Lower Duwamish Waterway

Technical Memorandum
Review of Urban Canada Geese
as Vectors of PCB Contamination

Prepared for

Toxics Cleanup Program
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Table of Contents

Figures

Tables

List of Acronyms

APHIS	Animal and Plant Health Inspection Service
BBS	North American Breeding Bird Survey
BMF	biomagnification factor
CBC	Audubon Society's Christmas Bird Count
CFR	Code of Federal Regulations
DW	dry weight
Ecology	Washington State Department of Ecology
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
USC	U.S. Code
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

Summary

Canada Geese are frequent visitors to the intertidal habitat areas in the Lower Duwamish Waterway site. Samples of Canada goose droppings collected by the Port of Seattle and The Boeing Company contained PCBs. The levels of PCBs in these samples represent a possible recontamination source to any new or future habitat areas. Canada goose populations in the Seattle area grew significantly from the 1960s, when resident populations were introduced, through the late 1990s. Their numbers have stabilized since 2000. Canada geese feed and rest year-round along the Duwamish Waterway; however, population data in the area are scarce. The largest number of Canada geese at a Duwamish area survey site was 73 birds, but most counts averaged fewer than 25 birds. Movements of resident geese have not been reported in western Washington, but it is likely that their daily and seasonal movements vary greatly among individuals and in relation to their breeding season. Canada geese ingest and accumulate chlorinated hydrocarbons in fat and muscle tissue. Contaminants may be excreted directly following digestion but may also be mobilized from body tissues and excreted. More sedentary individuals may ingest and re-deposit contaminants on a site, whereas more wide-ranging individuals may disperse contaminants to other sites.

Available site-specific information was not sufficient to determine whether Canada geese pose a significant risk to remediation efforts at the Lower Duwamish Waterway site. With better site-specific information on population numbers, residence time, defecation rates, and polychlorinated biphenyl (PCB) loads of pellets, it may be possible to extrapolate the amount of PCB deposited by geese on these sites.

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1.0 Introduction

Canada goose droppings were collected at two upland sites adjacent to the Duwamish Waterway (Terminal 117 and Boeing Plant 2) and analyzed for PCBs (Keeley 2013; Sealaska Environmental 2012). One composite sample, consisting of droppings from nine separate locations at Terminal 117, contained 280 parts per billion (ppb) total PCBs. Four composite samples from Boeing Plant 2 (each with ten or more droppings) contained 28, 45, 57, and 103 ppb total PCBs. Some of these samples exceeded action levels for long-term monitoring at these sites. This report provides a review of background information on population abundance, feeding behavior, movements, and occurrence of industrial contaminants including PCBs in Canada geese in order to improve our understanding of the significance of geese as contaminant vectors. Additionally, we evaluated relevant literature on other waterfowl species (ducks and other goose species) and seabirds (gulls, terns, cormorants, herons, grebes, and other species that forage on marine resources). There is an extensive literature on industrial and agricultural contaminants in waterfowl seabirds, and many of these species also occur in Puget Sound and may be vectors of contaminants. Moreover, an evaluation of contaminant burdens in other species may help put the risks associated with Canada geese in the study into perspective. Urban goose population management techniques are reviewed.

2.0 Canada Goose Populations

2.1 Resident and Migratory Populations

Canada geese (*Branta canadensis*) were formerly uncommon in breeding bird records in the Puget Sound area, and were introduced to the area by state wildlife agencies in the 1960s (Manuwal and Ettl 1989, as cited by Woodruff et al. 2004). Two behaviorally distinct types of Canada goose populations exist in most parts of the United States: migratory and resident. Migratory Canada geese nest in Alaska and Canada and overwinter in the lower 48 states including the Puget Sound region. Resident, or non-migratory, Canada geese are those that nest within the lower 48 states during March–June, or that reside there during the months of April–August (USDA APHIS 2011). Non-migratory geese were released in many states during the 1970s and 1980s in the hope that the establishment of non-migratory goose populations would provide more hunting opportunities for local hunters (Conover 2011). However, throughout the United States, non-migratory geese spend most of their time in urban and suburban golf courses, parks, and sports fields where hunting is prohibited (Holevinski et al. 2007; Groepper et al. 2008; Seamans et al. 2009).

Some resident geese flocks will migrate during the summer prior to molting ("molt-migration") while others may migrate temporarily during the fall/winter when inland waters freeze, returning to these sites when they thaw (Conover 2011). Molt-migration primarily involves non-breeding geese or geese that have lost their nests or broods. This behavior is different from the movements of migratory populations to and from breeding sites in the Arctic and sub-Arctic. Molt-migration and weather-related winter migrations have not been studied in urban flocks in the Puget Sound region but, if they occur, would contribute to variability in the occurrence and sizes of goose flocks in the area.

2.2 Subspecies in Western Washington

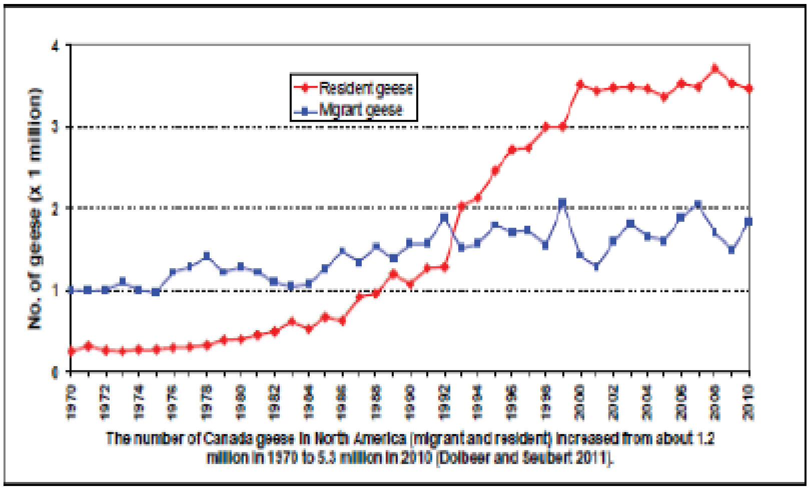
The status of Canada goose populations is complicated by a number of subspecies that are distinguished primarily on the basis of body size, voice, other field marks, and timing of migration and are grouped into two categories. The common name "Canada goose" is currently applied to the group of large-bodied subspecies. Essentially all of the geese that nest in the lower 48 United States and southern Canada are large-bodied; these are considered resident or non-migratory birds. *Branta canadensis moffitti* is the most abundant resident subspecies in the Pacific Northwest; from late spring into early fall almost all Canada geese in the region are this subspecies (Wahl et al. 2005). *B. c. maxima* was nearly extirpated in the early 1900s but was introduced into western Washington in the 1970s and has likely interbred with local *moffitti*. In addition to resident Canada geese, large-bodied migrants that breed in Alaska and Canada arrive in late September to overwinter in the Puget Sound region, departing in March–April. The closely related cackling goose (*Branta hutchinsii*) was split off as a separate species in 2004 (Sibley 2010) and includes the smaller-bodied subspecies. These migratory subspecies breed in the tundra in Alaska and Canada and overwinter from central California to western Washington.

2.3 Population Size, Productivity, and Mortality

2.3.1 Trends in North America

Numbers of resident Canada geese in North America have increased enormously since 1990 in urban environments because there is abundant food available year-round, few predators, and hunting is prohibited (Conover 1992). Canada goose resident and migratory populations in North America are estimated annually based on breeding period counts coordinated by the U.S. Fish and Wildlife Service (USFWS 2012). As shown in Figure 1, the overall Canada goose population increased fivefold from 1970 (1.08 million) to 2005 (5.01 million) (Dolbeer and Seubert 2006). Most of the increase was due to growth of resident populations, especially during the 1990s when the population increased at a mean annual rate of 13.8 percent. Since 2000, the resident Canada goose population has stabilized at about 3.4–3.6 million. The migrant population has not increased at the same pace, and has remained stable since 1990 at about 1.7 million. By 2009, resident Canada goose populations outnumbered migratory geese in all North American flyways[1] (Conover 2011).

[1] Flyways are the major seasonal routes followed by concentrations of birds migrating to and from their breeding areas. From east to west, there are four major flyways in North America: Atlantic, Mississippi, Central, and Pacific.



Source: USDA National Wildlife Research Center. November 2011.

Figure 1. Resident and Migratory Canada Goose populations in North America, 1970 to 2010

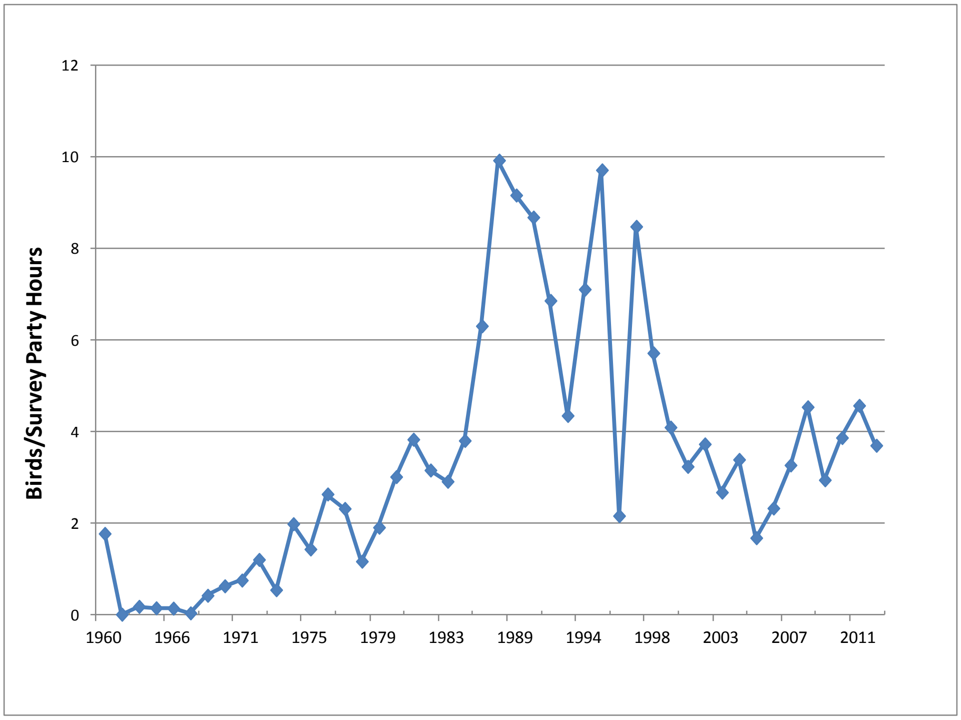
2.3.2 Trends in Washington

A number of data sources were queried to identify population abundance and long-term trends of Canada geese in Washington and the study area. At the state level, the North American Breeding Bird Survey (BBS) conducted by the U.S. Geological Survey (Sauer et al. 2012) monitors bird species status and population trends following a rigorous protocol based on thousands of randomly established survey routes. Survey routes have a fixed length, uniformly spaced survey points, and fixed duration and spatial extent within which birds are counted. BBS data provide an index of population abundance that can be used to estimate population trends and relative abundances over various geographic scales. Long-term trend estimates for the Canada goose in Washington during the period 1968–2011 show a 9.4 percent increase. The increase has not been evenly distributed over the time period; rapid population growth began in the state in the late 1980s and has continued since then. There are no BBS routes in Seattle, and finer resolution of Canada goose abundance in the project area or similar urban settings in western Washington is not available in this database.

2.3.3 Trends in Seattle

No information on Canada goose population sizes was available from local agencies, but Seattle Parks and Recreation estimated that the resident Canada goose population in Seattle was 3,000 (Seattle Parks and Recreation 2002).

In the absence of protocol-based population monitoring data, citizen science efforts provide useful information on the occurrence, distribution, and numbers of Canada geese. Conducted on one day each year in December, the Audubon Society’s Christmas Bird Count (CBC) is a nationwide effort to identify and count bird species within prescribed circles that have a 15-mile diameter. Region-wide, the 30-year trend for the Seattle, Olympia, and Tacoma CBC “circles” is thought to have increased from approximately 36 geese in 1969 to 6,600 geese by 1999 (Woodruff et al. 2004). CBC data are available for the Seattle “circle” from 1960 to the present (Figure 2). Numbers reported include migratory Canada geese as well as resident geese. Canada geese were relatively uncommon in Seattle CBC reports in the 1960s but subsequently increased rapidly (Audubon Society 2013). Within the Seattle CBC circle, numbers of detected geese corrected for sampling effort peaked from the late-1980s to mid-1990s (Figure 2), declined in the late 1990s (likely because of management programs), and have been relatively stable from 1999 to the present. Numbers of geese detected during the CBC represent trends in the total population of resident and migrant birds in the Seattle area.



Source: Audubon Society 2013

Figure 2. Canada Goose Abundance in Seattle during Christmas Bird Counts, 1960 to 2013

CBC results are available for the Duwamish Waterway area, which is a subset of the larger Seattle circle. The general vicinity of the Duwamish area CBC is depicted in Figure 3, but CBC data do not specify the precise locations where Canada geese were detected or the numbers encountered at each site. As discussed in Section 3.1, Canada geese are most often associated with a body of water; thus, geese reported in the Duwamish area CBC were most likely detected close to the waterway. The total number of Canada geese reported in the annual one-day counts conducted from 2000 to 2013 in the Duwamish area averaged 52.5 birds (range 24 to 105 birds per count), with no correction for sampling effort. The counts typically are conducted over a 6- to 7-hour period. It is not known how much movement occurs among goose flocks during the course of the day, and it is possible that some individuals may have been double-counted. It is also very likely that others are not counted because the CBC is a sample of birds in the area, not an exhaustive survey. Relatively few migratory Canada geese (primarily cackling geese) have been reported in the Duwamish area CBC, and it is likely that most geese in the area are residents.

An older report cited in the Baseline Ecological Risk Assessment of the Lower Duwamish Waterway Remedial Investigation (Lower Duwamish Waterway Group 2007) stated that:

"Migratory Canada geese arrive in the LDW in January and February and remain until the end of July as a spring nesting population…40 to 50 birds overwinter from September to April along Kellogg Island and the west bank of the waterway along the South Park district and in the Upper Turning Basin (Canning et al. 1979)."

The field studies supporting this report occurred during the period of rapidly increasing population growth of resident Canada geese, and the numbers stated for the LDW appear to be too low based on more recent information. Moreover, it is currently recognized that geese breeding in western Washington are resident, not migratory, birds.

Another source of observations of Canada geese in the Duwamish Waterway area is eBird, a website operated by the Cornell Lab of Ornithology to compile birdwatchers' records of bird species occurrence and abundance. These data are recorded in the form of daily checklists of birds detected at specific sites that are submitted by birdwatchers to the eBird website. These samples have no protocols regarding the timing, frequency, or duration of site visits, or the size of the area surveyed, and therefore the data have limited utility in estimating the overall abundance or population trends of Canada geese. However, they do indicate that Canada geese are almost always present in all areas that have been surveyed. They also offer the average and maximum numbers of geese detected at each site and some insight into differences in seasonal occurrence. Checklists have been posted to eBird for 18 sites in the Duwamish Waterway area (Figure 3) including two sites that have been visited multiple times over a number of years, the T-107 Park (N = 17 checklists from 2011 to 2013) and a nearby site called the Duwamish River site (N = 24 checklists from 2005 to 2013). The remaining survey sites shown in Figure 3 had 4 or fewer checklists from 2010 to 2013.

Checklists have been posted to eBird in every month except December and most checklists have noted the presence of Canada geese (Table 1). Thus, Canada geese are year-round residents in the vicinity of the Duwamish waterway and are widespread in the area. The average and highest counts of Canada geese at these sites each month indicate peaks in winter months (November and January; no checklists were recorded in December) and summer months (June through July). Geese detected during summer months are residents that likely are breeding in the area surrounding the Duwamish Waterway. Both migrant and resident geese may be present during winter months, but the checklists do not distinguish between the two populations. Only a few checklists identified geese to the subspecies level—all of these were *B. canadensis moffitti/maxima*, the large-bodied resident subspecies in the Seattle area. No records of the migratory cackling goose were found in the Duwamish area eBird checklists, but many birdwatchers do not distinguish between the two species.

In summary, available data in the Duwamish area indicate that Canada geese are widespread and present year-round. Peaks in abundance may occur in winter months and summer brood-rearing months, but the CBC and eBird data sets are not sufficient to reliably estimate population abundance in the Duwamish area.

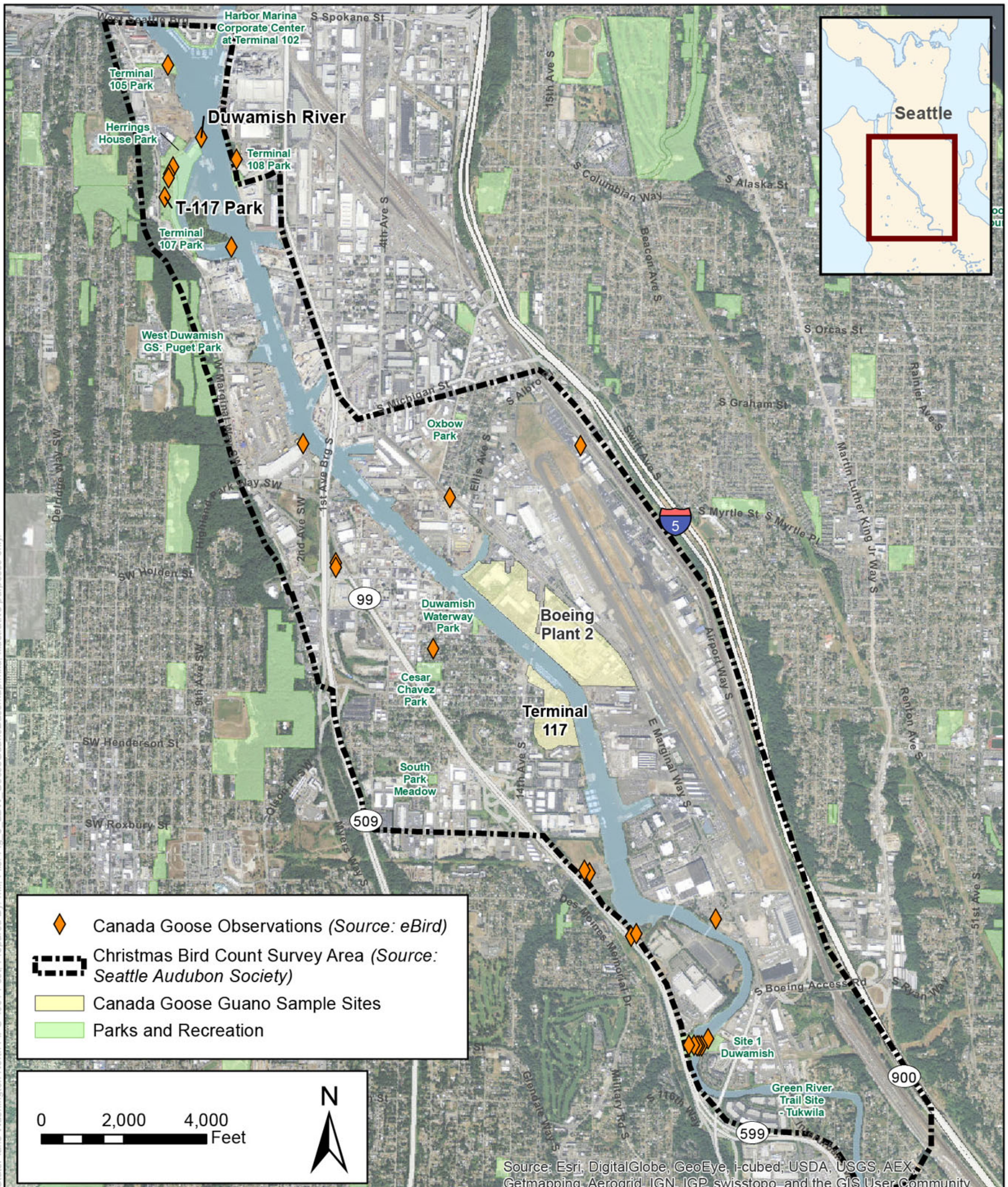


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Figure 3. Canada Goose Observations Near the Lower Duwamish Waterway

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Table 1. Canada Goose Counts at Duwamish Area Sites by Month, 2005–2013 Surveys

Month	Number of Checklists	Average Number of Geese per Checklist	Range
January	4	30.5	3–73
February	2	2	2
March	3	4	2–3
April	13	5.8	1–15
May	12	11.8	1–30
June	4	24.8	12–35
July	6	26.7	1–73
August	3	15.7	4–22
September	4	4.3	2–9
October	2	3	2–4
November	3	26.7	1–49
December	0	0	
Total No. of Checklists	**56**		

Source: eBird 2013

2.4 Productivity and Mortality

The productivity of Canada goose populations that nest in temperate regions of the United States and southern Canada (primarily resident geese) tends to be less variable than productivity of tundra-nesting populations (i.e., migratory geese). Predation on eggs and severe weather are major sources of mortality affecting productivity in the tundra (Sargeant and Raveling 1992); localized drought and flood events are the most important factors influencing productivity of resident geese (USFWS 2012). Urban Canada geese are highly productive, producing up to six young per pair each year, and have high fledging success (Allan et al. 1995). Canada geese hatched in urban environments have low first-year mortality relative to goslings hatched elsewhere: for example, goslings in a long-term study in urban Connecticut sites had a survival rate of 76 percent through fledging (Conover 1998), and urban-born juveniles' survival was well above 90 percent from September through the first hunting season (Smith et al. 1999). In contrast, first-year survival of migratory juvenile Canada geese averages 59 percent (Samuel et al. 1990; Smith et al. 1999). Adult Canada geese have few natural predators and adult mortality is low in urban areas because there is little shooting. High nesting productivity and juvenile and adult survival have allowed urban populations to grow rapidly.

3.0 Habitat Use, Movements, Diet and Feeding Habits

3.1 Habitat Use

In urban-suburban areas, breeding Canada geese prefer sites associated with a body of water, and if available, select those ponds and small lakes with islands (Conover 1998). Geese tend to occur in areas where lawns abut a water body, have the least flight-clearance angle (angle from center of lawn the goose would have to fly to clear surrounding obstacles), and have the ability to detect approaching predators (Conover and Kania 1991). The Puget Sound region provides a mosaic of lawns, golf courses, airports, parks, and recreational fields in close proximity to water that is well suited to Canada geese. The Duwamish area offers feeding opportunities for resident Canada geese in lawns and habitat restoration sites where sedges have been planted and other preferred wetland plant foods, such as *Polygonum* and *Triglochin*, are available (Cordell et al. 2001).

Canada geese usually nest in close proximity to water. They prefer to nest on islands that afford some protection from mammalian predators such as foxes, coyotes, and raccoons, but these sites are typically limited in the landscape (Klopman 1958; Vermeer 1970). In rural areas Canada geese nesting on islands have higher nesting success than geese nesting where terrestrial predators are present. Predators were responsible for almost half of nest failures in an analysis of 17 studies (Bellrose 1980). However, nesting success at urban mainland nest sites in a long-term New England study was similar to success at island nest sites, likely because fewer terrestrial predators are present, and availability of insular nesting sites probably does not limit reproduction in urban Canada goose populations (Gosser and Conover 1999). Most nests are placed on the ground, although elevated locations such as abandoned beaver or muskrat lodges or manmade structures are used. After goslings hatch, adults may move their broods to sites with mowed lawns that provide food for the goslings and open sight lines that enhance detection of predators. Broods frequent wet, gradually sloping banks of streams or ponds, moist river and slough levee meadows, shallow ponds, and mudflats where forage is abundant (Bellrose 1980; Sedinger and Raveling 1986). Broods generally remain within a few kilometers of their nest sites unless the nest site is on an island in a large river; in these cases a greater distance may be covered to reach suitable feeding areas.

Resident Canada geese are considerably more tolerant of human presence than migratory geese, and the following discussion pertains primarily to urban resident geese. Geese use lawns, agricultural fields, marshes, lagoons, parking lots, and wooded areas for feeding and resting. Secure industrial complexes and urban public parks are preferred sites where suitable habitat is available. In parks where geese are fed by humans, large numbers of adults and goslings will congregate during the summer and sometimes become aggressive toward people. Geese prefer to rest and feed on grassy areas next to water, although they will readily forage in fields a mile or more from water. During the summer molting period, when they are flightless, they are reluctant to move far from the safety of water. When geese leave a water body, they generally use routes that allow them easy access onto land as well as a clear view of potential danger. Areas with vegetative cover such as tall grasses, hedges, and shrubs may be less attractive to geese because of the threat of undetected predators.

3.2 Movements of Resident Geese

Resident Canada goose flock movements have not been studied in Washington (Kreage 2014, personal communication). Based on studies of urban geese elsewhere, Canada geese show site fidelity; i.e., pairs tend to nest and forage in the same places from year to year, but within the population a wide range of movement patterns may occur. Radio-tagged adult resident female geese in Wisconsin traveled less than 1 km to 109 km from their nesting area during the breeding season, but movement patterns of individuals did not vary markedly between years (VerCauteren and Marks 2004). Similarly, nest sites were consistent among years within individuals. A long-term study in Connecticut indicated that hatch-year geese may disperse long distances, for example to adjacent states, but those that are recruited into the local breeding population rarely leave the region (Conover 2011). Migratory Canada goose populations retain cohesive family units (i.e., parents and their hatch-year offspring), and juveniles learn migration routes from their parents. The extent of family unit cohesiveness among resident populations has not been described in the literature but is likely to last also for the first year of an individual's life.

Only anecdotal information on resident goose movements was obtained from Seattle-area wildlife biologists and the birding community, but in general it is thought that geese do not move far from occupied urban sites unless they are stressed by humans, predators, or the food supply dwindles. Otherwise resident geese appear to be fairly sedentary. M. Hobbs (2013), who conducts bird surveys in Marymoor Park, stated that flocks are almost always seen flying overhead during his weekly surveys, and approximately one-third of the time they will land in large numbers on grassy fields in the park, where they remain typically for about half the day. Numbers of geese vary widely from day to day. Particularly with regard to cackling geese, he believes the flocks are not stable in composition based on the occurrence of neck-banded individuals in various combinations within a flock. However, no banded Canada geese are ever detected in these surveys, so less anecdotal information is available about their movements or origins. D. Kraege (2014), Washington Department of Fish and Wildlife (WDFW) Waterfowl Section Manager, stated that WDFW's best information on urban geese is from leg band recoveries from hunters and sightings of coded neck collars. Unfortunately, no urban geese from western Washington have been marked recently. Urban flocks in the Puget Sound region are probably fairly sedentary, but some cohorts may undertake molt migrations to other areas (sometimes as far away as northern Canada), and some geese from other areas molt in the Puget Sound region. There is a fair amount of migration into the region from geese originating in Alaska, but WDFW does not conduct migration counts in the urban areas.

3.3 Diet and Feeding Habits

Canada geese evolved as tundra-dwelling birds that graze on vegetation while walking on land and also feed on submerged aquatic plants. They are unusual among birds because they are almost exclusively herbivorous. Canada geese will take a wide variety of wild plant foods such as native grasses, pondweed, sedges, cattails, and rushes. Agricultural crops including corn, alfalfa, wheat, soybeans, and other grains are used by almost all populations of Canada geese when available. *B.C moffitti/maxima* have become acclimated to urban environments in which they graze on domesticated grasses (lawn and pasture grasses and clover) throughout the year (Conover and Kania 1991). As grazers, Canada geese clip stems and leaves of plants; they also extract rhizomes and bulbs, and strip seeds and berries from plants.

4.0 Canada Geese as Contaminant Vectors

Large numbers of Canada geese can lead to accumulation of feces in areas that drain into surface waters. Studies of the impacts of large urban Canada goose populations have focused on two areas of concern: degradation of aquatic ecosystems and dispersal of human pathogens in drinking water supplies. Additionally, the occurrence of agricultural and industrial contaminants in body tissues of Canada geese has been studied because of the effects of contaminants on the health and reproduction of wild geese and humans who consume them.

4.1 Impacts on Water Quality and Aquatic Ecosystems

Canada geese and other waterfowl congregate in flocks within urban settings, likely due to available water sources, predator-free grasslands, and readily available food, some of which is supplied by humans. They contribute to the degradation of terrestrial and aquatic environments because they deposit large amounts of fecal matter which can overfertilize areas where geese congregate (Manny et al. 1975, 1994; Scherer et al. 1995; Unckless and Makarewicz 2007). Some of these studies reported daily production of guano by geese and other waterfowl; results are discussed below in Section 5. Guano deposited in terrestrial sites can be transported in runoff into nearby surface waters. The result may be eutrophication of ponds and lakes, leading to excessive algal growth, reduced oxygen, and die-off of the aquatic biota (VerCauteren and Marks 2004).

Canada geese and other waterfowl have been studied as vectors of fecal coliforms and other bacteria that degrade water quality, and pathogens (Graczyk et al. 1998, 2008). Studies at Juanita Beach on Lake Washington in 1998 identified ducks and geese as the major source of fecal coliform pollution, but in other locations domestic pet waste and sewage leaks were identified as the sources (WDFW 2013). Waterfowl may excrete large amounts of fecal bacteria and occasionally excrete enteric pathogens including *Cryptosporidium parvum*, microsporidia species, *Salmonella spp*., and *Giardia* spp. (Hussong et al. 1979; Graczyk et al. 1998; Alderisio and DeLuca 1999; Unckless and Makarewicz 2007; Graczyk et al. 2008; Jellison et al. 2009; Lu et al. 2009; Kullas et al. 2002; Moriarty et al. 2011). The extent of the impact of waterfowl on aquatic sites depends on the numbers of fecal indicator bacteria discharged, the accumulation of organic matter in sediments, and the presence or absence of pathogens in the bird feces (Hussong et al. 1979). The geese appear to act as mechanical dispersal agents of pathogenic microorganisms after ingesting them in feeding areas such as cattle pastures, and do not host chronic intestinal populations (Hussong et al. 1979; Graczyk et al. 1998). For this reason Canada geese do not appear to be a significant source of any infectious disease that is transmittable to humans or domestic animals.

4.2 Canada Geese as Vectors of Industrial Contaminants

The literature review of fecal contaminants did not identify any studies of waterfowl guano as a vector of contaminants derived from agricultural or industrial chemicals such as organochlorines or heavy metals. Instead, research has focused on the occurrence of these contaminants in body tissues and eggs of waterfowl and seabirds, biomagnification, and thresholds of toxic effects (Bosveld and Van den Berg 1994; Hoffman et al. 1996; Van den Berg et al. 1998).

Organochlorine contaminant loads including PCBs in body tissues of birds are of great concern to wildlife managers because of the demonstrated adverse effects. Acute toxicity of PCBs in birds depends on the amount of chlorination of the PCB mixtures; brain residues greater than 300 mg/kg are generally associated with mortality (Barron et al. 1995). Sublethal effects in adults include abnormal reproductive behavior. PCBs cause adverse developmental effects, endocrine disruption, immunotoxicity, and teratogenesis, but the assessment of injury to birds from PCBs has been complicated by interactions with other chlorinated hydrocarbons that are present in field-collected specimens and soil and water samples (Barron et al. 1995). Canada geese and various duck species have been a particular focus in research because samples obtained from fat and muscle of some wild waterfowl have exceeded the consumption guideline for PCBs in edible poultry (3 ppm [fat basis]) (21 CFR 109.30).

4.2.1 PCB Concentrations in Seabirds

In avian species, PCB bioaccumulation is related to composition of food items, sex and age of the bird, migratory and breeding status, and residence time in PCB-contaminated areas (Struger and Weseloh 1985; Weseloh et al. 1989). Although most studies that were reviewed considered total PCBs or the most prevalent congeners in the environment, differences in dietary congener content, and differences in congener hydrophobicity and resistance to metabolism contribute to observed patterns of PCB occurrence in bird species (Barron et al. 1995). In the environment, PCBs are slowly degraded through abiotic and biological transformations such that the dietary congener composition may not represent the original mixture on a site. Variation in PCB concentrations of different bird species, age classes, and sexes may be related to congener specific toxicokinetics, differences in feeding behavior and intake, or PCB transfer by adult females to eggs (Barron et al. 1995). A subset of about 20 planar PCBs, in particular the highly chlorinated PCBs 138, 153, and 180, appears to account for most of the PCB burden in liver and adipose tissues and eggs of birds (Eisler and Belisle 1996).

Since the presence of PCBs in North American seabirds was first documented in the 1960s, many studies have documented elevated contaminant loads in eggs and body tissues of seabirds (double-crested cormorant, tern species, gulls species), fish-eating raptors (bald eagle, osprey); wading birds (great blue herons and black-crowned night herons); and waterfowl (Canada goose, snow goose, diving ducks, and dabbling ducks). Some comparisons of contaminant loads, in particular PCBs, are described below for various taxa.

Organochlorines including PCBs biomagnify in food chains, accumulate primarily in adipose tissues and eggs, and generally have the highest concentrations in fish-eating birds (review in Eisler and Belisle 1996). The most extensive early monitoring studies of contaminants in waterfowl were conducted between 1969 and 1981/1982 by the U.S. Fish and Wildlife Service, using wing muscle tissue provided by hunters from two dabbling duck species, mallards (*Anas platyrhynchos*) and black ducks (*Anas rubripes*) (Heath and Hill 1974; White 1979; Prouty and Brunck 1986). The highest PCB concentrations were found in sites along the Atlantic flyway in 1972, where mean levels were 1.36 µg/g wet weight in black ducks and 1.24 µg/g wet weight in mallards (White 1979). Dabbling ducks feed primarily on aquatic vegetation but also consume some invertebrates including insects.

Fish-eating waterfowl (such as merganser species) and seabirds had comparatively high total PCB and high planar PCB concentrations; waterfowl and seabirds that feed on invertebrates had lower PCB concentrations (Focardi et al. 1988; Borlakoglu et al. 1990; Gonzalez et al. 1991). Diving ducks, which consume fish and benthic invertebrates, have greater exposure to sediments than dabbling ducks, which consume primarily vegetation but also some invertebrates; for this reason, diving ducks tend to bioaccumulate higher concentrations of persistent organochlorine compounds. Several diving duck species that were collected during winter from the Detroit River (common goldeneye [*Bucephala clangula*], lesser scaup [*Aythya affinis*], and greater scaup [*A. marila*]) had mean PCB carcass concentrations of 7.6, 10, and 11 µg/g wet weight, respectively (Smith et al. 1985). Other studies have compared organochlorine contaminant patterns in diving ducks and dabbling ducks at sites in the Great Lakes (Mazak et al. 1997), across Canada (Braune et al. 1999; Braune and Malone 2006), and New York (Kim et al. 1984, 1985). Results of these studies support the finding that waterfowl feeding at a higher trophic level acquire higher concentrations of organochlorine contaminants.

PCB concentrations were higher in adipose tissues of the Arctic tern (*Sterna paradisaea*) than in those of their fish and invertebrate food items (Scharenberg 1991a), indicating biomagnification. PCB concentrations in adipose tissues of cormorants, when compared to the fishes they consume, were 10 to 100 times higher than marine fishes and 100 to 1,000 times higher than freshwater fishes (Scharenberg 1991b). Double-crested cormorants (*Phalacrocorax auritus*) biomagnify total PCBs from their fish diet to their eggs by a factor 31.3 (Jones et al. 1994). High biomagnification factors (BMF, measured variously as the ratio of tissue to water PCB concentrations, or the ratio of tissue to prey PCB concentration) were reported in herring gulls and mallards (Anderson and Hickey 1976; Norstrom et al. 1976; Braune and Norstrom 1989).

Because they are herbivores, Canada geese tend to accumulate lower organochlorine loads, including total PCBs, than fish- and invertebrate-consuming waterfowl. The median concentration of total PCBs in goose muscle samples from Tennessee was 0.32 ppm (ATSDR 2009) and 0.7 ppm wet weight in Lake Erie (Weseloh et al. 1995). Migratory Canada geese shot in New York had significantly lower levels of PCBs in fat and breast muscle than several dabbling and diving duck species (black duck, mallard, scaup, and bufflehead) (Foley 1992) and fish-eating mergansers (Kim et al. 1984, 1985). Canada geese eggs had consistently lower contaminant loads than any of the fish-eating colonial waterfowl species in long-term studies in an industrial site on Lake Ontario (Weseloh et al. 1995): the maximum recorded total PCB loads in eggs of double-crested cormorants, black-crowned night-herons, Caspian terns, and common terns were 9.4, 8.0, 10.5, and 6.6 mg/kg wet weight, respectively, compared to 0.7 mg/kg in Canada geese eggs.

Several patterns of PCB accumulation related to sex and age have been demonstrated in seabirds and waterfowl. For example, Arctic terns and herring gulls feeding on PCB-contaminated fish exhibited the highest concentrations of PCBs in adults and newly hatched chicks, and lowest concentrations of chicks just prior to fledging (Lemmetyinen et al. 1982). Total PCB concentrations are usually higher in male seabirds and fish-eating waterfowl, but this varies by species (Norstrom et al. 1976; Lemmetyinen et al. 1983; Eisler and Belisle 1996).

4.2.2 Environmental Sources of Contaminants in Seabirds and Waterfowl

Barron et al. (1995) reviewed studies of reproductive and developmental toxicology of PCBs in birds in relation to congener composition in order to provide information needed to assess risk of environmental PCB exposure to bird populations. This review and subsequent studies also examined patterns of accumulation of specific PCB congeners in bald eagles (e.g., Glaser and Connolly 2002) and seabirds (O'Keefe et al. 2005), and waterfowl species, in relation to sampling location and species trophic level in an attempt to deduce the sites where the contaminants were ingested. However, these studies focused on fish-eating birds, not Canada geese.

Post-hatching Canada geese likely acquire their contaminant burdens from soil or sediments and plant material. Soil or sediments are typically ingested by grazing animals like Canada geese (Beyer et al. 1994). Ingested soil may be the principal means of exposure to some environmental contaminants (Beyer et al. 1994). The average acid-insoluble ash content of the feces, a measure of sediment ingestion, was 18% for Canada geese and tundra swans, and 12% for ducks. The 18% value corresponded to an estimated 9% sediment ingestion rate (dry weight) (Beyer 1994). Plants consumed by Canada geese are also a source of environmental contaminants. In terrestrial plants, the principal pathway of contamination is the atmospheric deposition of contaminated particles on soils and leaves (Campanella et al. 2002). In aquatic systems, contaminants are present in the water column but accumulate in sediments, particularly in organic matter. Submerged aquatic vascular plants (i.e., plants that grow under the water's surface) such as the American wild celery *Vallisneria americana,* are capable of accumulating significant amounts of organochlorine contaminants (Lovett-Doust et al. 1994). Root tissue concentrations were higher than other plant parts, suggesting contaminant transfer occurred from sediments to the roots. Little information was found on contaminant concentrations of other wild aquatic plants in the diet of Canada geese, but it is possible that other species are involved in the transfer as well. Migratory Canada geese likely acquire most of their contaminant loads while on wintering grounds in the lower 48 states and southern Canada, since their breeding grounds in the Arctic and sub-Arctic are relatively freer of environmental sources.

Dietary PCBs are rapidly and extensively absorbed by birds and then internally distributed according to the lipid content of tissues (deFreitas and Norstrom 1974). PCB concentrations in bird tissues may change rapidly during migration, periods of starvation, or egg formation (Ram and Gillett 1993). For example, PCBs were redistributed from adipose tissue to muscle tissue in pigeons during starvation and then returned to adipose tissue after food was resupplied (deFreitas and Norstrom 1974), and tissue concentrations of PCBs changed in herring gulls depending on seasonal changes in lipid deposition (Anderson and Hickey 1976).

4.2.3 Elimination of PCBs

Similar to other animal species, PCBs are eliminated by birds through the processes of biotransformation, excretion in feces, and egg formation (Braune and Norstrom 1989). The dominant elimination process and elimination rate appears dependent on congener structure. It has been suggested that fecal excretion may be most important for eliminating PCBs that are resistant to metabolism (Barron et al. 1995), but studies exploring this possibility were not found in the literature search. In herring gulls, contaminant elimination varied seasonally in relationship to the size of the bird's fat reserves; decreasing lipid content was associated with an increase in the elimination rate (Clark et al. 1987). In resident Canada geese this would probably occur during the winter. It is likely that some contaminants mobilized from fat tissues would be excreted in their feces, but no information was found in the literature.

Metabolism is an important elimination process in birds for specific PCB congeners (Barron et al. 1995). In general, increasing chlorination decreases the rate of metabolism, although the substitution pattern appears to be the principal structural determinant of biotransformation (deFreitas and Norstrom 1974). In addition, PCBs are maternally transferred to eggs when yolk lipids are deposited in the forming eggs but the patterns of transfer vary with different species. For example, Adelie penguins transferred a relatively small fraction of maternal PCBs to eggs compared to Arctic terns and herring gulls (Tanabe et al. 1986; Lemmetyinen et al. 1982), perhaps because clutches of tern and gull eggs comprised a larger fraction of the maternal body weight. On an annual basis, however, maternal transfer may be less important than other elimination processes such as excretion (Barron et al. 1995).

In spite of the data available on PCB occurrence and metabolic pathways in the tissues of waterfowl, and studies of the occurrence of pathogens in guano, there are no reports in the literature of PCB content of bird guano. Ecology's data on PCB occurrence in goose guano samples at T-117 and Boeing Plant 2 are the only values we found.

5.0 Waste Production

A few studies have reported waste production of Canada geese (summarized in Table 2) in the context of water quality studies. Goose guano production varies depending on the quantity, quality, and moisture content of the food that was consumed, and the size of the goose. Estimates of daily guano production are expected to vary considerably by season and geographical location, in part because of the body size range of the different Canada goose populations. The highest values were reported by Kear (1963) for relatively large geese at an Atlantic flyway site (Table 2). Scherer et al. (1995) and Manny et al. (1975) reported more conservative estimates of daily guano production by captive and wild Canada geese in Seattle, Washington, and by wild Canada geese at a Midwestern site, respectively. Thus, total daily production per bird in these studies ranged from 156.8 g/day wet weight (32.76 g/day dry weight) to 1,030.4 g/day wet weight (174.8 g/day dry weight). In general, production of droppings (dry weight) by waterfowl species at Green Lake in Seattle was estimated to be 2.25 percent of their body weight per day (Scherer et al. 1995).

Grazing animals consume diets with relatively low content of digestible matter and large amounts of fiber. Geese have low digestive efficiencies compared to mammalian grazing animals, and process their food quickly. In flying birds, excess weight must be kept to a minimum and so a quick digestive action is to be expected. Through-put time (i.e., the time taken for food material to pass through the alimentary canal) in domestic geese was about two hours (Mattocks 1971), in contrast to the microbial fermentation processes requiring twelve hours or more in cows, sheep and goats (Durant 2003). Processing time in the alimentary canal and the degree of absorption of ingested matter have implications for the possible contamination of sites by waterfowl, although no studies of geese were found. Mallards, which are largely herbivorous, absorbed far less of PCB, dieldrin, and mercury than several other non-grazing species (northern bobwhite, screech owl, and American kestrel) (Serafin 1984). Among avian species (geese and ducks) that consume diets with a low content of digestible matter, there seems to be a very large capacity to consume food and to pass it quickly through the alimentary tract. Rapid transit rates reduce the chances that absorption of contaminants will occur because exposure to absorptive surfaces is limited (Serafin 1984). After feeding on lawn grasses or aquatic plants, resident geese frequently will rest in the same area, particularly during the nesting, brood-rearing, and molting periods. Thus, sedentary individuals may consume contaminated soil, sediments, and vegetation and redeposit these materials on the same site. Other resident geese, however, may use sites differently, feeding in one area and flying to another to rest.

Table 2. Characteristics of Canada Goose Pellets

Parameter	Kear (1963)[1]	Manny et al. (1975)[1]	Scherer et al. 1995[1]	Alderiso and DeLuca 1999	Graczyk et al. 1998	Hussong et al. 1979
Goose Size	4.64 kg avg wt	2.56 kg avg wt	3.63 kg avg wt			
Daily pellet production	92/day	28/day				
Wet weight/pellet	11.2 g	5.6 g		8.35 g	17.2 g	
Dry weight/ pellet	1.9 g	1.17 g				
Moisture Content of pellets	83%	79%				
Estimated Wet Weight of Droppings/Day	1,030.4 g	156.8 g				250 g (wild) 202 g (captive)
Estimated Dry Weight of Droppings/Day	174.8g/day	32.8 g/day	81.6 g/day			

1. Adapted from Mandaville 2000

The following are very rough estimates of PCB dispersal on Duwamish sites by Canada geese, based on limited available information and two sets of assumptions. These estimates are included in an effort to focus on the potential significance of geese as contaminant vectors but are not sufficiently reliable to base management decisions involving, for example, population control. Under a highly conservative scenario, we assume that 100 Canada geese are present on the waterway every day, that each bird produces 175 g (dry weight [DW]) of droppings per day (from Kear 1963), and that the PCB load of goose pellets is 280 ppb (µg/kg DW), based on a single composite sample collected at Terminal 117. Under a more realistic scenario, we assume that each bird produces 33 g of droppings per day (from Manny 1975) and the PCB load of goose pellets is 58 ppb, based on the average of four composite samples collected at Boeing Plant 2. Based on these assumptions, we estimate that between 70 g and 1,800 g of PCBs may be deposited in or near the Duwamish Waterway by Canada geese each year.

6.0 Recommendations

6.1 On-Site Surveys

The literature review supports the concern that Canada geese can disperse contaminants in their guano. However, the significance of the risk of re-contaminating Duwamish remediation sites cannot be determined with existing data. The only available Canada goose occurrence data for the Duwamish waterway area is from citizen science efforts that were not designed to answer this question. If better information on population abundance were available, it may be possible to more reliably extrapolate the quantity of guano deposited on the sites by Canada geese. Seasonal changes in population abundance should be better documented to confirm that numbers of birds vary over time. Moreover, we do not have a good understanding from available data on how Canada geese use locations on the Duwamish waterway, and how much time they tend to spend on the waterway and adjacent sites. The amount of residence time in the Duwamish system may affect the deposition of contaminants there.

More frequent surveys of the sites with a well-defined sampling protocol will permit comparisons over time. The survey effort might focus on summer and winter months when numbers of geese are likely to be highest due to possible influx of resident goose broods (in summer) and migratory geese (in winter). We recommend a once-weekly survey lasting 20 minutes at sites of interest in the Duwamish corridor to count the Canada geese, note their behavior (i.e., feeding or resting, what they are feeding on, and movements to and from feeding and resting sites). At a minimum these weekly surveys should be conducted during the periods of highest Canada goose numbers as indicated by previous survey efforts (May – August; November – February). Initial reconnaissance visits to the Duwamish area would be required to identify the best survey sites, in collaboration with Ecology staff. Suitable survey sites would include locations that drain into the Duwamish Waterway, provide forage for geese, and are known to be regularly occupied by geese in CBC and eBird surveys. We recommend that surveys be considered at a minimum of 10 sites initially, with the expectation that some sites may not be occupied by geese during every survey. Additional focal behavioral surveys lasting 4 hours twice per month should be conducted to sample how long individual geese remain on the sites, their feeding rates, and defecation rates, in order to refine estimates of daily guano production.

Given the speed of their digestion, geese may ingest contaminants on a site and re-deposit them in close proximity during the course of a single foraging/resting bout. PCB concentrations in goose guano, lawn grasses, aquatic vegetation, and soils should be tested at all of the survey sites in order to identify whether the problem of ingestion and re-deposition of contaminants within the Duwamish system is widespread.

6.2 Evaluate Other Waterfowl and Seabirds as Contaminant Vectors

As discussed in Section 4.2, fish-eating and invertebrate-eating birds generally have higher organochlorine loads than herbivores such as Canada geese. The scope of this report did not include evaluation of populations of other seabirds and waterfowl known to occur in the Duwamish area, such as cormorants, gulls, mallards, and American wigeon. We recommend evaluating available data on occurrences of other species that are thought to be abundant in the area to consider whether they may be contributing to the dispersal of contaminants.

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