raccoon liver samples with means of 1.7 µg/g (range: 0.7 – 4.4 ng/g) and 2.5 ng/g (range: 1.5 – 4.4 ng/g) at the reference areas and refuge, respectively. *p*,*p*'-DDT was below detection in liver samples from the reference areas and refuge (< 0.2 µg/g). Mean ΣDDT in raccoon liver samples was 1.9 ng/g at the reference areas and 2.9 ng/g at the refuge.

5.3.6 Other Organochlorine Compounds. Five other organochlorine compounds were included in the analytical scan – dieldrin, endrin, hexachlorbenzene (HCB), mirex, and toxaphene. These compounds were below detection limits (< 2.0 ng/g, < 50.0 ng/g for toxaphene) in all five adipose tissue samples from the reference areas (Table 3). HCB was detected in all four adipose tissue samples from the refuge (mean 15.5 ng/g). Dieldrin was detected in one raccoon adipose tissue sample from the refuge at the detection limit (0.7 ng/g). Endrin, mirex, and

toxaphene were below detection limits (< 1.0 µg/g, < 38.0 ng/g for toxaphene) in adipose tissue samples from the refuge.

All raccoon liver samples from the refuge had detectable levels of dieldrin (mean 0.9 ng/g, range: 0.5 – 1.2 ng/g) and one raccoon from the reference areas had a concentration of 0.4 ng/g. Endrin was below detection (< 0.5 ng/g) in all raccoon liver samples. HCB was detected in all liver samples. Mean HCB concentration in liver was identical at the reference and refuge sites - 0.8 ng/g. Mirex was detected in two liver samples from the refuge (0.1 ng/g, 0.2 ng/g). Toxaphene was below detection in all liver samples (< 10.0 ng/g).

6. Discussion

Raccoons have been used as sentinel species in several organochlorine investigations (Nalley *et al*. 1975, Frank *et al*. 1979, Layher *et al*. 1987, Valentine *et al*. 1988, Ford and Hill 1990, Herbert and Peterle 1990, Smith *et al*. 2003). Raccoon trapped within city limits can contain several-fold higher concentrations of PCBs than animals trapped in rural areas (Valentine *et al*. 1988). No difference in organochlorine uptake between sexes in raccoons has been reported (Herbert and Peterle 1990). The raccoon is fairly resistant to organochlorine compounds and no obvious adverse effects have been reported in raccoons with elevated contaminant levels in organ tissue (Herbert and Peterle 1990)

Too few animals were collected in this screening-level contaminant assessment to allow for robust statistical comparisons. A non-parametric test (Mann-Whitney U Test) was used to test for significant difference between variables. There was no significant difference in raccoon liver weight between the refuge and reference area ($p = 0.221$). For organochlorine contaminants with detections at the reference areas and Aroostook NWR, significantly higher concentrations were detected at the refuge ($p < 0.05$). More samples would be required, however, to sufficiently validate this correlation.

In the sections below, raccoons from Aroostook NWR and reference areas are qualitatively compared regarding organochlorine contamination. Contaminant concentrations in adipose tissue and livers for this assessment were also qualitatively compared to results in other raccoon studies (Valentine *et al*. 1988, Herbert and Peterle 1990, and Smith *et al*. 2003). In this assessment, organochlorine concentrations were higher in adipose tissue than liver tissue. Smith *et al*. (2003) reported similarly that ΣPCBs were higher in raccoon adipose than liver tissue.

6.1 ΣPCBs. PCBs were found extensively in a variety of media during the Superfund investigation of the former Loring Air Force Base. During the 1994 remedial investigation of surface waters at Loring Air Force Base, the maximum concentration of Aroclor 1260 in fish tissue was 2,100.0 ng/g or 2.10 µg/g (ABB-ES 1997). Despite the massive extent of sediment remediation in Greenlaw Brook, follow-up fish tissue sampling has not resulted in brook trout PCB concentrations that would preclude the need for consumption advisories (Figure 4).

Mean ΣPCB in raccoon adipose tissue at Aroostook NWR was 898.3 ng/g (Table 3). ΣPCB in raccoon adipose tissue was 25-fold higher at the refuge than adipose tissue samples from the reference area. Three studies were located in the literature that reported ΣPCB concentrations in adipose tissue – one on a wet weight basis, one on a dry weight basis and one presumably on a lipid weight basis. In a Kentucky raccoon study, mean ΣPCB (based on the sum of PCB congeners) in adipose tissue from animals collected near a Superfund Site was 2,075.0 ng/g wet weight, while at a reference area the mean was 1,916.0 ng/g (Smith *et al*. 2003). Herbert and Peterle (1990) reported elevated PCB concentrations in adipose tissue of nine adult raccoons from Shiawassee NWR in Michigan collected in 1986. In their study, the mean PCB concentration (assumed to be expressed wet weight basis) was 13,800.0 ng/g (Herbert and Peterle 1990). Valentine *et al*. (1988) analyzed fat from 16 raccoons collected in central New York and reported a mean ΣPCB concentration of 460 ng/g on a dry weight basis (range: 130.0 – 2,100.0 ng/g dw). At Aroostook NWR, the mean ΣPCB concentration in raccoon adipose tissue on a dry weight basis was 1,046.3 ng/g dw (range: 438.0 – 1,660.0 ng/g dw)(Table 5).

Mean ΣPCB in raccoon livers from Aroostook NWR was 83.0 ng/g (Table 4). Mean ΣPCB in raccoon livers was 9-fold higher at the refuge than livers from the reference area (mean 9.1 ng/g). Two studies were located in the literature that reported ΣPCB concentrations in raccoon livers. In the Kentucky study mentioned previously, raccoons from the reference area had higher liver ΣPCB concentrations (117 ng/g) than raccoons from the Superfund Site (80 ng/g, Smith *et al*. 2003). In southern Ontario, livers of 26 raccoons collected between 1972 and 1974 had a mean ΣPCB concentration of 16 ng/g (Frank *et al*. 1979).

ΣPCB – Potential Effect Summary

Although PCBs have been shown to impair reproduction in mink experiments and the compound has been extensively measured in mammal tissues, a link between residue levels and toxic effects has not been established in wild mammals (Kamrin and Ringer 1996). Based on the best available information, PCB adipose tissue or fat concentrations above 10,000.0 ng/g wet weight (or 10 µg/g) may be linked to reproductive impairment and liver concentrations above 4,000.0 ng/g wet weight (or 4 µg/g) are suggested to be associated with lethality (Kamrin and Ringer 1996).

Zwiernik *et al*. (2011) suggested a liver tissue effect threshold for aquatic mammals of 2,000.0 ng/g or 2 µg ΣPCB/g on a wet weight basis and 41 µg ΣPCB/g of a lipid weight basis. On both a wet weight and lipid weight basis, ΣPCB in Aroostook NWR raccoon livers (mean 83.0 ng ΣPCB/g ww Table 4, mean 1.64 µg ΣPCB/g lipid Table 8) was well below the suggested tissue effect thresholds (Zwiernik *et al*. 2011).

ΣPCB was several times higher in raccoon adipose tissue and livers from the refuge than at the reference areas, suggesting enhanced PCB uptake is occurring in refuge raccoons. However, as noted above, raccoon ΣPCB concentrations in both adipose tissue and livers from the refuge are well below suggested effect thresholds.

Data comparisons to other raccoon studies were mixed. Compared to three other raccoon studies in the literature, PCB concentrations in adipose tissue of Aroostook NWR raccoon was lower than two studies (Smith *et al*. 2003, Herbert and Peterle 1990) and higher than one (Valentine *et al*. 1988). PCB concentrations in livers of Aroostook NWR raccoons were similar to levels in raccoons collected from a Kentucky Superfund site (Smith *et al*. 2003), but higher levels than raccoon livers collected from Ontario (Frank *et al*. 1979).

6.2 Chlordane Compounds. Chlordanes are cyclodiene insecticides that were widely used in agriculture and were the leading pesticide used in the control of termites (Eisler 1990). Of the six chlordane-related compounds included in the analytical scan, only *cis*-nonachlor was not detected in raccoon samples.

Oxychlordane was detected in all raccoon adipose tissue and liver samples. In rat exposure studies, Bondy *et al*. (2000) found that the major chlordane metabolite that accumulated in adipose tissue was oxychlordane. Ford and Hill (1990) found a mean adipose tissue oxychlordane level of 10 ng/g (range: below detection to 140 ng/g) in raccoons collected from the Delta Region of Mississippi in 1988. Mean oxychlordane in Aroostook NWR raccoon adipose tissue was 14.0 ng/g, while the mean was 4.6 ng/g at the reference areas (Table 3).

Heptachlor epoxide was detected in three of the four refuge raccoon adipose tissue samples (0.6 ng/g, 0.8 ng/g, 0.9 ng/g) and in none of the reference animals (Table 3). Layher *et al.* (1987) reported heptachlor epoxide lipid levels from Kansas ranging from 43.0 to 580 ng/g. Ford and Hill (1990) reported a mean adipose tissue heptachlor epoxide level of 10 ng/g (range: below detection to 620 ng/g) in raccoons collected from the Delta Region of Mississippi in 1988.

In Florida, Nalley *et al*. (1975) found heptachlor epoxide in raccoon omental fat[c] ranging from 40.0 to 1,530.0 µg/ g lipid. The maximum level of heptachlor epoxide found in raccoon adipose tissue from the refuge on a lipid weight basis was 0.001 µg/g lipid. This heptachlor epoxide concentration from the refuge is orders of magnitude lower than the minimum reported by Nalley *et al*. (1975).

ΣChlordane – Potential Effect Summary

Chlordane levels greater than 300 ng/g in animal fat exceed U.S. Food and Drug Administration Action Levels for consumption (FDA 1992). Mean ΣChlordane in adipose (fat) tissue from Aroostook NWR raccoon was 16.5 ng/g (Table 3). Criteria on chlordane for protection of mammalian wildlife do not exist and criteria developed for human health protection have been recommended as temporary guidelines (300 ng/g, Eisler 1990). Mean ΣChlordane in livers from Aroostook NWR raccoon was 12.3 ng/g.

Chlordane levels in Aroostook NWR adipose tissue and livers were well below action levels and suggested effects criteria.

6.3 DDT and its metabolites. DDT metabolites were detected in several raccoon samples, mostly in adipose tissue samples from the refuge. DDT was used in northern Maine in the 1950s and 1960s for the control of spruce budworm (*Choristoneura fumiferana*). In an early 1960s study in northeast Aroostook County, Warner and Fenderson (1962) reported DDT concentrations in whole-body brook trout ranging from 300.0 to 25,900 ng/g (assumed wet weight, original data converted to ng/g). The insecticide was last used in Maine in 1967 (Dimond and Owen 1996), but the compound decays slowly in the state due to low soil temperatures, high organic matter, and low microbial population (Owen *et al*. 1977). During the 1996 remedial investigation of surface waters at Loring Air Force Base, the maximum concentration of DDT metabolites in fish tissue was 140.0 ng/g or 0.14 µg/g (ABB-ES 1997). The levels of DDE currently detected in brook trout samples from the Greenlaw Brook and in raccoon samples illustrate the persistence of this insecticide after its last use in Maine 40 years ago.

Mean *p*,*p*'-DDE in raccoon adipose tissue at Aroostook NWR was 71.0 ng/g (Table 3). In a 1988 study of raccoons from the Upper Steele Bayou that drains into Yazoo NWR in Mississippi, Ford and Hill (1990) reported a mean *p*,*p*'-DDE concentration in adipose tissue 2,240.0 ng/g (range: 60.0 – 59,000.0 ng/g). Herbert and Peterle (1990) reported elevated DDE concentrations in adipose tissue of nine adult raccoons from Shiawassee NWR in Michigan collected in 1986. In their study, the mean DDE concentration (assumed to be expressed on a wet weight basis) was 540.0 ng/g with a range of 50.0 ng/g to 1000.0 ng/g (Herbert and Peterle 1990).

In Florida, Nalley *et al*. (1975) found *p*,*p*'-DDE in raccoon omental fat ranging from 0.18 to 2.27 µg/g lipid. Lower levels of *p*,*p*'-DDE were found in adipose tissue at Aroostook NWR (mean 0.092 µg/g lipid) and the reference areas (mean 0.027 µg/g lipid) (Table 7).

Twenty-six raccoon livers from Ontario contained a mean DDE level of 3.1 ng/g (Frank *et al*. 1979). At Aroostook NWR, raccoon livers had a mean *p*,*p*'-DDE concentration of 2.5 ng/g, while the mean in livers of raccoons from the reference areas was 1.7 ng/g (Table 4).

ΣDDT – Potential Effect Summary

DDT and its metabolites are classified as moderate to high pesticide poisons in mammals (Briggs 1992). DDT is highly lipophilic and tends to accumulate in adipose tissue where it remains sequestered until starvation mobilizes the compound into the blood system (Murphy 1986). Reported LC_{50}s for DDT and DDE in mammal tissue were

[c] stomach fat covered by the peritoneum

210,000.0 ng/g and 600,000.0 ng/g dry weight, respectively (USDOI 1998). Mean ΣDDT residues in Aroostook NWR raccoon adipose tissue and livers were 119.1 ng/g and 9.5 ng/g dry weight, respectively (Tables 5 and 6).

DDT and its metabolites in Aroostook NWR raccoon adipose tissue and livers were lower than concentrations reported in other U.S. raccoon studies and well below LC_{50}s reported in other mammal species.

6.4 Other Organochlorine Compounds.

Dieldrin, a cyclodiene pesticide, was detected in one adipose tissue from Aroostook NWR (0.7 ng/g) and was undetected in samples from the reference areas (Table 3). In comparison, Ford and Hill (1990) found a mean adipose tissue dieldrin level of 20.0 ng/g (range: below detection to 140.0 ng/g) in raccoons collected from the Delta Region of Mississippi in 1988. In Florida, Nalley *et al*. (1975) found dieldrin in raccoon omental fat with a maximum concentration of 2.30 µg/g lipid. As noted above, among the nine samples from Maine, only one adipose tissue sample had a detectable level of dieldrin that on a lipid weight basis was 0.001 µg/g lipid. This dieldrin concentration from the refuge is orders of magnitude lower than the minimum reported by Nalley *et al*. (1975). One raccoon liver sample from the Perham/Woodland reference areas (0.4 ng/g) and all five Aroostook NWR raccoon liver samples contained dieldrin (mean 0.9 ng/g, range: 0.5 ng/g to 1.2 ng/g) (Table 4), but no studies were found in the literature that reported dieldrin concentrations in raccoon liver tissue. Little information was found in the literature regarding adverse effects of dieldrin and toxic residue amounts in mammals. Brain levels of dieldrin at 5,000.0 ng/g or 5 µg/g were suggested to be lethal in mammals (Peakall 1996).

Hexachlorbenzene (HCB) is an organochlorine fungicide that was used as a seed protectant treatment (Extoxnet 1996). HCB was detected in all four refuge raccoon adipose tissue samples (mean 15.5 ng/g), but was below detection limits in the five raccoons from the reference areas (Table 3). Layher *et al.* (1987) found HCB in Kansas raccoon lipid samples ranging from 12.0 ng/g to 440.0 ng/g. Liver samples of raccoons from Aroostook NWR and the reference area had the same mean HCB concentration, 0.8 ng/g (Table 4).

Mirex is an organochlorine pesticide that was used as a replacement for dieldrin and heptachlor and as a fire retardant in electronic components, fabrics, and plastics (Blus 2003). It is moderately toxic to mammals and persistent with a half-life in soil of ten years (UNEP 2002). Mirex use was cancelled in the U.S. in 1976 (Briggs 1992). Mirex was un-detected in raccoon adipose tissue and detected at slightly above the detection limit in two Aroostook NWR raccoon livers (0.1 ng/g, 0.2 ng/g) (Table 4). In a study using mammals collected from Alabama and Georgia following a mirex treatment to control fire ants, Hill and Dent (1985) found decreasing mirex levels in raccoon livers over a two year period. Mirex concentrations in raccoon livers were 400 ng/g six months after treatment and 110 ng/g two years after treatment.

Benzene hexachlorides (*alpha*, *beta*, *gamma*, *delta*), endrin and toxaphene were below detection limits in all raccoon adipose tissue and liver samples.

7. Summary and Management Recommendation

A screening-level assessment of raccoons at Aroostook NWR found that considerably higher organochlorine contaminant concentrations were detected in raccoons from the refuge than the reference areas. Sample sizes, however, were extremely small at the both locations.

Organochlorine contaminant levels in nine raccoon adipose tissues and livers from Aroostook NWR and reference areas were well below threshold ranges associated with adverse effects for mammals. Highlights of the assessment were:

● ΣPCB was 25-fold higher in raccoon adipose tissue from the refuge than the reference areas. ΣPCB in raccoon adipose tissue, while considerably higher at the refuge (mean 898.3 ng/g wet weight) than at the reference areas (34.8 ng/g), was well below the suggested threshold effect level of 10,000 ng/g.

● Raccoon livers contained 10-fold lower concentrations of ΣPCB than adipose tissue. ΣPCB was 9-fold higher in raccoon livers from the refuge (mean 83.0 ng/g) than the reference areas (mean 9.1 ng/g). On a lipid weight basis, ΣPCB in refuge raccoon livers (mean 1.64 µg ΣPCB/g lipid) was well below the suggested tissue effect threshold (41 µg ΣPCBs/g lipid).

● Similar to ΣPCB, but less pronounced, ΣDDT was 3.6-fold higher in refuge raccoon adipose tissue (mean 103.2 ng/g) than in animals from the reference areas (mean 28.6 ng/g).

● Raccoon livers contained 35-fold lower concentrations of ΣDDT than adipose tissue. ΣDDT was 1.5-fold higher in raccoon livers from the refuge (mean 2.9 ng/g) than the reference areas (mean 1.9 ng/g).

● Oxychlordane was the only other organochlorine compound consistently detected in both raccoon adipose and liver tissue. Concentrations were 3-fold higher in adipose tissue of raccoons from the refuge (mean 14.0 ng/g) than animals from the reference areas (mean 4.6 ng/g). Oxychlordane concentrations in raccoon livers were 20-fold higher at the refuge (mean 10.1 ng/g) than at the reference areas (mean 0.5 ng/g).

Fish tissue data collected during Air Force monitoring of Greenlaw Brook over the past fourteen years indicate a decline in PCB contamination since remediation, but current fish tissue levels continue to exceed Maine Action Levels for human consumption.

Recommendations

This screening-level assessment will be provided to human-health risk assessors (e.g., ATSDR, EPA) so a determination can be made on whether tribal members of the Aroostook Band of Micmacs using raccoons for food, medicinal purposes, or other uses are being harmfully exposed to organochlorine contaminants on Micmac lands that abut Aroostook NWR.

The raccoon has an omnivorous diet and may not adequately reflect potential organochlorine uptake of piscivorous wildlife using Greenlaw Brook. Follow-up studies to this screening-level assessment should consider using mink or otter which have a greater component of fish in their diet and higher sensitivity to PCBs (Smit *et al*. 1996, Bursian *et al*. 2006).

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Figure 1. Location of assessment area

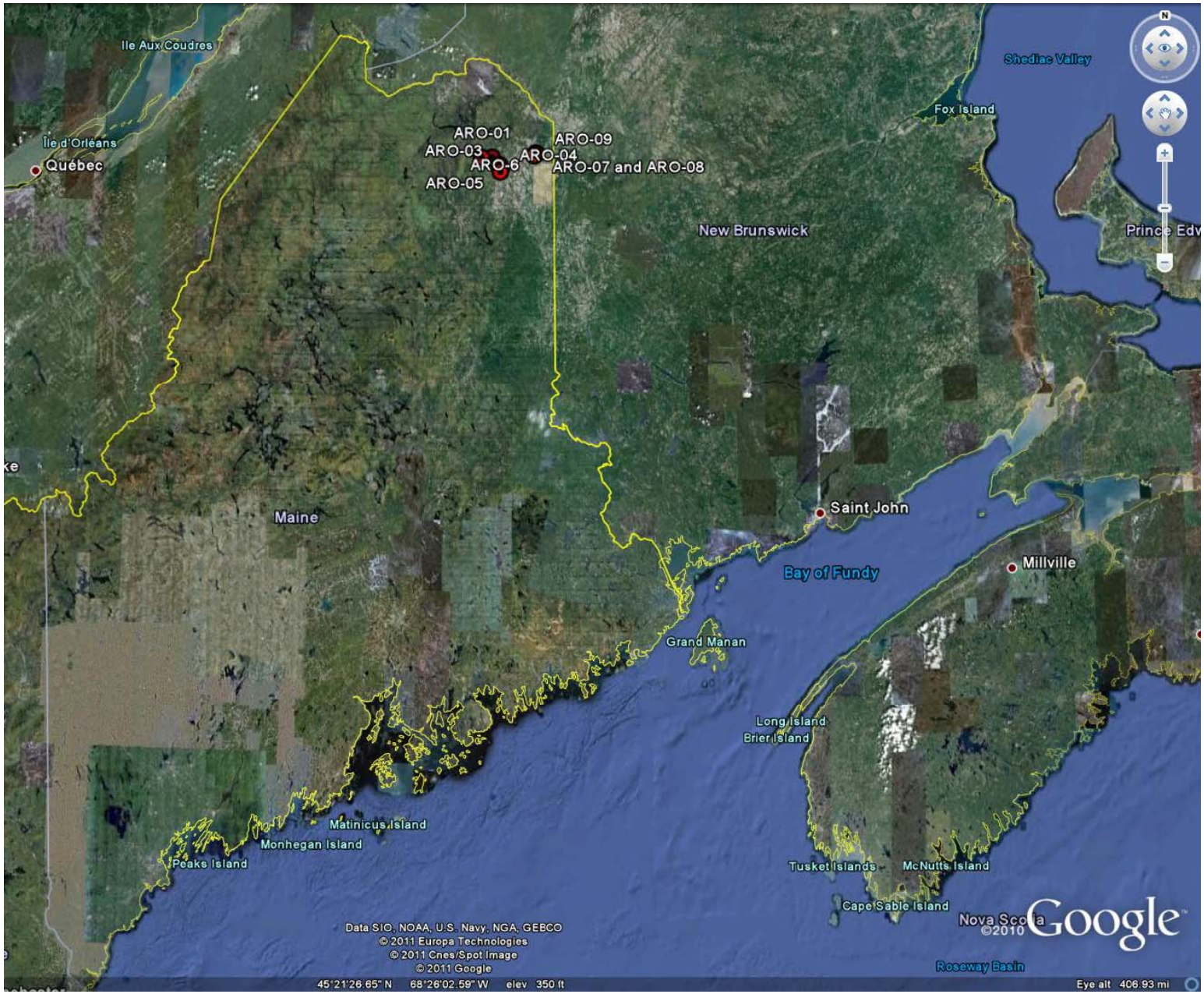


Figure 2. Raccoon collection locations in the reference area

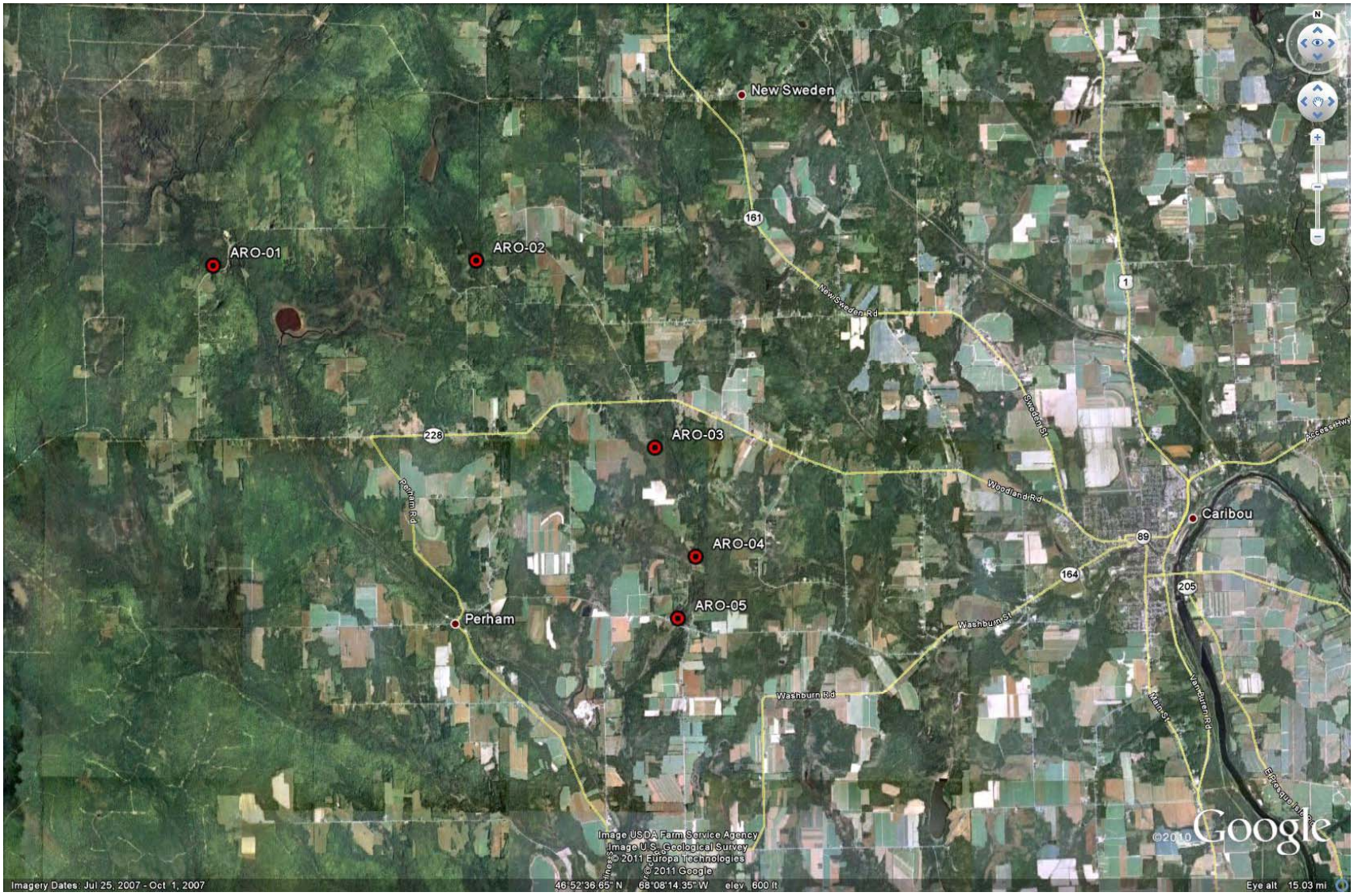


Figure 3. Raccoon collection locations on Aroostook NWR

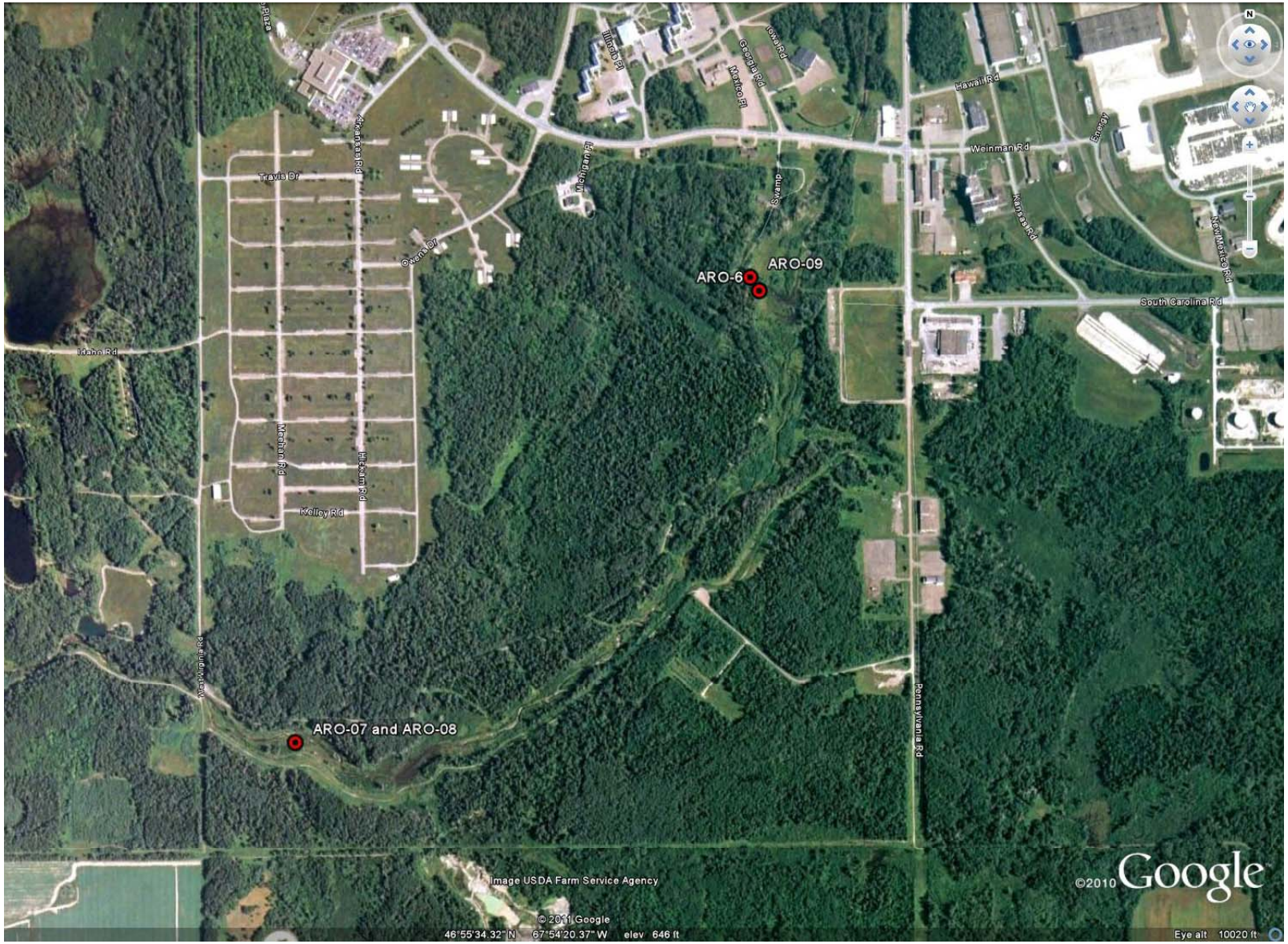
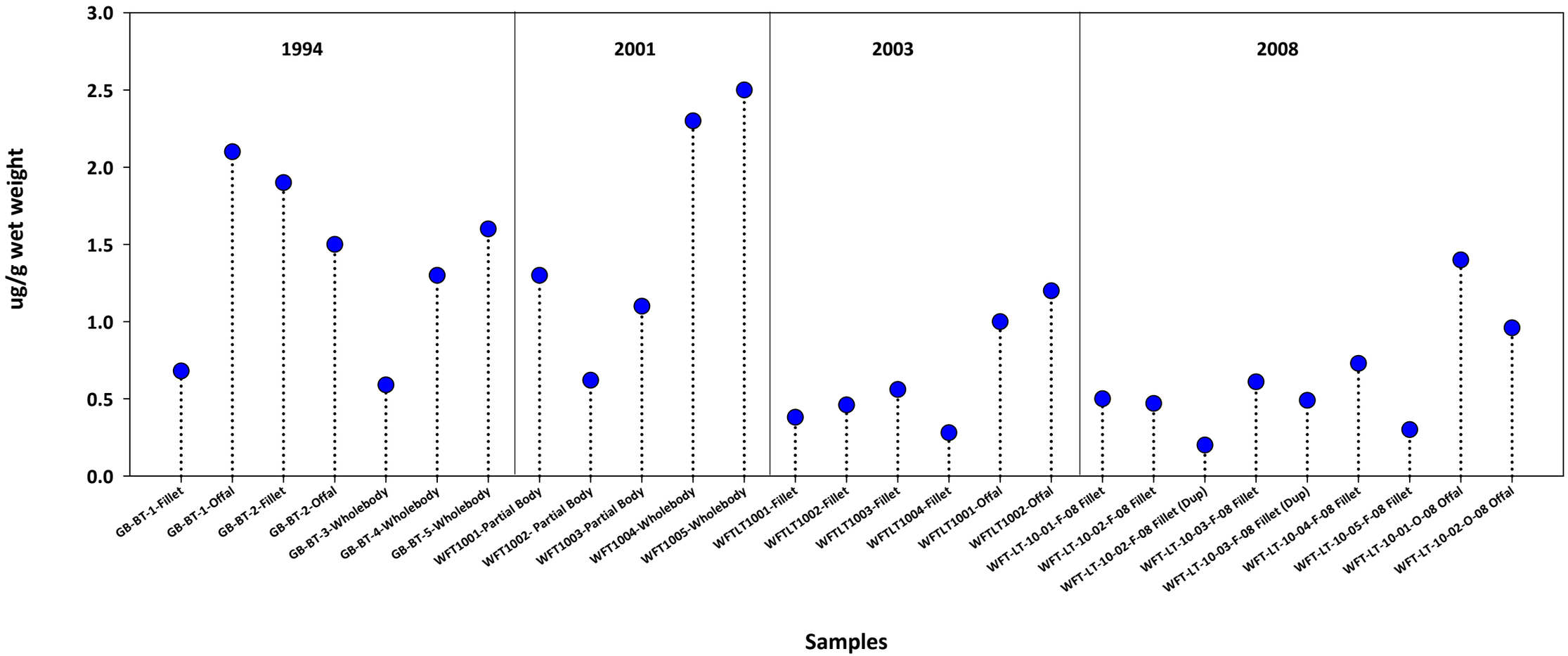


Figure 4. Aroclor 1260 in brook trout samples from the East Branch of Greenlaw Brook - 1994 through 2008, ug/g wet weight



Fillet samples were individual fish skin-off, boneless fillets
Offal samples included head, tail, fins, skin, and viscera from corresponding fish

Partial body samples were individual fish skin-on minus head, tail, fins, and viscera
Wholebody samples were multi-fish composites of small trout (total lengths < 150 mm)

Data Sources: ABB 1997, Woodlot Alternatives 2002 and 2004, Stantec 2009

All samples exceed the Maine Action Levels for PCBs
(Cancer Action Level 0.011 ug/g, NonCancer Action Level 0.043 ug/g)

Table 1. Raccoon collection locations

Animal No.	Date of Collection	Township	Latitude	Longitude	Trapper
Reference Areas					
ARO-1	1-Nov-06	Perham	46° 54' 37" N	68° 15' 46" W	J. Libby
ARO-2	1-Nov-06	Perham	46° 54' 41" N	68° 11' 30" W	J. Libby
ARO-3	1-Nov-06	Woodland	46° 52' 37" N	68° 08' 36" W	J. Libby
ARO-4	1-Nov-06	Woodland	46° 51' 25" N	68° 07' 56" W	J. Libby
ARO-5	1-Nov-06	Woodland	46° 50' 44" N	68° 08' 13" W	J. Libby
Aroostook NWR					
ARO-6	3-Nov-07	Limestone	46° 55' 48" N	67° 54' 00" W	J. McLaughlin
ARO-7	3-Nov-07	Limestone	46° 55' 14" N	67° 54' 51" W	J. McLaughlin
ARO-8	9-Nov-07	Limestone	46° 55' 14" N	67° 54' 51" W	J. McLaughlin
ARO-9	11-Nov-07	Limestone	46° 55' 49" N	67° 54' 01" W	J. McLaughlin

Table 2. Raccoon metrics

Animal No.	Total Weight (g)	Skinned Carcass Weight (g)	Adipose Tissue Weight (g)	Lipid Content Adipose Tissue (%)	Liver Weight (g)	Lipid Content Liver (%)	Sex	Bacula Length (mm)	Bacula Weight (g)	Age	Body Fat Condition
Reference Areas											
ARO-1	8618	7100	44.7	74.1	100.7	3.32	M	104.1	4.2	Adult	Excellent
ARO-2	9525	7800	49.0	68.2	165.7	4.34	M	97.9	4.4	Adult	Very Good
ARO-3	9072	7400	67.2	82.0	211.8	2.89	M	105.5	3.6	Adult	Excellent
ARO-4	11567	9500	86.0	80.3	304.7	2.82	M	103.8	4.3	Adult	Excellent
ARO-5	9979	8300	63.5	69.0	220.9	2.97	M	98.0	3.7	Adult	Excellent
Mean	9752	8020	62.1	74.7	200.8	3.27		101.9	4.0		
StdDev	1014	842	14.7		67.2			3.2	0.3		
Refuge											
ARO-6	8845	7200	184.9	78.6	184.7	6.20	F			Adult	Good
ARO-7	9979	8200	130.6	77.5	139.4	8.18	F			Adult	Very Good
ARO-8	8074	6600	138.5	69.1	124.6	4.68	F			Adult	Good
ARO-9	12065	9800	165.5	85.2	135.5	4.58	F			Adult	Very Good
Mean	9741	7950	154.9	77.6	146.1	5.91					
StdDev	1503	1211	21.6		23.0						

Total weight originally determined in pounds (lbs.) then converted to grams. StdDev = standard deviation
Age was determined by tooth wear (Grau *et al.* 1970).
Body fat condition was qualitatively ranked on a 0 to 5 scale based on subcutaneous, intra-abdominal, and mesentary fat content.
0 Emaciated, 1 Thin, 2 Fair, 3 Good, 4 Very Good, 5 Excellent

ADIPOSE TISSUE - WET WEIGHT

Table 3. Organochlorine compounds in raccoon adipose tissue, ng/g wet weight

Sample No.	Reference Areas ARO-F-1	ARO-F-2	ARO-F-3	ARO-F-4	ARO-F-5	Mean	Aroostook NWR ARO-F-6	ARO-F-7	ARO-F-8	ARO-F-9	Mean
Aroclor 1242	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	BDL	< 17.6	< 16.5	< 14.2	< 16.0	BDL
Aroclor 1248	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	BDL	< 17.6	< 16.5	< 14.2	< 16.0	BDL
Aroclor 1254	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	BDL	738.0	228.0	970.0	415.0	587.8
Aroclor 1260	90.0	12.0	20.0	24.0	28.0	34.8	492.0	152.0	416.0	178.0	309.5
PCB-TOTAL	90.0	12.0	20.0	24.0	28.0	34.8	1230.0	380.0	1390.0	593.0	898.3
alpha BHC	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.377	< 0.353	< 0.304	< 0.342	BDL
beta BHC	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.731	< 0.685	< 0.591	< 0.664	BDL
gamma BHC	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.572	< 0.537	< 0.463	< 0.520	BDL
delta BHC	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.776	< 0.727	< 0.627	< 0.705	BDL
alpha chlordane	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.475	< 0.445	< 0.384	< 0.431	BDL
gamma chlordane	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.467	< 0.438	< 0.377	< 0.424	BDL
cis-nonachlor	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.490	< 0.459	< 0.396	< 0.445	BDL
trans-nonachlor	< 2.00	< 2.00	2.0	< 2.00	< 2.00	NC	1.3	0.9	2.3	3.2	1.9
heptachlor epoxide	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.550	0.6	0.8	0.9	NC
oxychlordane	8.0	4.0	4.0	3.0	4.0	4.6	16.4	5.8	19.7	14.2	14.0
ΣChlordane	8.0	4.0	6.0	3.0	4.0	5.0	17.7	7.2	22.7	18.3	16.5
o,p'-DDD	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.610	< 0.572	0.6	< 0.554	NC
o,p'-DDE	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.414	< 0.388	< 0.335	< 0.376	BDL
o,p'-DDT	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	8.7	2.2	7.6	5.1	5.9
p,p'-DDD	5.0	< 2.00	< 2.00	< 2.00	6.0	NC	5.6	1.9	3.3	3.2	3.5
p,p'-DDE	28.0	6.0	15.0	19.0	31.0	19.8	124.0	31.5	64.6	63.7	71.0
p,p'-DDT	7.0	< 2.00	6.0	12.0	8.0	NC	37.5	15.7	12.9	24.7	22.7
ΣDDT	40.0	6.0	21.0	31.0	45.0	28.6	175.8	51.4	89.0	96.7	103.2
dieldrin	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.859	< 0.805	0.7	< 0.780	NC
endrin	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.814	< 0.762	< 0.658	< 0.739	BDL
HCB	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	15.1	23.7	14.5	8.8	15.5
mirex	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	BDL	< 0.482	< 0.452	< 0.390	< 0.438	BDL
toxaphene	< 50.0	< 50.0	< 50.0	< 50.0	< 50.0	BDL	< 37.7	< 35.3	< 30.4	< 34.2	BDL

ng/g = parts-per-billion
Values in red preceded by < symbol indicate non-detects and detection limit
BDL = below detection limit, NC = not calculated

LIVERS - WET WEIGHT

Table 4. Organochlorine compounds in raccoon livers, ng/g wet weight

Sample No.	Reference Areas ARO-L-1	ARO-L-2	ARO-L-3	ARO-L-4	ARO-L-5	Mean	Aroostook NWR ARO-L-6	ARO-L-7	ARO-L-8	ARO-L-9	Mean
Aroclor 1242	< 3.55	< 3.18	< 3.06	< 3.56	< 3.06	BDL	< 3.59	< 3.61	< 3.21	< 3.39	BDL
Aroclor 1248	< 3.55	< 3.18	< 3.06	< 3.56	< 3.06	BDL	< 3.59	< 3.61	< 3.21	< 3.39	BDL
Aroclor 1254	< 3.55	< 3.18	< 3.06	< 3.56	< 3.06	BDL	< 3.59	< 3.61	< 3.21	< 3.39	BDL
Aroclor 1260	5.9	3.3	3.3	29.6	3.2	9.1	57.7	30.2	162.0	82.2	83.0
PCB-TOTAL	5.9	3.3	3.3	29.6	3.2	9.1	57.7	30.2	162.0	82.2	83.0
alpha BHC	< 0.278	< 0.249	< 0.239	< 0.279	< 0.239	BDL	< 0.281	< 0.282	< 0.251	< 0.265	BDL
beta BHC	< 0.255	< 0.229	< 0.220	< 0.256	< 0.220	BDL	< 0.258	< 0.259	< 0.231	< 0.244	BDL
gamma BHC	< 0.137	< 0.123	< 0.118	< 0.138	< 0.118	BDL	< 0.139	< 0.139	< 0.124	< 0.131	BDL
delta BHC	< 0.282	< 0.253	< 0.243	< 0.283	< 0.243	BDL	< 0.285	< 0.287	< 0.255	< 0.269	BDL
alpha chlordane	0.6	0.2	0.2	2.3	0.2	0.7	1.7	0.3	0.1	0.8	0.7
gamma chlordane	0.6	0.3	0.3	0.1	0.2	0.3	1.8	0.3	< 0.101	0.8	NC
cis-nonachlor	< 0.134	< 0.120	< 0.116	< 0.135	< 0.116	BDL	< 0.136	< 0.136	< 0.121	< 0.128	BDL
trans-nonachlor	0.3	0.1	< 0.0920	< 0.108	< 0.0920	NC	0.6	0.2	< 0.0970	0.5	NC
heptachlor epoxide	< 0.298	< 0.267	< 0.257	< 0.299	< 0.257	BDL	0.4	0.6	0.5	0.3	0.4
oxychlordane	0.6	0.5	0.3	0.9	0.4	0.5	11.2	5.4	18.4	5.3	10.1
ΣChlordane	2.2	1.0	0.8	3.4	0.8	1.6	15.7	6.8	19.0	7.7	12.3
o,p'-DDD	< 0.192	< 0.172	< 0.166	< 0.193	< 0.166	BDL	< 0.195	< 0.195	< 0.174	< 0.184	BDL
o,p'-DDE	< 0.0910	< 0.0820	< 0.0790	< 0.0920	< 0.0790	BDL	< 0.0920	< 0.0930	< 0.0830	< 0.0870	BDL
o,p'-DDT	< 0.144	< 0.129	< 0.124	< 0.144	< 0.124	BDL	0.3	< 0.146	0.4	0.1	NC
p,p'-DDD	0.4	< 0.173	0.2	< 0.194	0.2	NC	0.4	< 0.196	< 0.175	0.3	NC
p,p'-DDE	1.6	0.7	4.4	0.8	1.2	1.7	4.4	1.5	2.3	2.1	2.5
p,p'-DDT	< 0.102	< 0.0920	< 0.0880	< 0.103	< 0.0880	BDL	< 0.103	< 0.104	< 0.0920	< 0.0980	BDL
ΣDDT	1.9	0.7	4.6	0.8	1.4	1.9	5.0	1.5	2.6	2.5	2.9
dieldrin	0.4	< 0.335	< 0.322	< 0.375	< 0.322	NC	1.1	0.9	1.2	0.5	0.9
endrin	< 0.455	< 0.408	< 0.392	< 0.457	< 0.392	BDL	< 0.460	< 0.462	< 0.412	< 0.434	BDL
HCB	1.0	0.7	0.8	0.8	0.7	0.8	0.7	0.9	1.3	0.2	0.8
mirex	< 0.0960	< 0.0860	< 0.0830	< 0.0970	0.2	NC	0.1	< 0.0980	0.2	< 0.0920	NC
toxaphene	< 9.84	< 8.82	< 8.49	< 9.88	< 8.49	BDL	< 9.96	< 10.0	< 8.91	< 9.40	BDL

ng/g = parts-per-billion. Concentrations expressed on a wet weight basis
Values in red preceded by < symbol indicate non-detects and detection limit
BDL = below detection limit, NC = not calculated

ADIPOSE TISSUE - DRY WEIGHT

Table 5. Organochlorine compounds in raccoon adipose tissue, ng/g dry weight

	Reference Areas						Aroostook NWR				
Sample No.	ARO-F-1	ARO-F-2	ARO-F-3	ARO-F-4	ARO-F-5	Mean	ARO-F-6	ARO-F-7	ARO-F-8	ARO-F-9	Mean
Aroclor 1242	< 12.4	< 13.1	< 11.3	< 12.3	< 13.1	BDL	< 20.1	< 19.0	< 17.0	< 18.2	BDL
Aroclor 1248	< 12.4	< 13.1	< 11.3	< 12.3	< 13.1	BDL	< 20.1	< 19.0	< 17.0	< 18.2	BDL
Aroclor 1254	< 12.4	< 13.1	< 11.3	< 12.3	< 13.1	BDL	845.0	263.0	1160.0	474.0	685.5
Aroclor 1260	112.0	15.7	22.5	29.4	36.6	43.2	563.0	175.0	498.0	203.0	359.8
PCB-TOTAL	112.0	15.7	22.5	29.4	36.6	43.2	1410.0	438.0	1660.0	677.0	1046.3
alpha BHC	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.431	< 0.407	< 0.365	< 0.391	BDL
beta BHC	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.836	< 0.789	< 0.708	< 0.758	BDL
gamma BHC	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.655	< 0.618	< 0.555	< 0.594	BDL
delta BHC	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.888	< 0.837	< 0.752	< 0.805	BDL
alpha chlordane	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.543	< 0.512	< 0.460	< 0.492	BDL
gamma chlordane	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.534	< 0.504	< 0.453	< 0.484	BDL
cis-nonachlor	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.560	< 0.528	< 0.474	< 0.508	BDL
trans-nonachlor	< 2.48	< 2.62	2.3	< 2.45	< 2.61	NC	1.5	1.0	2.7	3.7	2.2
heptachlor epoxide	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.629	0.7	0.9	1.0	0.9
oxychlordane	9.9	5.2	4.5	3.7	5.2	5.7	18.8	6.7	23.6	16.2	16.3
ΣChlordane	9.9	5.2	6.8	3.7	5.2	6.2	20.3	8.3	27.2	20.9	19.2
o,p'-DDD	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.698	< 0.659	0.7	< 0.633	NC
o,p'-DDE	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.474	< 0.447	< 0.401	< 0.430	BDL
o,p'-DDT	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	10.0	2.6	9.1	5.9	6.9
p,p'-DDD	6.2	< 2.62	< 2.25	< 2.45	7.8	NC	6.4	2.2	4.0	3.6	4.0
p,p'-DDE	34.7	7.9	16.9	23.3	40.5	24.7	141.0	36.3	77.5	72.7	81.9
p,p'-DDT	8.7	< 2.62	6.8	14.7	10.4	NC	42.9	18.1	15.5	28.2	26.2
ΣDDT	49.6	7.9	23.7	38.0	58.7	35.6	200.2	59.2	106.8	110.4	119.1
dieldrin	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.983	< 0.927	0.8	< 0.891	NC
endrin	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.931	< 0.878	< 0.788	< 0.844	BDL
HCB	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	17.3	27.3	17.4	10.0	18.0
mirex	< 2.48	< 2.62	< 2.25	< 2.45	< 2.61	BDL	< 0.552	< 0.520	< 0.467	< 0.500	BDL
toxaphene	< 62.0	< 65.5	< 56.3	< 61.3	< 65.3	BDL	< 43.1	< 40.6	< 36.5	< 39.1	BDL

ng/g = parts-per-billion
Values in red preceded by < symbol indicate non-detects and detection limit
BDL = below detection limit, NC = not calculated

LIVERS - DRY WEIGHT

Table 6. Organochlorine compounds in raccoon livers, ng/g dry weight

	Reference Areas						Aroostook NWR				
ppb DW	ARO-L-1	ARO-L-2	ARO-L-3	ARO-L-4	ARO-L-5	Mean	ARO-L-6	ARO-L-7	ARO-L-8	ARO-L-9	Mean
Aroclor 1242	< 12.2	< 11.7	< 11.1	< 13.6	< 11.0	BDL	< 11.4	< 11.4	< 10.8	< 11.6	BDL
Aroclor 1248	< 12.2	< 11.7	< 11.1	< 13.6	< 11.0	BDL	< 11.4	< 11.4	< 10.8	< 11.6	BDL
Aroclor 1254	< 12.2	< 11.7	< 11.1	< 13.6	< 11.0	BDL	< 11.4	< 11.4	< 10.8	< 11.6	BDL
Aroclor 1260	20.3	12.3	11.9	113.0	11.6	33.8	183.0	95.3	543.0	282.0	275.8
PCB-TOTAL	20.3	12.3	11.9	113.0	11.6	33.8	183.0	95.3	543.0	282.0	275.8
alpha BHC	< 0.952	< 0.916	< 0.870	< 1.07	< 0.861	BDL	< 0.892	< 0.889	< 0.843	< 0.910	BDL
beta BHC	< 0.876	< 0.842	< 0.800	< 0.981	< 0.792	BDL	< 0.820	< 0.818	< 0.775	< 0.837	BDL
gamma BHC	< 0.471	< 0.452	< 0.430	< 0.527	< 0.425	BDL	< 0.440	< 0.439	< 0.416	< 0.449	BDL
delta BHC	< 0.968	< 0.931	< 0.884	< 1.08	< 0.875	BDL	< 0.906	< 0.904	< 0.857	< 0.925	BDL
alpha chlordane	2.1	0.9	0.6	8.8	0.7	2.6	5.5	1.1	0.4	2.8	2.4
gamma chlordane	2.2	1.0	1.0	0.5	0.8	1.1	5.6	0.9	< 0.339	2.9	NC
cis-nonachlor	< 0.460	< 0.442	< 0.420	< 0.515	< 0.416	BDL	< 0.431	< 0.430	< 0.407	< 0.440	BDL
trans-nonachlor	1.2	0.4	< 0.336	< 0.412	< 0.332	NC	1.9	0.7	< 0.325	1.8	NC
heptachlor epoxide	< 1.02	< 0.982	< 0.933	< 1.14	< 0.924	BDL	1.2	1.8	1.6	1.1	1.4
oxychlordane	1.9	1.7	1.2	3.5	1.3	1.9	35.6	17.1	61.6	18.1	33.1
ΣChlordane	7.4	3.8	2.8	12.8	2.9	6.0	49.8	21.5	63.6	26.6	40.4
o,p'-DDD	< 0.660	< 0.635	< 0.603	< 0.739	< 0.597	BDL	< 0.618	< 0.616	< 0.584	< 0.631	BDL
o,p'-DDE	< 0.313	< 0.301	< 0.286	< 0.351	< 0.283	BDL	< 0.293	< 0.292	< 0.277	< 0.299	BDL
o,p'-DDT	< 0.493	< 0.474	< 0.450	< 0.552	< 0.445	BDL	0.9	< 0.460	1.3	0.5	NC
p,p'-DDD	1.2	< 0.637	0.6	< 0.742	0.6	NC	1.2	< 0.618	< 0.586	1.1	NC
p,p'-DDE	5.4	2.4	16.1	3.2	4.5	6.3	13.9	4.7	7.6	7.1	8.3
p,p'-DDT	< 0.351	< 0.337	< 0.320	< 0.393	< 0.317	BDL	< 0.328	< 0.327	< 0.310	< 0.335	BDL
ΣDDT	6.6	2.4	16.7	3.2	5.1	6.8	16.0	4.7	8.9	8.7	9.5
dieldrin	1.4	< 1.23	< 1.17	< 1.44	< 1.16	NC	3.5	2.9	4.1	1.7	3.0
endrin	< 1.56	< 1.50	< 1.43	< 1.75	< 1.41	BDL	< 1.46	< 1.46	< 1.38	< 1.49	BDL
HCB	3.3	2.6	3.1	2.9	2.6	2.9	2.1	2.7	4.4	0.9	2.5
mirex	< 0.330	< 0.317	< 0.301	< 0.370	0.6	NC	0.4	< 0.308	0.5	< 0.315	NC
toxaphene	< 33.8	< 32.5	< 30.9	< 37.8	< 30.5	BDL	< 31.6	< 31.5	< 29.9	< 32.3	BDL

ng/g = parts-per-billion. Concentrations expressed on a dry weight basis
Values in red preceded by < symbol indicate non-detects and detection limit
BDL = below detection limit, NC = not calculated

Table 7. Total PCB, p,p'-DDE, and oxychlordane in raccoon adipose tissue, ug/g lipid

	Total PCB	p,p'-DDE	Oxychlordane
ARO-F-1	0.1215	0.0378	0.0108
ARO-F-2	0.0176	0.0088	0.0059
ARO-F-3	0.0244	0.0183	0.0049
ARO-F-4	0.0299	0.0237	0.0037
ARO-F-5	0.0406	0.0449	0.0058
Mean - Reference	0.0468	0.0267	0.0062
ARO-F-6	1.5649	0.1578	0.0209
ARO-F-7	0.4903	0.0406	0.0074
ARO-F-8	2.0116	0.0935	0.0285
ARO-F-9	0.6960	0.0748	0.0167
Mean - Refuge	1.1907	0.0917	0.0184
	25 x Higher at Refuge	3.4 x Higher at Refuge	3 x Higher at Refuge

LIVER - LIPID WEIGHT

Table 8. Total PCB, p,p'-DDE, and oxychlordane in raccoon livers, ug/g lipid

	Total PCB	p,p'-DDE	Oxychlordane
ARO-L-1	0.1780	0.0470	0.0170
ARO-L-2	0.0770	0.0152	0.0105
ARO-L-3	0.1131	0.1536	0.0109
ARO-L-4	1.0496	0.0293	0.0324
ARO-L-5	0.1088	0.0418	0.0122
Mean - Reference	0.3053	0.0574	0.0166
ARO-L-6	0.9306	0.0708	0.1806
ARO-L-7	0.3692	0.0180	0.0664
ARO-L-8	3.4615	0.0481	0.3932
ARO-L-9	1.7948	0.0452	0.1151
Mean - Refuge	1.6390	0.0455	0.1888
	5.4 x Higher at Refuge	0.8 x Higher at Reference	11 x Higher at Refuge