Waterfowl management in stormwater management ponds

by

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Author's Declaration for Electronic Submission of a Thesis

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Urbanization, which is ever increasing on a global scale, can negatively affect wildlife and habitat as well as biotic realms including air, soil, and water. One of the impacts of urbanization is urban runoff. A method commonly employed to mitigate runoff is the construction of stormwater management ponds (SWMPs). These ponds have created new habitat for urban wildlife, especially waterfowl such as Canada geese and mallard ducks. In some municipalities, increased numbers and densities of waterfowl near SWMPs are considered a nuisance due to their large numbers, considerable amount of fecal matter and because they may create health hazards. This research specifically examines the influence of species composition and height of vegetation around SWMPs on waterfowl use and whether changes in *Escherichia coli* counts are attributed to waterfowl use. Ponds were visited 140 times between April 2005 and June 2006. At each site, the number of Canada geese, mallard ducks, and other waterfowl species was recorded. Geese significantly preferred ponds with short vegetation ($F = 53.45$, $p < 0.0001$) and ducks exhibited no preference ($F= 2.17$, $p = 0.347$). The time (day) that observations were made was a factor indicating that there were temporal variations among seasons; geese were slightly more affected by time ($F = 16.08$, $p < 0.0001$) than ducks ($F = 11.18$, $p < 0.001$). This was not surprising given that waterfowl generally migrate locally across seasons. This result also supported the hypothesis that geese respond to changes in vegetation height. The influence of time coincides with the development of vegetation between spring and summer. Geese moved to the ponds with short vegetation as the growing season progressed, whereas they tended to avoid ponds with more naturalized vegetation due to the increased height. From a management perspective, municipalities can discourage nuisance geese at SWMPs through the naturalization of ponds and decreasing the level of maintenance via less mowing. There was no significant correlation between waterfowl use of ponds and *E. coli* counts. The Pearson's correlation ranged from -0.152 to 0.990, associated p values ranged from 0.07 to 0.981. While further study is required, it appears that waterfowl do not offer any noticeable addition of *E. coli* to stormwater management ponds beyond what is already in the water column from other sources. Therefore, waterfowl may not present a health threat, at least within the pond itself.

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Chapter 1: Introduction

Of the many environmental management issues in urban areas (Appendix A), the impacts of urbanization on urban water courses are extensive. One method to address these concerns are stormwater management ponds (SWMPs). SWMPs are a relatively common approach to address the need for storage capacity because of increased runoff from non- or less-permeable surfaces (e.g. rooftops, roads, lawns) and loss of capacity in riparian zones and increased chanelization (Adams *et al.*, 1984; Marsalek, 1991, 2003; Van Buren *et al.*, 1997; Murphy & Martin, 2001; Ministry of the Environment, 2003, pp. 1-3 - 1-9; Marsh, 2005). Generally SWMPs are designed to collect stormwater runoff, impound pollutants and sediment, and then release water at a controlled rate (Adams *et al.*, 1985b; Ministry of the Environment, 2003; Wheater, 1999, p. 125). The Ontario Ministry of the Environment (MOE) recognizes that ponds are required to attain four objectives: (1) maintain the hydrologic cycle, (2) prevent an increase in the risk of flooding, (3) prevent undesirable stream erosion, and (4) protect water quality (Ministry of the Environment, 2003). In terms of policy, the MOE produced a manual offering guidance on SWMP design. The manual included physical constraints to the use of ponds: sizing and configuration, design details on inlets and outlets, filter media and pipes, cold climate considerations, and incorporating vegetation into pond design as a functional component (for the purpose of reducing flow velocity and preventing re-suspension). The manual also offers guidance on environmental design criteria, development of stormwater management plans, operation, maintenance and monitoring, and capital and operational costs.

Further to this manual, many resources focus on improving pollutant impoundment rates (Van Buren, Watt & Marsalek, 1996, 1997; Pettersson, 1998), adaptations to cold climates (Marsalek *et al.*, 2000; Marsalek, 2003); and monitoring and maintenance (Graham & Lei, 2000; Yousef *et al.*, 1996). Despite detailed research on the above SWMP components, there is little on the cumulative ecological impacts, especially in terms of how wildlife – especially waterfowl – use and affect SWMPs. Specifically, waterfowl that use SWMPs may be perceived as a nuisance and a health hazard.

Canada geese are often a vexing problem for politicians, municipal staff, and citizens if only because of the copious amounts of green-tinged feces on the surrounding land or sometimes visible in the water (Ankney, 1996; Chasko & Conover, 1988; Conover & Chasko, 1985; Conover & Kania, 1991; Converse *et al.*, 1999; Cooper & Keefe, 1997; Sherman & Barras, 2004; Smith *et al.*, 1999). Geese utilize areas that are often shared, however reluctantly, by humans. These areas include parks (often with lawn areas), residential lawns, beaches and golf courses. As of 2002, geese were considered a problem in more than 100 urban areas in 37 U.S. states (Mowbray *et al.*, 2002). Geese have been implicated in water pollution episodes such as the over-fertilization of small lakes and reservoirs (Conover, 1996; Hussong *et al.*, 1979), lost revenue for golf courses because of feces on the greens (Conover & Chasko, 1985), reduction of the aesthetic and recreational value of playing fields and beaches (Ankney, 1996; Conover, 1996), and the human health risk associated with fecal contamination of urban habitats (Abulreesh *et al.*, 2005; Fallacara *et al.*, 2004; Kassa *et al.*, 2001).

Nuisance geese in urban-suburban areas tend to occur in areas where lawns abut a water body, where there is the least flight-clearance angle (the angle from the centre of a lawn that geese would have to fly to clear surrounding obstacles), and where they have the ability to detect approaching predators (Conover & Kania, 1991). Thus, urban water bodies attract geese and they remain in these areas on nearby lawns. Open water habitats have increased in urban-suburban areas with the creation of SWMPs. In many locations it is aesthetically pleasing for manicured landscapes to surround SWMPs, and this provides the most ideal habitat for Canada geese.

1.1 Objectives

The primary objective of this study is to determine if there are vegetation characteristics surrounding SWMPs that affect waterfowl use of a particular pond. The vegetation characteristics of importance are vegetation height and species composition. This information can assist city planners and urban ecologists in understanding how to manage the nuisance goose populations in suburban/urban areas through planting strategies.

The secondary objective is to determine if the number of waterfowl at a site influences the levels of *E. coli* in the pond. Waterfowl have been implicated in the pollution of water courses and this study will test for levels of *E. coli* in the pond and determine if waterfowl are responsible for increased levels of *E. coli* in SWMPs.

This thesis will:

1. Ascertain if there are vegetation characteristics affecting waterfowl use at a site
2. Determine the specific vegetation characteristics exerting influence
3. Determine if increased numbers of waterfowl cause elevated levels of *E. coli* in the water column of SWMPs

Chapter 2: Literature Review

This review seeks to provide an understanding of the main components of this study: SWMPs in general and the habitat that they provide; urban waterfowl and associated issues, and problems associated with increased waterfowl from an ecological and health risk perspective. The knowledge gained from this research provides direction for the study in order to investigate the research objectives.

2.1 Why stormwater management ponds are used in urban areas

Urbanization increases impervious cover, and the resulting changes to runoff negatively impact aquatic ecosystems and changes the flow characteristics in receiving water courses (Booth & Jackson, 1997; Ministry of the Environment, 2003). Urbanization specifically disrupts the water balance, which, in turn causes an increase in flood peaks and a decrease in lag time (Strahler, 2002; Turner-Gillespie *et al.*, 2003 Ministry of the Environment, 2003). Impervious areas cause runoff rates to increase and infiltration rates to decrease. The effect is that groundwater is not recharged because precipitation flows at too high a discharge rate. Indeed, urbanization interferes with the natural transfers of water between storage zones in the hydrologic cycle (Ministry of the Environment, 2003).

Concomitant with changes to the hydrologic cycle and flood risk, pollutants are problematic as the increased runoff will capture human-created debris and chemicals and the loss of wetlands combined with greater flows means debris and chemicals are transported into any low areas or remaining water courses. The result is turbid waters with higher temperatures and pollutants like sediment from development and new construction; oil, grease and toxic chemicals from vehicles; nutrients and pesticides from turf management and gardening; viruses and bacteria from failing septic systems; sodium and chloride from road salts; and heavy metals (Papiri *et al.*,2003, p.327; Ministry of the Environment, 2003, p.1-9).

The negative effects stemming from urbanization can be addressed through three levels of stormwater management practices that work together: lot-level, conveyance, and end-of-pipe (Table 1). Controls at the lot-level address stormwater on a residential property (an area < 2 ha). Conveyance is a system that drains water from lot-level to the end-of-pipe facilities. The end-of-pipe facilities accept the discharge from the conveyance system, and release the collected stormwater into a receiving water course. This research will focus on the end-of-pipe facilities of SWMPs or 'wet ponds') However, none of these controls are designed with wildlife in mind, and they generally do not consider other issues beyond those focused on hydrology. Introductory documents on planning and design of facilities provided by the MOE (2004) do not include any mention or recognition of wildlife use of these facilities.

In the future, a fundamental solution to stemming the effects of urbanization, probably will involve the reduced use of resources and some form of planning and building alternatives like greenroofs, street buffers, direct stormwater to treatment plant investment, decreased roads in favour of walkable neighbourhoods, and public transit in high density urban cores (*viz*, smart growth) and a range of others provided in Table 1 (Matteo *et al.*, 2006; Ministry of the Environment, 2003; Pim & Ornoy, 2005; Walsh *et al.*, 2005). On a shorter time frame, SWMPs have been a popular intervention. Some SWMPs have achieved removal rates of 90% or higher for many pollutants (Van Buren *et al.*, 1997, p.6). SWMPs (also known as *retention basins* or *wet ponds*) are areas of open water, which can accept extra volume during stormwater events (Adams *et al.*, 1985b; Ministry of the Environment, 2003; Wheater, 1999, p. 125). Water is then released slowly into receiving water courses, lessening the impact of urban runoff downstream (Ministry of the Environment, 2003). Ponds retain pollutants that could create undesirable conditions for aquatic life downstream, in natural water courses (Helfield & Diamond, 1997).

Table 1 - Stormwater Management Practices (adapted from MOE, 2003, p. 1-13)

Stormwater Management Practice	**Water Balance**	**Water Quantity**	**Water Quality**	**Erosion**
Lot Level and Conveyance Controls				
Rooftop storage	L	H	L	L
Parking lot storage	L	H	L	L
Superpipe storage	L	H	L	L
Reduced lot grading	H	L	M	M
Roof leader to ponding area	H	L	M	M
Roof leader to soakway pit	H	L	M	M
Infiltration trench	H	L	H	M
Grassed swales	H	M	M	M
Pervious pipes	H	L	H	M
Pervious catchbasins	H	L	M	M
Vegetated filter strips	H	L	M	M
Natural buffer strips	M	L	M	M
Rooftop gardens	L	L	M	M
End-of-Pipe Controls				
Wet pond	L	H	H	H
Artificial wetland	L	H	H	H
Dry pond	L	H	M	H
Infiltration basin	M	L	H	M
Filters	L	L	H	L
Oil/grit separators	L	L	M	L

H - High Suitability M - Medium Suitability L - Low Suitability

Wet ponds are now the most common end-of-pipe facility employed in Ontario (Minstry of the Environment, 2003, p.4-51). The use of SWMPs is increasing, as planners now require the construction of SWMPs within new residential, commercial and highway developments (Scheuler *et al.*, 1992). Landscaped ponds enhance the attractiveness of the adjacent urban development by maintaining greenspace, offering recreation opportunities for residents, and increasing property values (Baxter *et al.*, 1985; Ministry of the Environment, 2003). In addition, SWMPs are generally inexpensive to construct (Pettersson, 1998, p.115). Thus, stormwater objectives can be achieved, as well as other ecological, functional, social, and economic objectives (Ministry of the Environment, 2003). Their popularity is evident as there are 30 SWMPs in the City of Waterloo, Ontario alone (McGoldrick, 2005), and 53 ponds in the Town of Richmond Hill, Ontario (Powell, 2005).

There are several components that contribute to the efficient design and operation of a SWMP. These are defined in the following table, reproduced from the MOE manual (Table 2).

Table 2 - Summary of design components of SWMPs

Design Element	**Design Objective**	**Minimum Criteria**	**Preferred Criteria**
Drainage area	Volumetric turnover	5 ha	> 10 ha
Treatment volume	Provision of appropriate level of protection (enhanced, normal or basic)	20-240 m^3/ha of storage volume for impervious levels of 35%-85%	Permanent pool volume increase by expected max. ice volume Active storage increase from 40 m^3/ha of total volume
Active storage detention	To promote settling of sediments solids	24 hrs. (12 hrs. if in conflict with minimum orifice size)	24 hrs.
Forebay	Pre-treatment – improve pollutant removal by trapping larger particles near the inlet	Minimum depth: 1 m Sized to ensure non-erosive velocities leaving forebay Max. area: 33% of total permanent pool	Min. depth: 1.5 m Max. volume: 20% of total permanent pool
Length-to-width ratio	Maximize flow path and minimize short-circuiting potential	Overall: min 3:1 (can be accomplished by berms) Forebay: min 2:1	From 4:1 to 5:1
Permanent pool depth	Minimize re-suspension, avoid anoxic conditions	Max. depth: 3 m Mean depth: 1 m – 2 m	Max. depth: 2.5 Mean depth 1 m – 2 m
Active storage depth	Storage/flow control	Water quality and erosion control: max. 1.5 m Total (including quantity control): 2 m	Water quality and erosion control: max. 1 m Total (including quantity control): 2 m
Side slopes	Safety Maximize the functionality of the pond	5:1 for 3 m on either side of the permanent pool Max. 3:1 elsewhere	7:1 near normal water level plus use of 0.3 m steps 4:1 elsewhere
Inlet	Avoid clogging/freezing	Min: 450 mm Preferred pipe slope: >1%	Continued on next page

		If submerged, obvert 150 mm below expected max. ice depth	
Outlet	Avoid clogging/freezing	Min: 450 mm outlet pipe Reverse sloped pipe should have a min. diameter of 150 mm Preferred pipe slope: >1% If orifice control used, 75 mm diameter min.	Min. 100 mm orifice
Maintenance access	Access for backhoes or dredging equipment	Provided to approval of municipality	Provision of maintenance drawdown pipe
Sediment drying area	Sediment removal	While preferable, should only be incorporated into the design when it imposes no addition land requirement	Provided above max. water quality water level Drainage returned to pond
Vegetation buffer	Safety	Min. 7.5 m above max. water quality/erosion control water level Min. 3 m above high water level for quantity control	
(Ministry of the Envrironment, pg. 4-53 – 4-54, 2003)			

While all ponds generally follow the above guidance and operational guidelines, casual observation of ponds indicate that they are very different in terms of size and shape once the basic criteria are met. Ponds can be moulded for other uses such as passive recreation including paved paths around a pond or the addition of a fountain for aesthetics. However, ponds are always designed to first meet engineering and hydrological requirements.

Despite very detailed criteria on the hydrological and engineering aspects of ponds, the detail on vegetation and landscaping surrounding a pond is lacking. The MOE has provided a basic planting strategy for SWMPs. The manual identifies five zones based on the depth of water and frequency of inundation: (1) Deep water (> 0.5 m); (2) Shallow water (< 0.5 m); (3) Shoreline fringe (zone of frequent wetting); (4) Flood fringe (zone of infrequent wetting); and (5) Upland (2003, E-1 – E-6). A catalogue of species is also provided in an

Appendix in the manual (See Appendix B for list). This list of species contains plants that are appropriate in the design and landscape of ponds, and not plants that will improve water quality (Ministry of the Environment, pg. 4-48, 2003).

This list of species is the only guidance provided by the MOE and only makes one mention of utilizing vegetation to deter geese. Other documents provide much more detail on how to deter geese when using strategies related to vegetation. For example, vegetation at the edge of the pond should be at least 70 cm tall to prevent geese from seeing through or over the plants, and dense enough to prevent geese from walking through gaps, and wide plantings of 6 to 9 m are more likely to be successful than narrower ones (Smith, 1999, p.15). While these characteristics may be inherent in the vegetation list provided by the MOE (See Appendix B), landscapers are not informed of the importance of the vegetation, and how to use it to efficiently manage waterfowl.

2.1.1 Drawbacks to the use of SWMPs

Because ponds are sinks for pollutants, they are harmful to wildlife and domestic pets that may come into contact with them. For example, elevated concentrations of zinc and copper were found in pond sediment and carcasses of 8-day-old red-winged blackbirds (*Agelaius phoeniceus*) nestlings that inhabited SWMPs in Maryland suburbs near Washington D.C. (Sparling *et al.*, 2004). However, there is only correlative information suggesting that zinc may have caused physiological problems in red-winged blackbird nestlings. Indeed, Bishop *et al.* (2000b) found that eggs of red-winged blackbirds in from two ponds in Toronto contained up to 1130 ng/g pp'DDE (a breakdown product of DDT) and up to 670 ng/g total PCBs. While these concentrations were much higher than in a reference site, they were an order of magnitude below concentrations associated with health effects in songbirds. Sparling's (2004) study determined that the risk that contaminants pose to wildlife is highest when ponds exceed five years of age. After five years, these concentrations increase, thus posing an increased risk to wildlife. However, if ponds are properly maintained and sediment is dredged regularly, the risk can be maintained at a low level (Sparling *et al.*, 2004).

Several studies have implicated specific elements in affecting certain species. With respect to mussels, phosphorous is of greatest concern, as this element was found in elevated levels in the soft tissues of mussels. Other elements were also examined, including nickel, chromium, copper and cadmium. None of these metals increased. Phosphorous is of concern in aquatic systems because of its availability to organisms for uptake. The other metals are not in readily available forms (Anderson & Combs, 2003). Copper, however, maintains limited availability in the water column and sediment, which has been shown to impact the benthic communities within SWMPs. Yousef *et al.* (1996) determined that benthic organisms in SWMPs showed less species diversity when compared to freshwater lakes, and copper appeared to be the most detrimental metal. Continued maintenance will also reduce the risk of pollutants entering groundwater, as the pollutants are generally stored in the top 15-20 cm of sediment (Legret *et al.*, 1995; Yousef & Yu, 1992). Research suggests that sediment dredging should occur every 25 years to prevent groundwater pollution (Yousef *et al.*, 1994; Yousef & Yu, 1992).

2.1.2 Wildlife use of SWMPs

SWMPs are essentially island habitats in urban/suburban areas. These ponds are extremely attractive to urban wildlife and are being used increasingly as habitat and foraging grounds (Adams, 1995). Ponds are exposed water bodies and may be located in or near natural green spaces. As such, Bishop *et al.*, (2000a) suggested that wildlife is attracted to SWMPs even if they are not enhanced for wildlife habitat. SWMPs in Guelph, Ontario, have been found to host up to seven species of amphibians and 71 species of birds (Bishop *et al.*, 2000a). In the Greater Toronto Area, ponds were found to host up to four species of amphibians and 40 species of birds (Bishop *et al.*, 2000a). The ponds in these studies were not enhanced for wildlife and most of the vegetation was mown. It was determined that while communities of plants, invertebrates, fish, amphibians, reptiles and mammals utilized these areas, there was a lack of richness for all biota, and the dominant species were "opportunistic, and stress tolerant species representative of marginal, urban habitats" (Bishop *et al.*, 2000a, p. 432). Diversity could be increased if the terrestrial vegetation was not mown. This would provide more habitat for bird nesting and feeding (Bishop *et al.*, 2000a). SWMPs in Guelph provide habitat to 42.9% of avian species found in the entire county (Wellington County). Overall, the most common avian species found in SWMPs are Canada geese and mallard ducks (Bishop *et al.*, 2000a; Figley & VanDruff, 1982).

2.2 : Canada goose and mallard duck use of SWMPs

Canada goose populations in North America are very large. The average spring population of Canada geese was 4.326 million during 2000 to 2002, with 1.138 million found in Canada (Moser & Caswell, 2003). Goose populations have been increasing rapidly across North America. In Ontario, the populations have grown exponentially from less than 1,000 in 1967 to 190,000 in 1994 (Ankney, 1996). Most of the growth occurs in urban areas. For example, populations in Montreal are growing 36-46% per year (Giroux *et al.*, 2001). Goose population in Minneapolis-St. Paul grew from about 450 in 1970 to almost 12,000 in 1987 (Hawkins 1970 and Cooper 1987, as reported in Adams, 1995).

The most important parameters influencing rapid population growth in urban goose populations are high survival rates of adult geese, nest success and survival of goslings (Mowbray *et al.*, 2002; Paine *et al.*, 2003). Survival rates are high in urban areas because of the lack of natural predators, such as foxes and coyotes, and the lack of hunting pressure (Gosser *et al.*, 1997, p.2; Mowbray *et al.*, 2002). In urban areas, 90% of goslings survive until their first year, whereas the rates of survival in rural areas range from 25% to 84% with an average of 59% (Smith *et al.*, 1999, p.8). The breeding success is also very high, as exhibited in urban Connecticut where each breeding pair laid an average of 5.6 eggs (n=20) per clutch, where as the average clutch of Canada geese is 5.14 (n=11,786 nests) and urban geese fledged 4.5 young per year (Bellrose, 1980; Chasko & Conover, 1988). In New Haven, Connecticut, mean clutch size was 5.4 eggs ±1.7 SD (n=11 nests) (Conover 1998 as reported in Mowbray *et al.*, 2002). Such success contributed to the increase of the goose population in Connecticut from 100 to 9,000 between 1950 and 1980 (Chasko & Conover, 1988).

Suburban/urban areas and their constructed ponds are favoured by several species of birds in Anchorage, Alaska. With respect to raising young, man-made water bodies supported 82.3% (*n*=437*)* of all broods and 84.5% (*n*=2418) of all young. The number of broods of Canada geese and mallards on man-made water bodies was significantly higher than the number on natural water bodies (North, 2001). In Anchorage, the number of lesser Canada geese (*Branta canadensis parvipes* L. [Anatidae]) totals approximately 4,700, with an annual increase of 6% (York *et al.*, 2000, p. 104). Increased urbanization in Anchorage has favoured the increase of the goose population. From 1950 to 1990 SWMPs and reservoirs increased the surface water area from 125 to 268 ha. In addition, lawns and other mown areas doubled as a result of new housing developments (York *et al.*, 2000, p. 104).

At least one study indicates that the number of geese in suburban areas is increasing. Quantitative studies are lacking for most areas despite anecdotal claims. Nonetheless, in the Chicago region, the mean goose density in suburban plots was three to four times higher than the number observed in rural plots, and almost twice the number of geese observed in urban plots (Paine *et al.*, 2003). While definitions of suburban/urban vary, these habitats are becoming important for goose success. Suburban/urban areas provide excellent nesting and brood-rearing goose habitat through the combination of mowed lawns, playing fields and numerous water bodies (York *et al.*, 2000, p. 205). The combination of ideal habitat, food availability and low rates of harvest and mortality has contributed to the large population and annual increase in urban areas (Adams, 1995; York *et al.*, 2000, p.105). The combination of these factors is seen in urban areas across the continent (Ankney, 1996; Chasko & Conover, 1988; Giroux *et al.*, 2001; Mowbray *et al.*, 2002).

As noted earlier, mallards frequently utilize SWMPs (Adams, 1995; Figley & VanDruff, 1982). Often, mallard use the same ponds as geese, and both species will use the same location to establish nests and mallards have been found to nest within 4 m of Canada goose nests (Costanzo & Bidrowski, 2004; personal observation). The mallard can be found in almost every biome of North America where open water is found, and is the most common duck on the continent, with the total number nearing ten million (Adams, 1995; U.S. Fish and Wildlife Service as reported in Drilling *et al.*, 2002; Figley & VanDruff, 1982). The density can be especially high in urban areas for several reasons. First, mallards are highly adaptable and can readily adjust to urban environments. Second, the microclimate of urban areas during the winter months is warmer than the surrounding areas resulting in more ice-free water. If, during colder winters, natural water does freeze over, mallards will move to cities and towns for open water and food (Figley & VanDruff, 1982). The last reason, and this is suggested as the most important reason for high densities, is supplemental feeding by humans (Adams, 1995). In many cases, ponds are placed in suburban developments composed of residential units, where families with children enjoy feeding ducks. This clearly increases the duck population (Personal observation; Smith *et al.*, 1999). Supplemental feeding by humans has also been identified as the primary reason why mallards ceased long range migration from Anchorage, Alaska (North, 2001). Indeed, over-wintering by mallards in Anchorage was first documented in 1947, and the population has since grown to 2000 (USGS 2000, as reported in North, 2001).

2.2.1 The goose's and duck's eye view: Why do they prefer SWMPs?

Aside from offering an area of open water required by waterfowl, SWMPs offer ample food suited to the diets of both geese and ducks. Geese prefer a wide expanse of manicured or mown lawn. This gives the birds ample foraging ground and the ability to detect and flee from advancing predators. Geese are herbivorous and their diet consists of grasses, sedges and other green monocots, but in urban areas they can subsist entirely on domesticated grasses from lawns (Chasko & Conover, 1988; Conover & Chasko, 1985; Mowbray *et al.*, 2002). Conover (1991) evaluated Canada geese preference of five common grass species (all of which are species in the Poaceae genus): tall fescue (*Festuca arundinacea* cv. K-31 L.) , red fescue (*Festuca rubra* L.), colonial bentgrass (*Agrostis tenuis* cv. Highland L.), perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.). While there was no grass species that they refused to eat, it was found that geese most preferred Kentucky bluegrass, and least preferred tall fescue. French and Parkurst (2001) also state that geese do not prefer tall fescue.

There are also several plant species that Canada geese will rarely, if ever, ingest. Geese do not generally eat goldenrods (*Solidago* spp. [Asteraceae]) because of the presence of secondary metabolites which interfere with digestion and can be poisonous (Buchsbaum & Valiela, 1987). In addition, French and Parkhurst (2001) found that geese also avoid plantain lily (*Hosta plantaginea* Lam. [Liliaceae]) and ground junipers (*Juniperus communis* L. [Cupressaceae]. Conover (1991) tested the hypothesis that geese will rarely graze on common periwinkle (*Vinca minor* L. [Apocyanaceae]), Japanese pachysandra (*Pachysandra terminalis* Sieb. & Zucc. [Buxaceae]), and English Ivy (*Hedera helix* L. [Araliaceae]), which are common plants used as ground cover (primarily in the north eastern United States) (Conover, 1991). In a controlled plot planted with these species, caged captive geese refused to eat these plants, even when denied food for 24 hours.

In contrast, Pochop *et al.*, (1999) used similar methods to Conover (1991) and compared feeding preferences of lesser Canada geese (*B.c. parvipes*) in Alaska. They compared preferences for *Poa pratnesis*, bluejoint reedgrass (*Calamagrostis canadensis* Michx. [Poaceae]), beach wildrye (*Elymus mollis* Trin. [Poaceae]), Bering hairgrass (*Deschampsia beringensis* Hultén [Poaceae]), nootka lupine (*Lupinus nootkatensis* Donn ex Sims [Leguminosae]), and "flightline turf" which is a mix of smooth brome (*Bromus* sp.), dock (*Rumex acetosella* L. [Polygonaceae]), and *Festuca rubra*. It was determined that geese most preferred the flightline turf followed by *Poa pratensis* (Pochop *et al.*, 1999).

Despite an affinity for mown lawns, geese species are reported to eat other foods. Arthur (1968) determined that for geese in southern Illionois, the order of preference among browse plants was: ladino clover (*Trifolium repens* L. [Fabaceae]), alsike clover (*Trifolium hybridum* L. [Fabaceae]), red clover (*Trifolium pratense* L. [Fabaceae]), bird's-foot trefoil (*Lotus corniculatus* L. [Fabaceae]), barley (*Hordeum vulgare* L. [Poaceae]), wheat (*Triticum aestivum* L. [Poaceae]), rye (*Secale cereale* L. [Poaceae]), alfalfa (*Medicago sativa* L. [Fabaceae]), brome (*Bromus* sp. [Poaceae]), orchard grass (*Dactylis glomerata* L. [Poaceae]), bluegrasses (*Poa* spp. [Poaceae]), *Festuca rubra*, and timothy (*Phleum pratense* L. [Poaceae]). Hunt (2003) also identified the high palatability of ladino clover.

Most of these species can be found around SWMPs in Southern Ontario (personal observation). However, many of these plants can grow very tall and thick (eg. reed canary grass, orchard grass, and brome) reducing a goose's ability to sense predators. Buchsbaum & Valiela (1987) found that food choices are modified by the need to select a safe feeding site. Furthermore, Owen (1975) also found that the nutritional value of grass species decreases as vegetation height increases, resulting in a demand for short vegetation to meet nutritional requirements. Overall, short vegetation provides security for a goose as well as biological necessities.

The height of vegetation is an important factor in the selection of a food source. In a study comparing use of agricultural fields in Illinois, green pastures with short (<13 cm) to medium (13-30 cm) grass height were used by geese more frequently than sites with taller grass (>30 cm) (Black *et al.*, 2003). Geese also find palatable vegetation in agricultural fields adjacent to SWMPs. Many new suburban developments, containing SWMPS, are on the urban-rural fringe, allowing geese close access between ponds and agricultural fields. Among agricultural plants, geese favoured foxtail millets (*Setaria italica* L. [Poaceae]) as their top grain preference, followed by corn (*Zea mays*. L. [Poaceae]), oats (*Avena sativa* L. [Poaceae]), buckwheat (*Fagopyrum* sp. [Polygonaceae]), sorghum (*Sorghum vulgare* [Gramineae]), and soybeans (*Glycine max* L. [Fabaceae]) (Bellrose, 1980). Agricultural fields provide an additional source of food for geese, and are especially important during winter where wintering geese can feed on waste corn from harvested fields (Bellrose, 1980, p. 148). Furthermore, some of these plants traditionally found in agricultural fields, such as foxtail, are frequently found in areas surrounding ponds (personal observation).

There are certain stages in a goose's life-cycle when requirements for dietary protein and carbohydrates are most critical. While nutrition is always important, it becomes paramount prior to fall migration (Mowbray, *et al.*, 2002). At this stage geese require a high concentration of soluble carbohydrates for storage as fat. It is difficult for geese to meet these requirements with tall vegetation, furthering the need for short species. The primary source of soluble carbohydrates is identified as cereal grains (Joyner, 1987 as reported in

Mowbray, *et al.*, 2002), which are found in high concentrations in agricultural fields or in lower concentrations among the vegetation at certain ponds.

Mallards are omnivorous and their diet consists of insects, aquatic invertebrates, moist-soil plants, aquatic vegetation and cereal crops. Mallards also feed on the seeds of bulrushes (*Scirpus* spp. [Cyperaceae]), wild millet (*Echinochloa muricata* Michx. [Poaceae]), reed canary grass (*Phalaris arundinacea* L. [Poaceae]), spike rushes (*Eleocharis* spp. [Cyperaceae]), sedges (*Carex* spp. [Cyperaceae]) and smartweeds (*Polygonum* spp. [Polygonaceae]) (Bellrose, 1980, p. 242-243). These plants often are present and may even be dominant around SWMPs in southern Ontario (Ministry of the Environment, 2003; personal observation). In winter, urban mallards often rely entirely on human-provided food including bread and seeds (Drilling *et al.*, 2002). As such, they may choose ponds designed for recreation that people tend to visit on a daily basis.

Several characteristics make a SWMP more attractive to mallards. For example, breeding pairs of mallards prefer shallow ponds planted with vegetation similar to natural marshes rather than deep ponds with steep slopes and lakes. The use of the former was 2.4 times greater than the latter (Adams *et al.*, 1985a). Hens with ducklings also preferred shallow ponds. This preference can be attributed to the mallard feeding style, which includes dabbling and dipping for food buried in bottom sediment (Drilling *et al.*, 2002, p. 9). Shallow SWMPs provide an environment that facilitates these actions.

Conversely, there are features of ponds that will discourage both geese and ducks from using them. Such features are emphasized in management literature as methods to discourage geese from using a site (Appendix C). For example, goose management techniques related to habitat modification that may discourage geese, can also serve as recreational amenities for humans or increase the aesthetics of a pond and the surrounding area. However, only those methods that relate to habitat modification will be discussed, as vegetation characteristics are a focus of this study.

First, geese are less likely to use a site that is surrounded by tall trees. Trees increase the angle geese must fly to clear surrounding obstacles to either land at a site or fly away from a predator (also known as flight clearance angle) (Conover & Kania, 1991, p.36). The greater the angle the less likely a goose will use the site, but the minimum angle for deterrence is 13 degrees (Conover & Kania, 1991). Second, geese prefer to rest and forage on grassy areas close to the water's edge. Therefore, if walking or jogging paths are placed along shorelines, geese may be less likely to utilize the immediate area (Smith *et al.*, 1999). However, the paths would have to be heavily trafficked to deter geese. Third, the use of dense woody vegetation at the edge of the pond can discourage geese. Smith *et al*. identified that vegetation should be at least 70 cm tall to prevent geese from seeing through or over the plants, and dense enough to prevent geese from walking through gaps. In addition, wide plantings of 6 to 9 m are more likely to be successful at discouraging geese than narrower ones (Ministry of the Environment, 2003; Smith *et al.*, 1999, p.15). As previously mentioned, planting vegetation that geese find unpalatable can also discourage geese. In contrast, ducks prefer dense vegetation as it closely resembles that of natural wetlands and marshes, and such vegetation provides enhanced cover during nesting (Drilling *et al.*, 2002, p. 29). However, the adaptable nature of mallards allows them to inhabit most SWMPs regardless of vegetation structure.

2.3 : Problems associated with geese and ducks in urban and suburban areas

2.3.1 Nuisance species

The new habitats that have been created in urban and suburban areas attract large numbers of Canada geese and mallard ducks. These large numbers pose several problems including fecal deposition in public and private lawns, playing fields and sports grounds, public parks, golf courses and lead to the contamination of drinking and recreational water sources (Conover & Chasko, 1985; Mowbray *et al.*, 2002). Thus, the aesthetic and recreational value of park areas are reduced (Conover, 1996; Conover & Chasko, 1985).

One goose is capable of producing up to three lbs. of feces per day (Sinnott as reported in Volz & Clausen, 2001) and the amount of goose feces in park areas can average 10 to 12 droppings per square meter (Kassa *et al.*, 2001). Furthermore, geese can be especially problematic because they range further from water to feed than other waterfowl, spreading their feces over a larger area (Kassa *et al.*, 2004). While ducks, like geese, are adapted to urbanized areas, ducks are not considered a nuisance species. There are several reasons for this: (1) ducks are smaller, (2) they do not produce as much fecal matter, and (3) unlike geese, ducks do not congregate in large numbers in areas shared with humans (ie. golf courses and beaches). A large body of literature is devoted to how to manage nuisance geese, but such a collection does not exist for ducks.

2.3.2 Ecological impact

With respect to ecological impacts, geese harm the vegetation communities surrounding ponds and disrupt the aquatic system. Canada geese feeding on *Festuca* meadows in northern Canada were responsible for converting the meadows into unvegetated mudflats. It was also found that once the areas were devegetated it was difficult to reverse the process. Vegetation was unable to colonize in the disturbed areas due to adverse changes in the soil chemistry (O *et al.*, 2005). In addition, goose activity on islands in Chesapeake Bay has contributed to island erosion (Costanzo & Bidrowski, 2003). Geese have also been implicated in damaging the turf in urban and suburban parks through excessive grazing and soil compaction, resulting in areas where further plant colonization or recolonization is difficult (Conover, 1985). These effects were also observed in the Alaska salt marshes which host migratory geese (Zacheis *et al.*, 2001).

The contamination of water bodies from geese has become a concern of residents, business and property owners, and municipal managers (Conover & Chasko, 1985). In 1982, questionnaires were sent to every water company in Connecticut to determine if geese were perceived as factors in reducing water quality. Forty questionnaires (out of 70) were returned. Of these 73% reported that Canada geese spent time on their property and 45% of respondents considered them a nuisance, citing that goose feces lowered water quality (Conover & Chasko, 1985). Indeed, geese have been linked to the over-fertilization of ponds causing eutrophication (Conover & Chasko, 1985; Smith *et al.*, 1999).

Results of *in situ* studies indicate that large flocks of waterfowl can cause elevated fecal coliform densities in the water column (Hussong *et al.*, 1979). Studies have indicated that bird species such as ring-billed gulls (*Larus delawarensis* Ord [Laridae]) have a greater average concentration of fecal coliform bacteria per gram (3.68×10^8) than do goose feces (1.53×10^4). However, geese excrete fifteen times more in weight than ring-billed gulls (Alderisio & DeLuca, 1999). Graczcyk *et al*., (1998) found that the mean weight of an individual fecal dropping was 17.2 g ± 1.9 g, further indicating the large amount of feces that geese deposit.

2.3.3 Health Concerns

Health concerns stem not from contact with geese and ducks themselves, but through human contact with their feces. Geese can be especially problematic because they produce a large amount of feces and there is a direct correlation between the number of infectious oocysts from pathogens and the weight of the fecal sample (Graczcyk *et al.*, 1998). Thus, the issue has been raised regarding the human health risk associated with fecal contamination of urban habitats, including SWMPs. The human health risks of concern focus on the virulent forms of *Escherichia coli* (Enterobacteriaceae) and other zoonoses such as, *Cryptosporidium* (Cryptosporidiidae), *Giardia* (Hexamitidae), and *Campylobacter* (*Campylobacteraceae).* Therefore, public health officials and other researchers are attempting to quantify the ability of geese and ducks to carry, and subsequently distribute, pathogens, bacteria and viruses. Each of these possible pathogens will be discussed in terms of infection of humans and the quantity found in the feces of geese and ducks, followed by an examination of the risk to human health.

2.3.3.1 Escherichia coli

There are several strains of *E. coli,* three of which are the most common. Enterotoxigenic *E. coli* strains (ETEC) cause secretory diarrhea, and are the most common cause of "travelers' diarrhea", experienced by people who travel from developed to developing countries (Salyers & Whitt, 2001). Enteropathogenic *E. coli* strains (EPEC) cause malabsorptive diarrhea and are a major killer of infants in developing countries and contribute to travelers' diarrhea. Enterohemorrhagic *E. coli* strains (EHEC) have caused many childhood deaths in developed countries. Included in this strain is *E. coli* O157:H7, responsible for the deaths from cow manure-contaminated drinking water in Walkerton, Ontario in May, 2000 (O'Connor, 2002). EHEC causes malabsorptive diarrhea that can become bloody (dysentery). EHEC strains are more deadly than other strains because EHEC produces a toxin (Shiga-like toxin) which enters the bloodstream and damages the kidneys (Salyers & Whitt, 2001).

Cole *et al*. (2005) evaluated the ability of geese to be carriers of *E. coli* O157:H7, and found there to be no occurrences of this type in goose feces. The authors recognize that their sample was small compared to the number of urban geese, and suggest that more research needs to be completed in order to eliminate the involvement of Canada geese in transmission of this pathogen (Cole *et al.*, 2005). However, the risk of geese carrying this pathogen and subsequently transmitting it to humans remains low. Although *E. coli* 0157:H7 has been found in the feces of gulls, it has not yet been reported in other waterfowl (Abulreesh *et al.*, 2005)

Other studies have been completed that investigate the amount of *E. coli* present in feces. In a study completed in the Red Cedar watershed in Michigan, fecal samples were collected from “wild Canada geese.” Of the 96 fecal samples, 56% tested positive for *E. coli* (Sayah *et al.*, 2005). In another study completed in Colorado, fecal samples of Canada geese were collected over one year. *E. coli* was found in 37% of 397 fecal samples (Kullas *et al.*, 2002). This study also examined the feces for specific strains of *E. coli*. During the time of year when nonmigratory geese dominated the local goose population (March–July) the prevalence of ETEC strains of *E. coli* was 13%. The prevalence of EHEC forms was 6%, while prevalence for enteroinvasive (EIEC) and enteroagglomerative (EAEC) forms was 4.6 and 1.3%, respectively, during the same period. Three isolates were positive for human virulence factors, representing a 2% prevalence for feces containing potential human toxins (Kullas *et al.*, 2002).

In a separate study performed in Ohio, it was determined that there was a significant difference (P = 0.0001) between Canada geese and mallards in terms of *E. coli* isolation (Fallacara *et al.*, 2004). Waterfowl were observed while foraging and fecal samples were collected immediately following defecation. *E. coli* was found in 72% of 342 samples of

Canada geese feces, while *E. coli* from mallards was only isolated in 50% of 100 samples. These results differ from other studies examining *E. coli* in waterfowl. With the same significance level (*P* = 0.0001) a different study, also conducted in Ohio found *E. coli* in 63% of 357 fecal samples from Canada geese, and in 89% 82 fecal samples from mallards (Fallacara *et al.*, 2001).

The health risk associated with *E. coli* in goose and duck feces is largely unknown, primarily because of a lack of research. Basic data such as the longevity of *E. coli* in goose feces is also unknown, mostly because of weather fluctuations that exist in the field. However, studies on *E. coli* O157:H7 found in ovine and bovine manure, suggest that longevities range from 47 to 360 days (Kudva *et al.*, 1998), and up to 30 days in tap water . Yet, this data is only available for one strain of *E. coli.*

It is suggested that the summer months provide the greatest possible health risk. First, during the day, geese may travel to agricultural areas to feed, and the fields may be surface-treated with manure from local feedlots and dairy farms (Kullas *et al.*, 2002). Second, summer months provide optimal growth conditions for *E. coli* because of high temperatures, as well as increased humidity (Salyers & Whitt, 2001). Kullas (2002) confirmed the importance of summer as the prevalence of *E. coli* ranged from 2% during the coldest month of the year (February) to 94% during the warmest month (August). Finally, summer is also the time of year when most people are enjoying public parks and other areas where geese and ducks defecate, increasing the risk of human contact with infected feces.

2.3.3.2 Cryptosporidium

The disease resulting from *Cryptosporidium* is primarily diarrhea and is most severe in immune-compromised individuals (Fayer, 2004). *Cryptosprodium* is most infectious in the oocyst stage. There are several species of *Cryptosporidium*, two of which, *C. hominis* and *C. parvum,* are most infectious to humans (Salyers & Whitt, 2001; Zhou *et al.*, 2004). These two species are responsible for the most severe human outbreaks worldwide (Peng *et al.*, 1997; Sulaiman *et al.*, 1998). It has been estimated that between 65 and 97 % of natural surface water bodies (including ponds, lakes, rivers, and streams) in the United States are contaminated with *Cryptosporidium* (Juranek, 1995). Some of this contamination stems from wildlife including waterfowl (Fayer, 2004; Graczcyk *et al.*, 1998; Salyers & Whitt, 2001).

In research carried out on Canada geese in Ohio, it was found that *Cryptosporidium* was the most common pathogen (among *Campylobacter* and *Giardia)*. It was detected in 78% of 18 fecal samples (Kassa *et al.*, 2001). In other research on Canada goose feces in Illinois and Ohio, it was found that the two infectious species (*C. hominis* and *C. parvum*) only constituted 2.4% of the *Cryptosporidium* positive feces (5 of 209 fecal specimens) (Zhou *et al.*, 2004). This low rate of *C. parvum* was confirmed in a study completed in Alberta where no *C. parvum* oocysts were found in 59 samples of Canada goose feces (Heitman *et al.*, 2002).

Kassa *et al.* (2004) note that recent evidence shows that different zoonotic types of *Cryptosporidium* have been found in the feces of infected persons. The bird genotype, *C. meleagridis*, has been isolated in stools from immunocompromised and immunocompetent people and the cat genotype, *C. felis*, was found in infected children. In addition, one study reported two isolates from two patients did not match any currently known species nor genotypes of *Cryptosporidium* (Chalmers *et al.*, 2002). Therefore, more than one genotype can cause infection in humans, and genotypes found in geese may soon be detected in humans (Kassa *et al.*, 2004).

Cryptosporidium has also been found in the feces of mallard ducks (Graczcyk *et al.*, 1996). In a study completed in the Rio Grande, the feces of 69 ducks (54 of which were mallards) were sampled for *Cryptosporidium*. It was determined that 49% of the ducks sampled were positive for *Cryptosporidium* sp., however, none was positive for the most infectious *C. parvum* (Kuhn *et al.*, 2002).

2.3.3.3 Campylobacter

There are several species of *Campylobacter* that cause disease (eg. *C. jejuni*, and *C. coli*). However, they all result in the same symptoms. The disease is similar to that of *E. coli*: diarrhea, which can be accompanied by severe abdominal pain (Salyers & Whitt, 2001, p.

351). Farm animals, such as chickens, cattle, and sheep, are natural hosts for *Campylobacter*. However, this bacterium is not virulent for most of the animals that carry it (Salyers & Whitt, 2001, p. 351). *Campylobacter* is a very common disease, and, for example, in New Zealand it is the most commonly reported notifiable disease. This is attributed to transmission from cattle, sheep and ducks into water courses (Savill *et al.*, 2003).

Several studies have been completed that examined the presence of *Campylobacter* in migratory waterfowl. However, the results of these studies vary considerably. With respect to ducks, a study in Colorado found that 35% of (155 of 445) ducks sampled (using fecal specimens) harboured *Campylobacter* (Luechtefeld *et al.*, 1980). When mallard ducks were isolated, 34% of 243 were positive. This study also found that mallard hens had a significantly higher carrier rate than drakes (50% versus 31%, $P < 0.05$) (Luechtefeld *et al.*, 1980). A study in Washington State found that of 113 ducks sampled (using the cloacal swab technique), 73% were positive for *Campylobacter* (Pacha *et al.*, 1987). Yet, a study of 50 ducks (using cecal specimens) in the Wisconsin found no presence of *Campylobacter* (Hill & Grimes, 1984). The differences in the results may be from different sampling techniques (fecal versus cloacal swab); however, it is most likely attributed to feeding habits (Pacha *et al.*, 1987). For example, waterfowl feeding on land may not have been exposed to *Campylobacter* as readily as those feeding in aquatic environments.

Campylobacter has also been isolated in feces from Canada geese. Pacha, *et al*., (1987) discovered that only 5% of 94 Canada goose samples were positive for the bacterium. This differs from results reported by Kassa, *et al*., (2001) where *Campylobacter* was found in 39% of 18 fecal samples.

2.3.3.4 Giardia

Giardia spp. are protozoan pathogens of vertebrates; their infectious stage, the cyst, is transmitted via water and fecal-oral contact or by feces-associated contamination (Matsubayashi *et al.*, 2005; Salyers & Whitt, 2001). *Giardia* causes persistent diarrhea for at least 2-3 weeks (Matsubayashi *et al.*, 2005).

Giardia was found in all nine flocks of geese sampled in Chesapeake Bay, Maryland (Graczcyk *et al.*, 1998). In this study, it was determined that *Giardia* was a more important pathogen than *Cryptosporidium*, as the former exhibited a significantly higher concentration of oocysts ($P < 0.02$) (Graczcyk *et al.*, 1998). However, in the study completed by Kassa *et al* (2001), *Giardia* was the least common pathogen found (among *Cryptosporidium* and *Campylobacter)*, as only 17% of 18 samples tested positive. In a study that focused on ducks on the Rio Grande in New Mexico, 28% of the 69 ducks sampled were positive for *Giardia* (Kuhn *et al.*, 2002).

2.3.3.5 Salmonella

Salmonella is a common pathogen that causes gastroenteritis in humans when food contaminated with animal waste is ingested. However, the detection of *Salmonella* in goose feces is a rare event (<0.5%) (Cole *et al.*, 2005). Several studies have attempted to quantify the amount of Salmonella, but most were unable to isolate the pathogen from ducks or geese (Hussong *et al.*, 1979). In a two-year study in New Jersey, Bigus (1996) isolated eight *Salmonella pullorum* isolates from Canada geese (the total number of geese sampled is unknown). Fallacara *et al* (2001) were only able to isolate *Salmonella* from 1 out of 82 mallards, and were unable to isolate the virus in Canada geese (n=357). Cole *et al.*, (2005) found two isolates of *Salmonella typhimurium*. This type of *Salmonella* is responsible for 20% of human cases. The presence of *Salmonella* in feces should be monitored closely as survival rates can be greater than nine months in the environment, providing for increased dissemination potential (Converse *et al.*, 1999).

2.3.3.6 Less common diseases

Other diseases have been reported, and are suspected to have come from geese. For example, two biologists, one in Wisconsin and Texas and the other in Saskatchewan and Manitoba, worked with wild waterfowl contracted *Chlamydiosis*. Canada geese constituted the largest portion of the birds they worked with. Humans contract the disease through inhalation of aerosols containing the causative agent *Chlamydia psittaci* found in deposited feces. It is possible that the biologists contracted the disease in this manner from Canada geese (Martinov, 1997).

Viruses exist that are harmful to ducks and geese, as well as other animals, but are less important in terms of infection and transmission to humans. A study conducted in Germany examined the embryos of 289 eggs and found that the embryos contained antibodies for the Newcastle disease virus (NDV) and Influenza A, proving that Canada geese are susceptible to both these diseases (Bönner *et al.*, 2004). The detection of antibodies in egg yolk also indicates that Canada geese are carriers and shedders of NDV (Bönner *et al.*, 2004; Kaleta & Baldauf, 1998). While NDV is not evident in humans it is important to note that waterfowl are thought to be the main and most effective transmitters of Newcastle disease to domestic chickens and turkeys (Alexander, 1998).

2.3.4 Summary

Most studies conclude that further research is required to define the public health importance of protozoan, viral, and bacterial pathogens found in the feces of waterfowl (Abulreesh *et al.*, 2005; Kassa *et al.*, 2004). Kassa *et al.*, (2001) did conclude that, with respect to *Cryptosproidium,* occupational exposure to the pathogen is “very plausible”. The authors recommend that workers at risk should wear protective gloves, “wash their hands after performing applicable activities and before touching their mouths, launder work clothes daily, and shower at the end of the work day” (Kassa *et al.*, 2001). However, no known cases of human cryptosporidiosis have been associated with exposure to goose feces (Kassa *et al.*, 2004). This may be attributed to the lack of detection of *Cryptosporidium* as it is not included as a standardized test when stool samples are collected from ill patients (Kassa *et al.*, 2004).

Further research needs to specifically study how long these pathogens can survive outside their host. It is suggested that the transmissive stage of *Giardia*, and *Cryptosporidium* can survive for prolonged periods under moist conditions, as they are susceptible to desiccation (Grimason *et al.*, 1993; Matsubayashi *et al.*, 2005). *Campylobacter* can survive in stream water for over one week at 4^{o}C; however, it is not known how long it can survive in feces exposed to other environmental conditions (Luechtefeld *et al.*, 1980).

It is evident that our ability to quantify the risk that geese and ducks pose to humans is still in its infancy. As the numbers of geese increase in urban and suburban areas, the amount of feces will increase and the subsequent risk may also increase. Therefore, further research is required to quantify the risk that geese and ducks pose to the health of humans.

Chapter 3 : Methods

This chapter details the methods used to gather and analyze all data acquired in the field and lab. The primary components outlined are: the selection of the study sites, how the waterfowl data were collected, how the vegetation survey was completed, how the water samples were collected in the field and subsequently analyzed in the lab, and finally, the statistical analysis applied for all of the above components. An overview of the experimental design will first be presented

3.1 Experimental design

The purpose of this study was to determine if there are vegetation characteristics surrounding SWMPs that affect waterfowl use of a particular pond. The vegetation characteristics of importance were vegetation height and species composition and the waterfowl species of concern were the Canada goose and the mallard. In order to achieve the objectives, eleven SWMPs (all with a permanent pool) with varying depth, area, vegetation, and surrounding land use were evaluated (See Table 3 for characteristics of the ponds included in this study). While there may be several factors that affect the behaviour of waterfowl at site, including pond depth, pond area, presence of predators (domestic pets and natural predators), influence of surrounding land use, and other landscape factors (eg. proximity to other water bodies), I chose to focus on vegetation. Vegetation was chosen as the variable of concern because it is a governing factor in survival of a species - waterfowl must find nutrition and have suitable habitat in order to survive. The height and composition of vegetation has been identified as a habitat modification variable that can have a direct influence on Canada geese use at a site (Conover & Chasko, 1985; Conover & Kania, 1991; Conover, 1996; Gosser *et al.*; Smith *et al.*, 1999; Ministry of the Environment, 2003).

Data were collected through personal observation. Waterfowl were counted at all ponds a total of 140 times over one and a half years (April 2005-June 2006). Sites were visited three times per week, except in the winter (December-March), when sites were only visited once per week. The observer walked the perimeter of the pond to ensure no birds were hidden. For analysis, the study period was then split into five time periods based on waterfowl phenology. These data were combined with the vegetation data for analysis. Vegetation data was collected in the field using the quadrat and transect methods combined with a stratified random sample. Descriptive data were collected which concerned species composition, percent cover, and general height of vegetation. The ponds were then placed into one of two categories based on the percent cover of short vegetation: (1) Tall (= 30% short vegetation, 9 ponds) and (2) Short (<30 % short vegetation, 2 ponds). The latter category included mown and trampled vegetation, stunted species, juveniles, and species with only basal rosettes. Descriptive statistics were also used to further describe the vegetation community at each site (evenness, richness, Simpson diversity index, Shannon diversity index, and the Bray-Curtis dissimilarity index). Finally, using the categories and the waterfowl observations, a GLM ANOVAR was used to test waterfowl response to the vegetation community at each site and over each of the five time periods based on waterfowl phenology (the test was run separately for geese and ducks). These data will indicate if geese respond to ponds with short vegetation versus tall vegetation, how significant the response is, and whether there are temporal variations (effect of seasonality or waterfowl phenology). This information can then be applied to future design and landscaping of SWMPs.

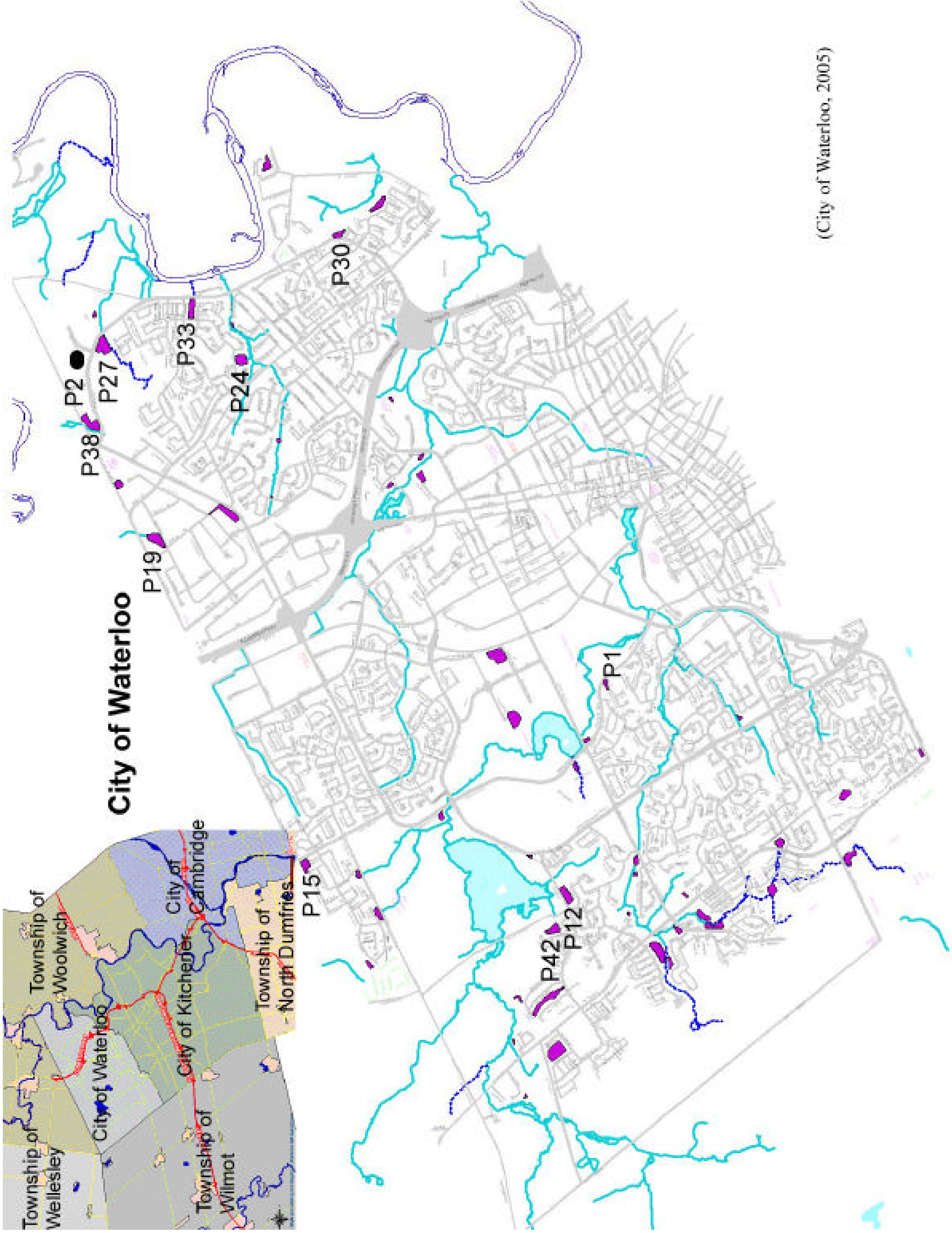
The final component of this research was to determine if waterfowl influence the level of *E. coli* in SWMPs. Three water samples were collected from the centre of nine ponds. Samples were collected a total of eleven times (seven samples of baseflow conditions and four samples after rain events exceeding 20 mm). Samples were placed in a cooler and analyzed within two hours following standard methods (American Public Health Association: *Standard Methods for the Examination of Water and Wastewater,* 1998). Samples were analyzed following methods outlined by Cieben *et al.* (1995).

3.2 Study sites

The study was conducted in Waterloo, Ontario. All SWMPs investigated in this study are within the city limits of the City of Waterloo. There were eleven sites dispersed throughout Waterloo (Figure 1). All of the ponds were constructed within the last twelve years (Table 3). Nine of the eleven study sites are official SWMPs containing a permanent pool. Pond 1 is actually a small pond created by a wider opening along Laurel Creek. It was chosen, as it is one of the few sites in the City of Waterloo to consist primarily of short/mown vegetation. Pond 2 is also not an official SWMP as it does not contain an inlet or an outlet, nor is it actively maintained. Visually, it is similar to other SWMPs and there exists a permanent pool. As such, it was included in this study (See Appendix D for photographs of all ponds). Table 3 provides an indication of the basic physical characteristics of each pond and addresses the main components evident in SWMPs (as outlined in Table 1). Table 3 only indicates data which could be collected from the City of Waterloo. As such, only information regarding pond area, forebay, number of inlets, type of outlet, and buffers is presented.

Ponds were selected based on a preliminary visual evaluation of the vegetation present. An effort was made to include ponds with different types of vegetation communities varying on a spectrum ranging from primarily mown lawns to dense and thick primarily naturalized vegetation. In addition, I tried to include ponds from all over the study area. While Figure 1 indicates several other ponds, it must be noted that many of these SWMPs were still under construction or did not have an established vegetation community. In addition, an effort was made to include some ponds that were spatially close and clustered as well as those that were isolated in an attempt to exclude spatial bias.

Figure 1 - Map of study sites within Waterloo. Map includes all wet ponds, major creeks and large water features.



(City of Waterloo, 2005)

Table 3 - SWMP characteristics for the eleven study sites

ID number[1]	Pond name[1]	Year constructed	Pond area (ha)	Presence of forebay	Number of inlets	Type of outlet	Presence of safety buffer	Presence of berms (serpentine or horseshoe design)	Land use surrounding pond	Street location of pond
30	Pillars Pond	1995	0.96	N	2	Perforated riser	N	N	Residential/ commercial/ industrial/forest	University Ave. E
24	Eastbridge Pond 1	1995	1.43	N	2	Reverse slope	N	N	Residential	Eastbridge Blvd..
33	Genstar Pond 2	1997	0.50	Y	1	Reverse slope	Absent on south side	Y	Residential	Eastbridge Blvd.
27	RIM Park Pond 1	2000	1.90	Y	2	Perforated riser	Only on south side	Y	Residential/ playing field	University Ave. E
2	RIM Park Pond A	2000	1.60	N	N/A	N/A	N	Y	Commercial/ prairie field	University Ave. E
38	Dorwood Pond	2001	1.72	N	2	Perforated riser	Y	N	Residential/ agriculture	University Ave. E
19	Bathurst Pond	2000	1.68	N	2	Perforated riser	Y	N	Industrial/ agriculture	Bathurst St.
15	Lakeshore West Basin 2	1995	0.97	Y	2	Perforated riser	N	Y	Residential/ agriculture	Westmount Rd. N.
42	Beaver Creek Pond	1998	1.10	Y	1	Perforated riser	Y	Y	Residential/ wetland	Brookemill Cres.
12	Laurelwood Pond	1994	1.20	N	1	Reverse slope	Y	N	Residential/ wetland/forest	Laurelwood Dr.
1	Laurel Creek Pond	N/A	1.40	N	N/A	N/A	Y	N	Institutional	Ring Road

[1] Identification numbers and names provided by the City of Waterloo, except for Pond 1 and 2, which are not official ponds and were assigned names and numbers by the researcher reflecting pond location

3.3 Waterfowl observation

Waterfowl were observed at eleven locations in the City of Waterloo. Observations of waterfowl were made three times per week at various times of the day during daylight hours to avoid temporal bias. This sampling schedule was maintained from April 2005 until the end of November 2005. Following this period, sampling occurred once per week to determine winter use of the ponds. In March 2006, the sampling schedule returned to three observations per week until the completion of sampling in June 2006. I emphasize that I did not seek to establish the size of waterfowl populations. The data represent sightings of waterfowl, not a definitive population of waterfowl in the City of Waterloo. Ponds were observed 140 times between April 2005 and June 2006.

Site visits were conducted between 30 minutes after sunrise and 30 minutes before sunset. This schedule has been used in other bird censuses to avoid the primary times when waterfowl leave roosting sites to feed, particularly on agricultural fields (Adams *et al.*, 1984; Cadman *et al.*, 1987; Mowbray *et al.*, 2002; Ruwaldt *et al.*, 1979). Where ponds exhibited dense shoreline vegetation, the observer walked the perimeter of each site to confirm that no waterfowl were hidden. Waterfowl were counted if they flew into or away from the pond, on the water, or on the shore within the boundaries set up by the observer. All waterfowl species were recorded. These included Blue heron (*Ardea herodias* L. [Ardeidae]), Herring gull (*Larus argentatus* Pontoppidan [Laridae]), and the Ring-billed gull (*Larus delawarensis* Ord [Laridae]). In addition, the Embden goose (a domestic breed) was also observed and recorded.

Roads were primarily used as boundaries to determine which geese were counted. Geese on the opposite side of the road from a pond were not included in the survey. This allowed the inclusion of geese and ducks that utilized the backyards of residences that bordered the ponds, as well as those on pathways and adjacent playing fields.

3.4 Vegetation survey

Quadrats for vegetation surveys were placed using the transect method combined with a stratified random sample. Five parallel transects were established across the pond in one direction/orientation. In most cases, transects were established parallel to at least one shoreline to evaluate the vegetation in this area. Where ponds exhibited a “horseshoe” shape, one transect ran through the deepest part of the horseshoe.

Transects were walked using an even pace, stopping at a maximum of ten positions, pre-determined by a random numbers list (produced in Microsoft Excel ©). The random numbers list was produced using paces (or strides). To generate the number of paces, I walked the length of each pond in between the established boundaries, using an even stride. Each pond thus had a number of paces associated with it. The random numbers produced were unique for each pond ranging from zero to a maximum of the number of paces. This randomization ensured an unbiased and accurate application of the quadrat. At these positions, a quadrat was established and percent cover of each species present was recorded. For the vegetation community present at the pond sites (primarily closely spaced herbaceous species), a 1m^2 quadrat was used (as recommended by (Brower *et al.*, 1990, p.81)). For consistency, the quadrat was always centred on the transect line. This method produced data from 42-50 quadrats for each pond (in some cases, positions along the transect fell within the pond; in these instances the location was noted and the survey commenced again when the number of paces was on the surrounding land).

In addition to identification and percent cover of each species, the general height of the vegetation was recorded. The ‘short’ vegetation category included mown vegetation, trampled vegetation, stunted species, juveniles, and species with only basal rosettes at the time of observation. The following table is a comprehensive list of all species that were considered short (these species are not exclusive to the short category as many species were also found in their mature state) (Table 4). These plants are short enough to avoid infringing on a goose's sense of security and were incorporated as the short vegetation category.

An effort was made to identify vegetation to the species level; however, this was complicated by mowing. *Poa* spp. are difficult to identify when they are not seeding. In these cases they were identified at the genus level. Other vegetation such as *Solidago* spp. was not classified to the species rank because the literature indicated that geese could not differentiate between species of *Solidago* when grazing and avoid them because of the presence of secondary metabolites (Buchsbaum & Valiela, 1987). As such, the identification of these species down to the genus level suffices for the purpose of this study.

All of the ponds were then placed into one of two categories based on the percent cover of short vegetation: (1) = 30% short vegetation, and (2) <30 % short vegetation. The threshold of 30% was chosen as it indicates that a large area of mown vegetation exists rather than small areas of short vegetation distributed throughout the entire site that may not be evident to the geese.

3.4.1 Vegetation analysis

Several indices were used to describe the vegetation communities at the study sites.

Evenness:

Evenness examines how close a set of observed species abundances are to those from an aggregation of species (Brower *et al.*, 1990, p. 161). The equation for evenness is given by,

$$n_i = \frac{N}{s}$$

Where n_i is the abundance of individuals, N is the number of individuals, and s is the number of species.

Richness:

Richness examines the number of species in a community. More robust measures, such as Menhinick's index, include both the species present and the number of individuals. Menhinick's index (D_b) is as follows:

$$D_b = \frac{s}{\sqrt{N}}$$

where s is the number of species, and N is the number of individuals.

Diversity:

Diversity takes into account both richness and evenness. To determine the diversity present in the vegetation structure at each site, two indices were used. The first is Simpson's index, which provides a level of probability that if two individuals are taken at random from a community, they will belong to the same species (Brower *et al.*, 1990).

$$l = \frac{\sum n_i\left(n_i - 1\right)}{N\left(N - 1\right)}$$

The second diversity index is the Shannon diversity index (*H'*). This index is widely used in ecological and biological research (Brower *et al*., 1990), and this study meets the assumption that a random sample of species abundances are from a larger aggregation (Brower *et al*., 1990). The Shannon diversity index is as follows,

$$H' = \frac{\left(N \log N - \sum n_i \log n_i\right)}{N}$$

Where N is the number of individuals, and n_i is the abundance of individuals.

Table 4 - Vegetation included in the short category

Achillea millefolium L. (Asteraceae)	*Echinochloa crusgalli* L. (Poaceae)	*Phalaris arundinacea* L. (Poaceae)
Agropyron repens L. (Poaaceae)	*Echinochloa muricata* Michx. (Poaceae)	*Physocarpus opulifolius* L. (Rosaceae)
Ambrosia artemisiifolia L. (Asteraceae)	*Epilobium* (Onagraceae)	*Plantago major* L. (Plantaginaceae)
Arctium minus Hill (Aseraceae)	*Euphorbia helioscopia* L. (Euphorbiaceae)	*Poa annua* L. (Poaceae)
Bidens (Asteraceae)	*Festuca* (Poaceae)	*Poa pratensis* L. (Poaceae)
Cerastium vulgatum L. (Caryophyllaceae)	*Festuca* arundinacea Schreb. (Poaceae)	*Poa spp.* (Poaceae)
Chenopodium album L. (Chenopodiaceae)	*Galium mollugo* L. (Rubiaceae)	*Polygonum aviculare* L. (Polygonaceae)
Cichorium intybus L. (Asteraceae)	*Gnaphalium palustre* Nutt. (Asteraceae)	*Polygonum persicaria* L. (Polygonaceae)
Cirsium arvense L. (Asteraceae)	*Juncus* spp. (Juncaceae)	*Setaria* Wiegel (Poaceae)
Convolvulus arvensis L. (Convolvulaceae)	*Lotus corniculatus* L. (Fabaceae)	*Solidago* spp. (Asteraceae)
Conyza Canadensis L. (Asteraceae)	*Matricaria matricariodes* Less. (Asteraceae)	*Sonchus oleraceus* L. (Asteraceae)
Daucus carota L. (Apiaceae)	*Medicago lupulina* L. (Fabaceae)	*Taraxacum officinale* Weber. (Asteraceae)
Digitaria (Poaceae)	*Melilotus albus* L. (Fabaceae)	*Tussilago farfara* L. (Asteraceae)
Dipsacus sylvestris Huds. (Dipsacaceae)	*Panicum capillare* L. (Poaceae)	

Bray-Curtis index:

The Bray-Curtis index (*BC)* measures the differences in species abundances between one community and all others. The index reveals how similar the group of communities are. The Bray-Curtis index is as follows,

$$BC = 1 - \frac{\sum |x_i - y_i|}{\sum (x_i - y_i)}$$

Where x_i is the abundance of species i in the first community and y_i is the abundance of that species in the other community.

3.5 Statistical analysis

A repeated measures analysis (GLM ANOVAR, SPSS statistical package, v. 13, SPSS Inc., 2004) of an unbalanced design (using Type IV sum of squares) was used to test the responses of waterfowl to the vegetation structures surrounding each site (short versus tall). To determine the true significance, Pillai's trace was used because of its robustness and its ability to protect against nonnormality and heterogeneity - characteristics that exist in this study (Olson, 1974). The analysis was run separately for geese and ducks on the complete dataset (140 observations), and for each of the five time periods.

The five time periods were chosen based on waterfowl phenology. The periods are as follows (unless otherwise stated, months are inclusive):

(1) Day of Year (DOY) 103-181 (mid-April-end of June 2005) to include the spring migration and subsequent events of breeding, brood-rearing and moult,

(2) DOY 182-258 (July-mid-September 2005) to include the time when waterfowl are mobile and can freely move between the ponds and young are fledged,

(3) DOY 259-334 (mid-September-November 2005) to include fall migration,

(4) DOY 335-86 (December 2005-mid-March 2006) to include wintering/resident waterfowl, and

(5) DOY 87-181 (mid- March-June 2006) to include a second spring migration and to compare these observations to the first time period.

3.6 *E. coli* analysis

With two exceptions (sample collection and lab analysis), the following methods follow standard methods as described in *Standard Methods for the Examination of Water and Wastewater* (1998).

3.6.1 Sample collection

Water samples were collected from nine of the eleven ponds (ponds 24 and 15 were excluded). Only nine ponds were included based on limited availability of lab resources. It was decided that three ponds from each of three categories based on vegetation would be sampled. These categories (based on a visual evaluation of the vegetation) were: (1) ponds containing primarily short/mown vegetation, (2) a mixture of vegetation heights, and (3) ponds exhibiting mostly taller vegetation. (However, once the detailed vegetation survey was complete it was revealed that there were only two ponds exhibiting mostly short/mown vegetation. Unfortunately, the pond selection could not be changed. The vegetation could not be surveyed prior to collecting water samples because the vegetation was not mature enough to accurately identify the plant species. However, as will be discussed, this did not skew the results).

Samples were collected using 250 ml sterilized glass “medicine bottles”. The collection method followed the procedure described in Standard Methods (Section 9060A.3). However, there were no methods described for sampling SWMPs. Therefore, a system was devised to collect samples using the resources available. Three samples were collected from the centre of each pond. This was accomplished by wading out, as far as safely possible, to the centre and then attaching the sample bottle to the end of an extendable pole to assist in reaching closer to the centre. The bottle and pole were then lowered into the water and water was collected from a depth that could be standardized across all ponds (this varied through the seasons due to water depth fluctuation). Samples were not collected from other points in the pond system, such as the pond inlet(s) and outlet, because of a lack of lab space, resources and adequate instrumentation in the field.

Samples were then placed in a cooler containing several ice packs. Upon arrival at the laboratory, samples were placed in a refrigerator until processing, which commenced immediately. All samples were processed within two hours, following Standard Methods (Standard Methods 9060B. Preservation and Storage, p. 9-19).

Samples were collected from the nine ponds, a total of eleven times, during the period of June 9-October 20. This included seven baseflow samples and four rain events where precipitation exceeded 20 mm in the 6 hours prior to sample collection. One rain event was sampled where 14 mm of rain fell in 15 minutes. The amount of precipitation was determined using the tipping bucket data (Texas Electronics Model: TE525) from the University of Waterloo weather station (University of Waterloo, 2006).

3.6.2 Laboratory procedures

All equipment used in the following procedures (including sample bottles) were cleansed and sterilized following standard methods (American Public Health Association, 1998, 9040 Washing and Sterilization, p 9-17).

Medium preparation: FC basal medium (Difco Laboratories) was used and contains the following ingredients (grams per litre): tryptose (10.0), Proteose Peptone no. 3 (5.0), yeast extract (3.0), sodium chloride (5.0), bile salts no. 3 (1.5), and agar (15.0). For this study, one quarter of the recommended recipe was used to make the required quantity of medium. Therefore, 9.875 g of the powder was suspended in 250 ml of purified water. To this mixture, 25 mg of 5-bromo-6-choro-3-indolyl-ß-D-glucuronide (BCIG) was added and boiled until all powder was dissolved. Using a glass pipette, 2.5 ml of the medium was dispensed into each petri dish (50 mm sterilized polystyrene dishes with absorbent pads) (Pall Corporation 7245). A total of 86 petri dishes were required for each sampling event distributed as follows: 81 dishes for water samples, three additional dishes, and two dishes for controls to evaluate test performance-*E. coli* test culture and sterilized water, as per standard methods (American Public Health Association, 1998, 9222 D Fecal Coliform Membrane Filter Procedure p. 9-63-9-64).

Media were prepared within 24 h of sample collection. Once the media were added and hardened in the petri dishes, the dishes were sealed in plastic containers and stored in a refrigerator until use. The addition of BCIG into the standard FC agar is not an official method and thus does not appear in the American Public Health Association's publication of standard methods (1998). However, Cieben *et al.,* (1995) evaluated the inclusion of BCIG and determined that target colonies were confirmed to be *E. coli* at rates of 98.6%.

Membrane filtration procedure: The membrane filter method was used, following standard methods (American Public Health Association, 1998, 9222 A and B Membrane Filter Technique for Members of the Coliform Group 9-62-65). In order to obtain as many countable *E. coli* colony forming units (CFU), three volumes of each water sample were filtered: 10 ml, 1 ml and 0.1 ml. Each sample was filtered using 47mm-diameter, 0.45 µm, gridded, sterile filters (Millipore), under partial vacuum. In between samples, the funnel was rinsed with 20-30ml of sterile dilution water.

The petri dishes containing the filtered samples were then incubated in a constant temperature water bath (BLUE M Electric Company) at 44.5^{o}C for 22 hours.

Enumeration of colonies: The inclusion of BCIG in the m-FC basal medium results in ß-glucuronidase-positive organisms, including *E. coli* producing visible blue colonies (Ciebin *et al.*, 1995). An effort was made to count all colonies on each filter, except in cases where there were too many colonies that individual colonies were unidentifiable.

The count was computed using membrane filters exhibiting 20 to 80 coliform colonies, but not more than 200 colonies, as per standard methods (American Public Health Association, 1998, 9222 B Standard Total Coliform Membrane Filter Procedure, p. 9-60) The count was reported as CFUs/100mL using the following equation:

$$\frac{Total\ coliform\ colonies}{100\,ml} = \frac{(coliform\ colonies\ counted \times 100)}{ml\ sample\ filtered}$$

All viable counts from the sample for each pond were then averaged in preparation for statistical analysis.

3.7 Analysis

A Pearson's correlation (using a two-tailed test of significance) was used to determine if a relationship existed between the amount of *E. coli* in a pond and the number of waterfowl that used a pond. Two correlations were run based on the number of waterfowl: (1) a moment correlation where only the waterfowl observed on the day of and day before the water sample was taken were included, and (2) a cumulative correlation which included all waterfowl sighted from the beginning of the study period up until the time the water sample was collected.

Chapter 4: Results

This section will present results from all components of the study. Waterfowl trends will first be discussed, followed by an examination of the vegetation communities, these two components will then be linked and analysed together. Lastly the levels of E. coli found will then be presented. The general results for each component will be illustrated and differences will be highlighted and anomalies in each dataset will be noted.

4.1 Waterfowl trends

Over the course of this study, a total of 38502 waterfowl were sighted. This total consists of 17381 Canada geese, 19918 mallard ducks, and 1203 other species of waterfowl. There exists considerable spatial and temporal variability of waterfowl sightings amongst the species of concern and amongst the eleven ponds.

4.1.1 Spatial variability

The total number of geese and ducks varied between the ponds (Table 5).

Table 5 - Total number of sightings for all eleven sites

Pond	Geese	Ducks
1	4188	1940
12	958	19
42	1599	1216
15	731	216
19	967	2417
38	1460	815
2	875	4230
27	6021	1833
33	254	909
24	296	3335
30	32	2988

The highest number of goose sightings occurred at Pond 27 with a total of 6021; the lowest number of goose sightings was at Pond 30 with 32 sightings. Pond 2 had the highest number of duck sightings and Pond 12 had the lowest with 4230 and 19 sightings, respectively. However, these totals were not evenly distributed throughout the entire study period, thus the data were evaluated temporally.

4.1.2 Temporal variability

The total number of waterfowl sighted during the study varied over the five, previously identified, time periods (Table 6) (See section 6.4 Statistical analysis, for clarification of time periods).

Table 6 - Total number of waterfowl sightings per time period

time period (# of obs.)	Geese	Ducks	Other	Total	Pond with highest number of geese (#)	Pond with highest number of ducks (#)	Pond with fewest number of geese (#)	Pond with fewest number of ducks (#)
1 (30)	2062	2494	243	4799	Pond 1 (409)[1]	Pond 30 (693)	Pond 24 (14)	Pond 12 (6)
2 (30)	2756	7964	244	10964	Pond 1 (1253)	Pond 24 (1862)	Ponds 12, 38, 30 (0)	Pond 12 (0)
3 (27)	8561	6541	644	15746	Pond 27 (4876)	Pond 2 (2463)	Pond 30 (0)	Pond 12 (4)
4 (14)	586	464	0	1050	Pond 1 (584)	Pond 1 (244)	All other Ponds (0), except Pond 30 (2)	Ponds 42, 12, 15, 38, 2, 27 (0)
5 (39)	3416	2455	71	5942	Pond 1(938)	Pond 30 (499)	Pond 30 (12)	Pond 12 (9)

[1] Includes only 12 observations

The largest number of waterfowl sightings occurred in time period 3; the least was in time period 4. There was a distinct change in the total number of sightings between each of the time periods with an increase or decrease of almost 5000. The number of ducks sighted did not fluctuate as greatly between the time periods. One highlight from Table 6 is that, although time periods 1 and 5 were over a similar time period of their respective years (DOY 103-181 in 2005; DOY 87-181 in 2006), the number of geese increased greatly (+1354), whereas the number of ducks decreased very slightly (-39).

The following graphs illustrate the use of ponds by geese (Figures 2 and 3) and ducks (Figures 4 and 5) over the five time periods. While the data are not continuous, the large dataset made the use of a bar graph unfeasible. Therefore, line graphs are used to clearly illustrate the variation in number of waterfowl sighted. In addition, the scales for each individual pond vary. These were chosen to illustrate the exact number of geese and ducks that were sighted at each pond.

Figure 2 indicates that during time periods 1 and 5, geese were sighted at all ponds. During time periods 2, 3 and 4 goose use of ponds varied considerably as they favoured some ponds over others. Throughout these time periods, there were extended phases where geese were not sighted at a pond. During time period 4, geese responded quite differently to the ponds, as they were only sighted at Pond 1. The most important time periods were 2 and 3 as this is when the vegetation matured and it was hypothesized that goose use of ponds would change. As such, time periods 2, 3 and 5 are highlighted in the following graph (Figure 3).

Figure 2 - Number of geese sighted at all 11 ponds for the duration of the study period April 2005 to June 28 2006. Vertical lines delineate the five time periods. The scales on the y-axis vary for each pond.

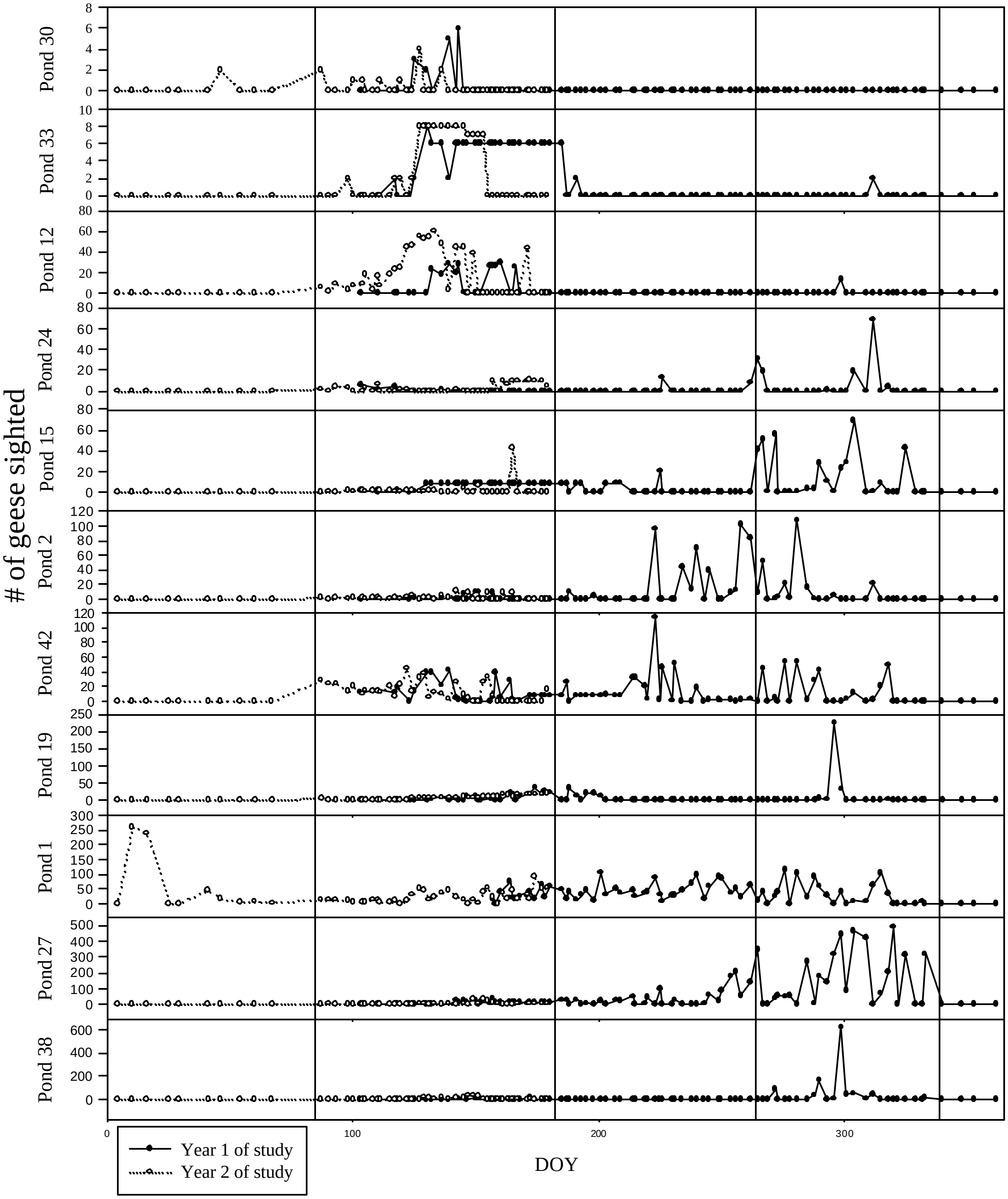
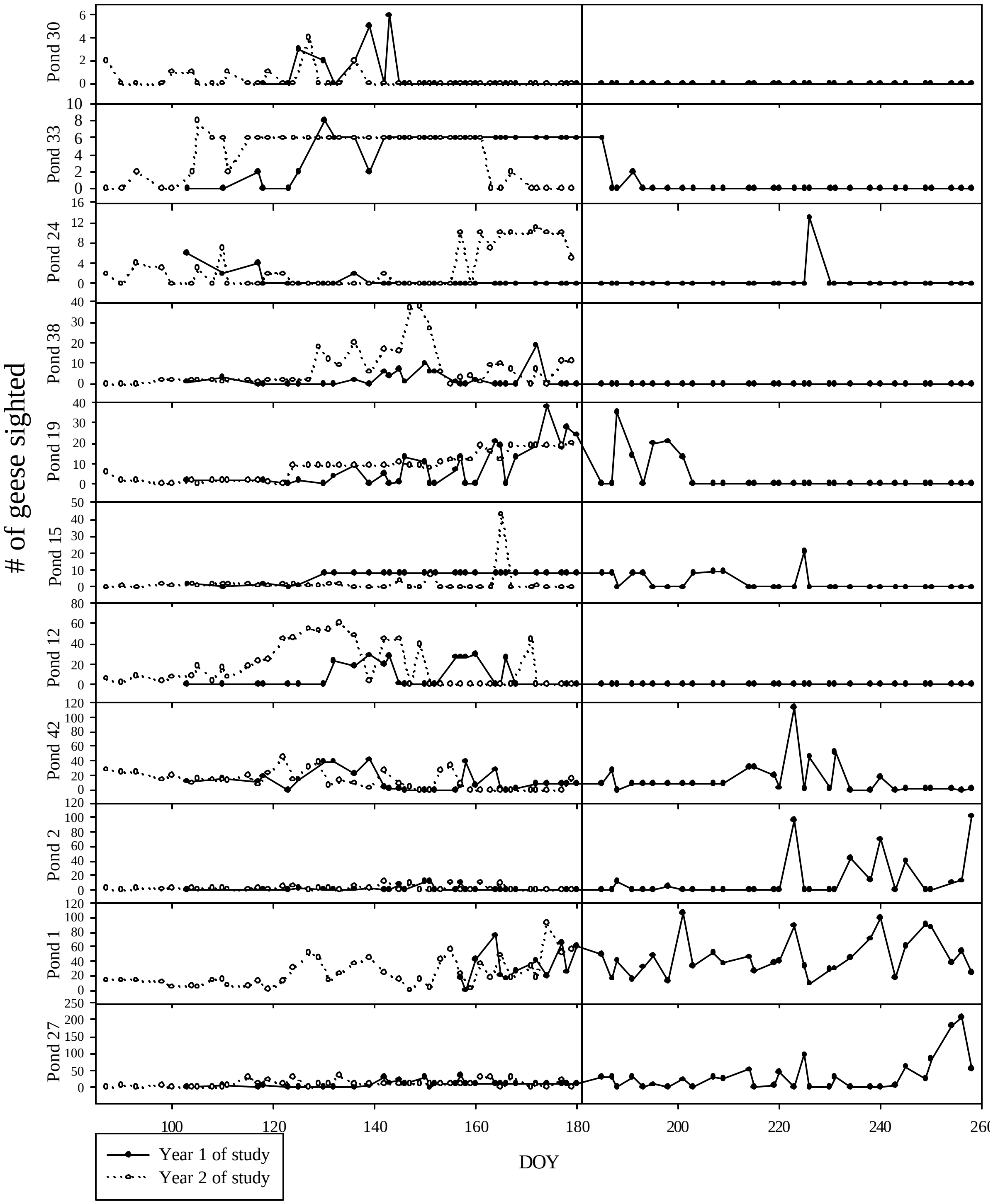


Figure 3 - Number of geese sighted at all 11 ponds for time periods 1, 2 and 5. Vertical lines delineate the time periods. The scales on the y-axis vary for each pond



The pattern of duck sightings appeared to be different than for geese. Ducks were sighted more consistently at all ponds (except for Pond 12) during each of the time periods (Figure 4). Where the number of goose sightings dropped to zero at many ponds after time period 1, ducks remained at most of the ponds through the rest of the time periods. Even in time period 4, ducks were seen at 5 of the 11 ponds. There were consistently more ducks than geese (Figure 3) sighted at the ponds during time periods 1, 2 and 5 (Figure 5).

Figure 4 - Number of ducks sighted at all ponds for the duration of the study. Vertical lines delineate time periods. The scales on the y-axis vary for each pond.

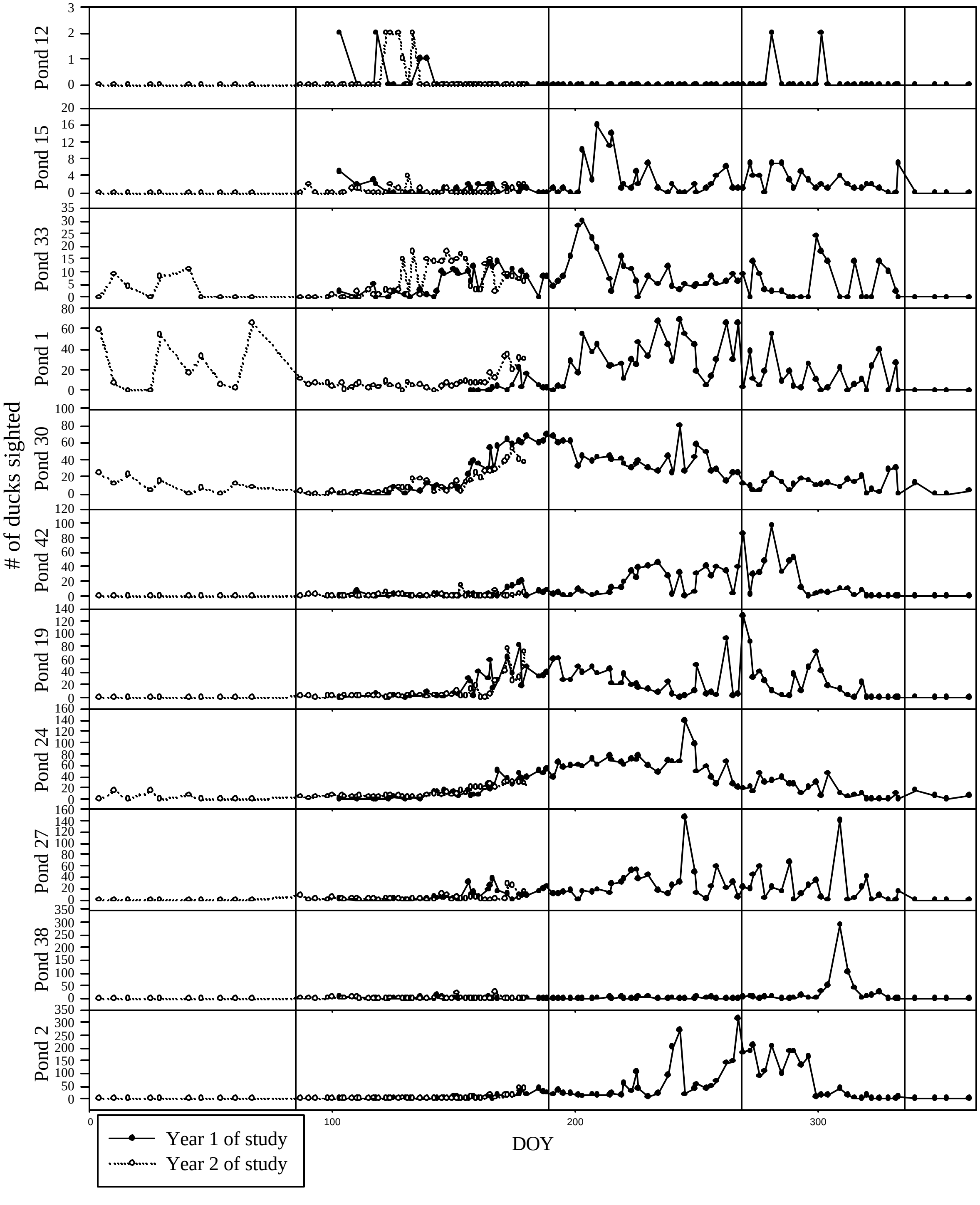
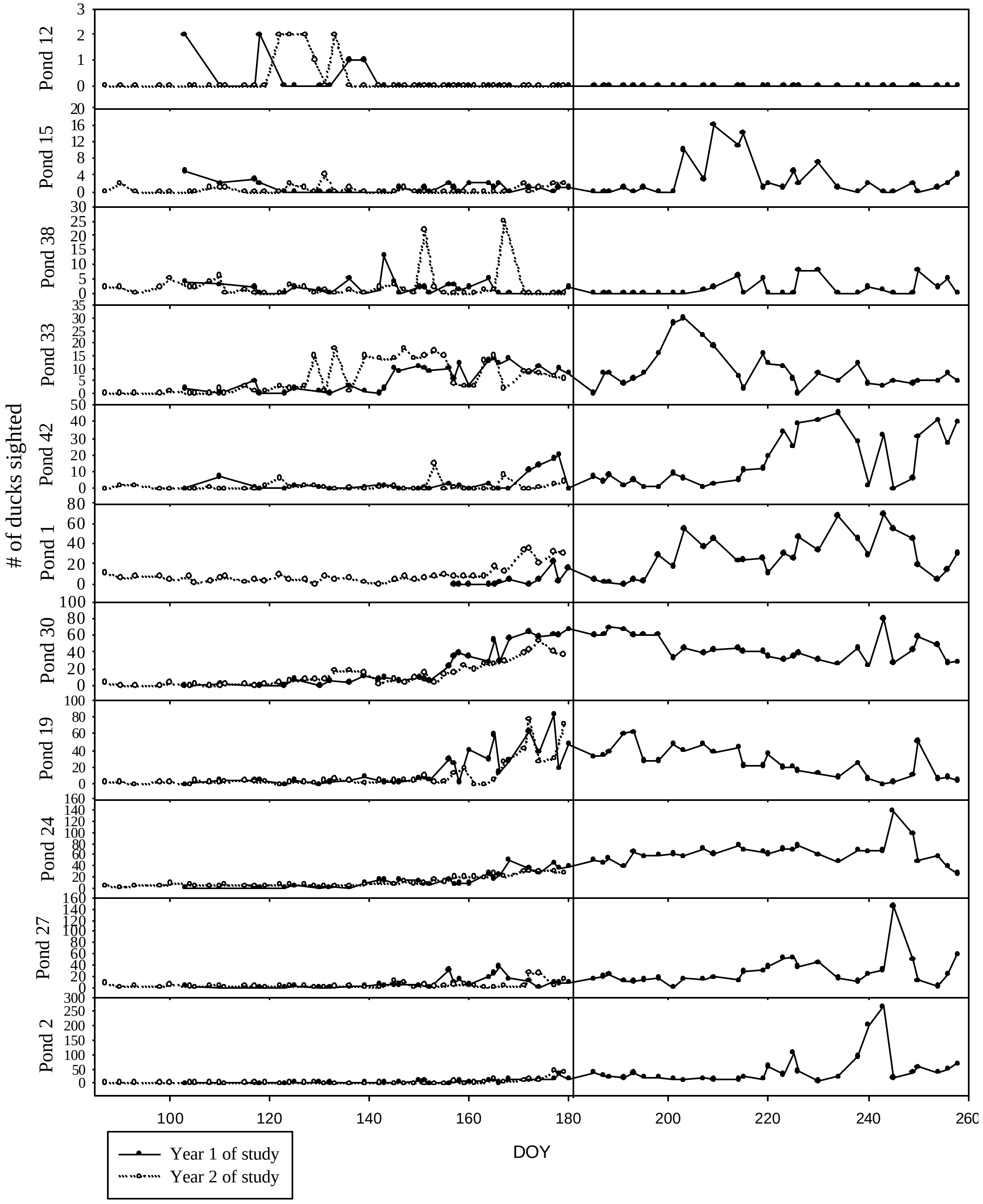


Figure 5 - Number of ducks sighted at all ponds for time periods 1, 2 and 5. Vertical lines delineate time periods. The scales on the y-axis vary for each pond.



4.1.3 Other waterfowl

Pond 27 had the highest number of species other than ducks and geese, and contained 81.3% (978 of 1203) of all the other waterfowl species sighted. Other species include great blue heron (*Ardea herodias*), Herring gull (*Larus argentatus*), Ring-billed gull (*Larus delawarensis*) and the Embden goose (a domestic breed). However, Embden geese were only seen at Pond 19.

4.2 : Vegetation description

Table 7 illustrates the percentage of the vegetation at a site that was short (short vegetation included all vegetation that was actively mown, stunted species, and juvenile species [See Table 4 for a full list species]).

Table 7 – Percent short versus percent tall vegetation at each pond

Pond	% short	% tall
1	87.40	12.60
42	4.05	95.95
12	6.68	93.32
15	11.54	88.46
19	16.37	83.63
38	16.05	83.95
2	18.06	81.94
27	34.96	65.04
33	19.81	80.19
24	15.99	84.01
30	2.05	97.95

Pond 1 had the highest percentage of short vegetation (87.40%), whereas Pond 30 had the lowest (2.05%). Pond 1 was the only site that contained more than 50% short vegetation. Ponds 42, 12 and 30 all exhibited <10% short, and a further 6 ponds had <20% short vegetation.

The vegetation survey identified 128 species belonging to one of 90 genera. The most dominant species and genus found at each pond are identified in Tables 8 and 9. Pond 1 exhibited the highest percentage of dominant vegetation and the highest percentage of short vegetation. Pond 15 was not dominated by any one species/genus. *Poa pratensis* was identified as a dominant species at three ponds, and at Ponds 1 and 15 it was of the short variety.

Table 8 – Dominant genus

Pond	%	Dominant genus	Short or tall
1	64.68	*Poa* spp.	Short
42	19.33	*Solidago* spp.	Tall
12	31.80	*Solidago* spp.	Tall
15	8.72	*Tussilago* spp.	Tall
	7.96	*Poa* spp.	Short
19	17.77	*Festuca* spp.	Tall
38	12.71	*Agropyron* spp.	Tall
2	21.77	*Phalaris* spp.	Tall
27	17.76	*Lotus* spp.	Tall
33	21.25	*Phleum* spp.	Tall
24	21.58	Poa spp.	Tall
30	15.21	*Festuca* spp.	Tall

Table 9 – Dominant species

Pond	% cover	Dominant species	Short or tall
1	47.98	*Poa pratensis*.	Short
42	19.33	*Solidago* spp.	Tall
12	31.80	*Solidago* spp.	Tall
15	8.72	*Tussilago farfara*	Tall
	7.96	*Poa pratensis*	Short
19	17.55	*Festuca arundinacea*	Tall
38	12.71	*Agropyron repens*	Tall
2	21.75	*Phalaris arundinacea*	Tall
27	17.76	*Lotus corniculatus*	Tall
33	21.25	*Phleum pratense*	Tall
24	21.46	*Poa pratensis*	Tall
30	8.32	*Festuca arundinacea*	Tall

Several other vegetation comparisons can be made which further illustrate the vegetation community present at each site (Table 10). Four characteristics were examined: Simpson's dominance, richness, evenness, and Shannon diversity. Pond 1 was at the extremes of all characteristics. Pond 15 had the highest level of richness and was the most diverse. However the results did not differ greatly from the other ponds. Indeed, aside from Pond 1, none of the other values varied greatly between ponds.

The similarities between the sites were further evaluated with the Bray-Curtis index (Tables 11 and 12). Pond 1 was different from all other ponds, though the matrix shows that Pond 1 was most similar to Pond 27. According to the Bray-Curtis index the most similar ponds are 19, 38, and 27; the next most similar ponds are 42, 12 and 30.

Table 10 – Characteristics depicting the vegetation community at each site

Pond	Simpson dominance	Richness	Evenness	Shannon diversity
1	0.258	0.59	3.00	2.08
42	0.08	0.82	2.13	3.04
12	0.123	0.63	2.38	2.77
15	0.075	0.87	1.92	3.34
19	0.067	0.73	2.00	3.01
38	0.079	0.77	2.00	3.27
2	0.075	0.71	2.13	3.17
27	0.067	0.8	1.82	3.23
33	0.079	0.59	2.70	3.00
24	0.092	0.64	2.38	2.91
30	0.058	0.73	2.00	3.19

Table 11 – Bray-Curtis dissimilarity matrix at the Genus level for all pond sites

	1	42	12	15	19	38	2	27	33	24	30
1		.08	.12	.18	.22	.17	.16	.28	.19	.16	.09
42	.08		.55	.23	.31	.29	.18	.36	.28	.17	.39
12	.12	.55		.29	.41	.32	.33	.43	.22	.23	.51
15	.18	.23	.29		.42	.35	.34	.37	.33	.22	.35
19	.22	.31	.41	.42		.54	.40	.49	.25	.31	.49
38	.17	.29	.32	.35	.54		.33	.43	.25	.31	.40
2	.16	.18	.33	.34	.40	.33		.35	.38	.30	.35
27	.28	.36	.43	.37	.49	.43	.35		.31	.33	.34
33	.19	.28	.22	.33	.25	.25	.38	.31		.23	.22
24	.16	.17	.23	.22	.31	.31	.30	.33	.23		.41
30	.09	.39	.51	.35	.49	.40	.35	.34	.22	.41	

Table 12 – Bray-Curtis dissimilarity matrix at the species level for all pond sites

	1	42	12	15	19	38	2	27	33	24	30
1		.08	.12	.15	.18	.15	.15	.25	.14	.39	.08
42	.08		.53	.19	.29	.24	.18	.35	.18	.17	.42
12	.12	.53		.28	.39	.25	.31	.40	.13	.20	.42
15	.15	.19	.28		.40	.31	.32	.33	.18	.18	.32
19	.18	.29	.39	.40		.46	.35	.42	.16	.24	.36
38	.15	.24	.25	.31	.46		.25	.29	.19	.18	.29
2	.15	.18	.31	.32	.35	.25		.32	.37	.26	.29
27	.25	.35	.40	.33	.42	.29	.32		.16	.31	.24
33	.14	.18	.13	.18	.16	.19	.37	.16		.14	.19
24	.39	.17	.20	.18	.24	.18	.26	.31	.14		.25
30	.08	.42	.42	.32	.36	.29	.29	.24	.19	.25	

4.3 Effect of vegetation on waterfowl use at each site

The results of ‘short’ versus ‘tall’ were used to create categories upon which the statistical analyses were run. The following table indicates which category each pond falls into based on percent short and verified by the Bray-Curtis index (Table 13). Based on these categories, an ANOVAR test was run for both ducks and geese for each time period and for the entire study (Table 14). For both ducks and geese, the MS value for Residual Error = 974. In addition, Mauchly’s test for sphericity was calculated and it was not significant ($P < 0.05$) - $\varepsilon = 0.9$, indicating only minor deviation from the ideal sphericity of 1.0.

Table 13 – Vegetation categories of ponds

Pond	Category	% short
1	Short	87.40
27	Short	34.96
33	Tall	19.81
2	Tall	18.06
19	Tall	16.37
38	Tall	16.05
24	Tall	15.99
15	Tall	11.54
12	Tall	6.68
42	Tall	4.05
30	Tall	2.05

The results indicate that there was a significant difference between use of a pond by geese and the vegetation present. Geese significantly prefer mown lawns. The results also indicate that the time effects, as measured by Pillai's trace, are significant. Therefore, the day of year is an important variable; however, the vegetation height is more important as indicated by the means (Table 15).

The statistical analyses for ducks indicate that they respond to the ponds differently. Ducks were not significantly affected by the short vegetation present; however, they were still affected somewhat by the time of year.

Table 14 - Results of the ANOVAR test for each time period for both Canada geese and mallards

	Between Subjects			**Within Subjects**			**Interaction**		
	Short vegetation			**Time**			**Time * Mowing**		
	MS	**F**	**P**	**Pillai**	**F**	**P**	**Pillai**	**F**	**P**
Entire study									
17381 geese observed	102,171	53.45	***	0.38	16.08	***	0.47	13.32	***
19918 ducks observed	889	2.17	0.347	0.29	11.18	**	0.07	1.10	0.469
Time period 1									
2062 geese observed	51,907	35.98	***	0.36	17.43	***	0.28	8.35	**
2494 ducks observed	478	0.45	0.689	0.12	2.36	0.257	0.08	1.24	0.408
Time period 2									
2756 geese observed	42,615	29.13	***	0.43	21.99	***	0.38	12.62	***
7964 ducks observed	724	1.03	0.497	0.16	5.12	*	0.11	1.77	0.286
Time period 3									
8561 geese observed	58,044	39.73	***	0.57	32.26	***	0.57	17.81	***
6541 ducks observed	689	0.67	0.714	0.14	4.28	*	0.09	0.97	0.451
Time period 4									
586 geese observed	38,462	26.63	***	0.82	37.03	***	0.53	17.15	***
464 ducks observed	217	0.71	0.650	0.10	1.08	0.318	0.07	0.92	0.533
Time period 5									
3416 geese observed	27,684	23.78	***	0.82	36.17	***	0.31	9.82	**
2455 ducks observed	642	1.04	0.475	0.17	5.64	*	0.12	2.03	0.279

P notation: *** = <0.0001, ** = <0.00, * = 0.01

Table 15 - Means and standard deviations for each time period for both Canada geese and mallards

	Short		**Tall**	
	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Entire study				
17381 geese observed	39.92	78.32	5.72	23.23
19918 ducks observed	13.46	19.82	12.81	27.76
Time period 1				
2062 geese observed	17.05	17.78	5.00	8.13
2494 ducks observed	4.48	8.01	8.24	14.48
Time period 2				
2756 geese observed	40.13	40.44	3.84	13.63
7964 ducks observed	27.72	23.75	23.34	30.85
Time period 3				
8561 geese observed	98.54	137.44	10.50	46.61
6541 ducks observed	20.31	25.08	22.40	46.63
Time period 4				
586 geese observed	20.86	65.48	0.02	0.18
464 ducks observed	8.71	19.33	1.75	4.59
Time period 5				
3416 geese observed	14.94	14.54	6.57	10.92
2455 ducks observed	6.41	8.12	5.57	10.30

4.4 *E. coli* analysis

The results indicate that some ponds had a higher level of *E. coli* than others (Table 16). After a rain event, the levels of *E. coli* were higher when compared to samples taken on baseflow occasions. However, this was not correlated to the amount of waterfowl utilizing the pond. The Pearson's correlation does not indicate any consistency or relation between the two variables (Table 17).

Table 16 - Mean *E. coli* level (CFU) in each pond from the 11 sampling events

Sample DOY	160	165	166	178	193	195	198	215	230	231	293	
mls of rain (24 hours prior)	0	0	29.6	0	0	17.8	59.8	0	0	47.1	0	
Pond	$\bar{x}$ **(CFU)**											Overall $\bar{x}$
1	1547	1113	9167	817	2300	18667	1733	2100	1283	19667	540	5358
42	17	0	9267	63	70	47	1800	100	1300	62667	240	6870
12	60	27	1300	297	97	150	1467	147	40	120	67	343
19	12667	430	5500	273	13	15333	3267	30	60	6167	157	3991
38	353	143	1833	60	180	1567	920	33	707	1433	57	662
2	7	33	237	87	147	6867	953	237	543	163333	547	15726
27	387	240	16333	1493	183	13167	113667	1403	2133	24333	997	6758
33	8800	1667	24667	327	183	21667	5400	5533	90	25333	610	8571
30	2483	1367	47667	1967	1867	16333	9467	4333	963	6667	217	8485

Table 17 – Results of Pearson's correlation analysis of *E. coli* and waterfowl at each pond

	Moment		Cumulative	
Pond	Pearson	Sig.	Pearson	Sig.
1	-.123	.719	.008	.981
27	-.102	.766	-.112	.743
42	.566	.070	.213	.529
12	.356	.282	.249	.460
19	.290	.387	.990	.386
38	.096	.780	-.259	.442
2	-.152	.656	.027	.935
33	.302	.366	-.182	.592
30	-.116	.733	-.342	.303

Chapter 5: Discussion, Implications, and Recommendations

The height of vegetation was the most important characteristic influencing use of a site by Canada geese (Table 14). This agrees with both qualitative claims (Chasko & Conover, 1988; Mowbray *et al.*, 2002; Smith, 1999) and quantitative claims (Black *et al*., 2003; Conover, 1991; Owen, 1975) which indicate that Canada geese prefer short vegetation. Time of year (seasonal variation) also had an impact, though it was not as strong as the vegetation characteristics. These vegetation characteristics can ultimately inform the design of SWMPs to address the issue of waterfowl use.

5.1 Canada goose response to vegetation height

There was a significant difference between the height of vegetation and the associated number of geese sightings at a pond. Sites that contain over 30% of mown vegetation hosted the largest numbers of geese. At the extremes, Pond 30 with the least amount of mown vegetation hosted the smallest number of geese. Conversely, Ponds 1 and 27 with the highest percentage of short vegetation had the highest number of geese (Table 6). At the beginning of the study in spring, there was little variation in waterfowl sightings at all ponds. At this time of year, almost all of the vegetation was immature and short, hence it did not discourage a goose from using a site as it could still sense and flee predators. This likely explains why geese were only seen at some ponds, in particular Ponds 12, 33 and 30, during this time of year. At Ponds 15 and 33, geese remained well into time period 2 despite the fact that the vegetation was high (Figure 3). I attribute this to a larger number of families with unfledged geese, which is enforced by the tendency of geese to feed as family units (Mowbray *et al.*, 2002). Thus, families remained at some ponds until such a time that the young were fledged (Figure 3).

As the growing season continued and vegetation matured (grew taller), goose use shifted to ponds that contained a higher percentage of mown, short vegetation. Thus, Pond 27 (containing a total of 5869 over the entire study) became heavily utilized near the end of time period 2 (about DOY 250) and into time period 3 (Figures 2 and 3). While the use of this pond may be attributed to the overall increase of waterfowl in the region during the migration period, this pond still provided a large percentage (approximately 35%) of short vegetation (Table 7), and was thus a preferred site.

As previously mentioned, there are certain stages in a goose's life-cycle when requirements for dietary protein and carbohydrates are required, including reproduction and migration (Mowbray, *et al.*, 2002). During the reproductive season (March-May), all of the ponds contained short vegetation meeting the nutritional requirements of geese. Therefore, all of the ponds may have seemed equal with respect to dietary demands. While nutrition is always important, it becomes paramount prior to fall migration (Mowbray, *et al.*, 2002). At this stage geese require a high concentration of soluble carbohydrates for the storage of lipids. It is difficult for geese to meet these requirements with tall vegetation, furthering the need for short species. Thus, there is a biological requirement for geese to shift to ponds with shorter vegetation for both security and nutrition.

Furthermore, the primary source of soluble carbohydrates is identified as cereal grains (Joyner, 1987 as reported in Mowbray, *et al.*, 2002), which are found in high concentrations in agricultural fields adjacent to ponds, or in lower concentrations among the vegetation at certain ponds. Indeed, the adjacent areas and surrounding ponds become increasingly important at this stage, indicating that landscape effects may be important (this is evaluated below in Section 5.5, Other factors).

These reasons likely explain why geese significantly preferred sites with short vegetation and why goose use shifted to ponds with shorter species. However, goose use of ponds with taller vegetation was not eliminated and the use of sites with taller vegetation was extremely varied. For the majority of ponds, including 30, 33 and 12, the number of geese sighted was very low (Figure 2). Indeed, despite momentary spikes in goose sightings at Ponds 19 and 24, goose usage of these sites was also low. However, goose sightings were higher at some of the other sites containing similarly high percent cover of tall vegetation. For example, the use of Pond 15 increased by 307 sightings (from 79 to 372) between time periods 2 and 3 despite the low percentage of short vegetation at this site (11.54%). In addition, other sites such as Pond 42 and 2 were used actively despite having a low percentage of short vegetation (4.05% and 6.68%, respectively). Possible reasons for this anomaly are explained in section 5.5 Other factors.

5.2 Canada goose response to vegetation type and the enforcement of height as the most important variable

Some sites are dominated by palatable vegetation that geese favour. It is known that the preferred source of food for Canada geese is *Poa pratensis* (Conover, 1991; Conover & Chasko, 1985; Conover & Kania, 1991; Mowbray *et al*., 2002; Smith, 1999). Thus, sites containing a large portion of this species should host a large number of geese (Tables 8 and 9). As such, Pond 1, which is dominated by mown *Poa* spp., contained the second highest total number of geese sightings (4188). This site contained a large amount of *Poa* species that could not be differentiated due to constant mowing. Therefore, the dominance of *Poa pratensis* may be underestimated. Pond 24 also exhibited a large percentage of *Poa pratensis* (21.46%). However, the vegetation at this site was not actively mown. As such, only a total of 296 geese were sighted. Therefore, species composition is important, but height is the more dominant factor, which agrees with statements in the literature (Black *et al.*, 2003; Owen, 1975). Indeed, the importance of the height factor is illustrated in the use of Pond 27. This site contained 30% short vegetation, but contained only a small percentage of *Poa* spp. 10.49%, of which 8.49% was *Poa pratensis.* However, this site had the highest number of waterfowl sightings over the entire study period.

While geese prefer *Poa pratensis,* there are several other species of green monocots and other browse plants that geese prefer. Arthur (1968) identified a specific list of browse plants that geese prefer, and many of these species were present at the ponds (see page 21 for the complete list). Many of these species such as all three species of clovers (*Trifolium repens, hybridum,* and *pratense*), *Lotus corniculatus, Phleum pratense*, and *Dactylis glomerata* were present at most ponds, and at some ponds, such species were dominant. For example, Pond 27 was dominated by *Lotus corniculatus* (21.75%), and Pond 33 was dominated by *Phleum pratense* (21.25%). However, while Pond 27 hosted 6021 geese, only 254 were sighted at Pond 33. Therefore, other factors may have been more important, such as height. Indeed, the percentages of mown vegetation varied significantly between Ponds 27 and 33 with 34.96% and 13.81%, respectively.

Other vegetation species may also have impacted the number of geese that utilized each pond. There are certain species of vegetation that geese find less desirable. One such species is *Festuca arundinacea*. Studies completed by Conover (1991) and French & Parkhurst (2001) identified *Festuca arundinacea* as one of the least preferred grasses. There were some ponds in this study, in particular, Ponds 19 and 30, which were dominated by *Festuca arundinacea* with percent covers of 17.55% and 8.32%, respectively. These ponds contained some of the lowest totals of goose sightings. Pond 19 contained 967 of 17381 goose sightings (0.06%) and Pond 30 contained only 32 sightings representing 0.002% of the total. However, the extent to which species type affected goose use at Ponds 19 and 30 may be limited because these ponds also contained some of the highest percentages of tall vegetation cover (83.63% and 97.95%, respectively).

Variable height has been identified in the literature as the most important variable. Geese will be discouraged from using a site based on a decreased sense of security. As mentioned previously, geese will modify their food choices based on the need to select a safe site (Buchsbaum & Valiela, 1987). Therefore, sites offering a higher percentage of mown vegetation, but not offering *Poa pratensis* should still host a large number of geese. This was evident at Pond 27, which was not dominated by *Poa pratensis*, but did exhibit 34.96% short vegetation. As such, this pond contained 36.64% of geese sightings.

5.3 Duck response to vegetation in general

Because ducks were viewed at all ponds with no significant preference for tall or short vegetation (Table 14), the discussion of their response to ponds and associated vegetation can be addressed in a more general sense. Overall, ducks were ubiquitous across the City of Waterloo as they were observed at most ponds throughout the entire study period. One exception is Pond 12 which was devoid of ducks for time period 2. Ducks were also sighted at more ponds than geese during the winter study period (time period 4). The primary reason for greater numbers of duck sightings may be that ducks were less sensitive to vegetation surrounding a pond than geese (Table 14). There are several reasons that support this interpretation. First, the duck's diet is more diverse than the goose's. While geese are herbivores (primarily terrestrial grazers) with strong affinity for mown lawns, ducks are omnivores so their vegetation choices are varied and dabbling ducks seek aquatic food (Drilling *et al*., 2002). Secondly, a duck's sense of security is not associated with vegetation height. Where geese will choose against a site for security reason, ducks will not. Finally, the vegetation surrounding most of the ponds in this study was similar to a duck's natural wetland habitat. Despite this, ducks are well adapted to urban habitats and will use any site containing open water (Adams, 1995; Adams *et al.*, 1985a; Figley & VanDruff, 1982).

However, some sites did host more ducks than others. Sites containing vegetation preferred by mallards hosted a large number of mallards. For example, Pond 2 contained a large percentage of *Phalaris arudinacea* (21.75%) and it is believed that this contributed to this pond having the most mallard sightings (4412). In addition, this was the only pond to host *Echinochloa muricata,* which is also a preferred food source of ducks (Bellrose, 1980; Drilling *et al.*, 2002).

5.4 Temporal variations

The peak use of ponds by waterfowl occurred in time period 3 (mid-September to the end of November), which is recognized as the period of fall migration for geese (Mowbray *et al.*, 2002). It is thus hypothesized that geese migrating through the region chose certain ponds as rest and foraging areas. Most ponds saw an increase in use by waterfowl. In particular, Pond 27 saw an increase of 3424 sightings, which represented a 77% increase. Furthermore, ponds that were devoid of geese in the earlier time period(s) hosted waterfowl. For example, Pond 38 saw sightings rise from zero sightings in time period 2 to 1099 in time period 3. Pond 38 along with Ponds 2 and 27, are in the area known as RIM Park. During this fall migration period, the RIM Park ponds contained 65.67% of all waterfowl sightings (10365 of 15783).

Conversely, Pond 1 saw a decrease in geese from 1339 to 888 during the same time period. There is no definitive explanation for this decline. Geese may have begun utilizing another site not included in the study. Pond 1 also exhibited another anomaly. In time period 1, 438 geese were sighted in only 12 observations. However, during time period 5 only 938 geese were sighted during 39 observations. If the time period 1 data were to be extrapolated, over 1300 geese should have been sighted during time period 5. One possible explanation for the large decrease in geese over the same time of year may be attributed to landscape factors. In 2005, the Columbia Lake reservoir, just upstream from Pond 1, was undergoing extensive engineering works. At times, there was no water in the lake and the shoreline was under constant change. Casual observation found that very few waterfowl utilized this site. The engineering works were completed in fall of 2005. The area surrounding this reservoir consists of playing fields with mown *Poa* spp. Therefore, in 2006 the reservoir contained a permanent pool of water surrounded by palatable vegetation. This site may have become a preferred site over the Pond 1 site.

Time period 4 (winter observations) confirmed previous data that waterfowl will winter as far north as open water exists. During this time period, vegetation is a less important characteristic due to its dormant state and open water exerts the most influence on habitat selection. As such, ponds that were completely frozen over did not support any waterfowl. This agrees with suggestions in the literature that geese and ducks will winter as far north as open water persists (Mowbray *et al.*, 2002). Thus, ponds that maintained open water (Ponds 1, 33, 30, and 24) generally hosted ducks, and in a few cases, geese. Pond 1, as previously mentioned, was part of the Laurel Creek water course and as such, a constant flow of water was present which allowed for quicker melting during warmer periods. Ponds 33 and 30 had only one large inlet, so all the runoff was concentrated in this one area, resulting in a pool of unfrozen water surrounding the inlet. This runoff was generally warmer than the water in the pond itself as it had been heated while flowing over the dark coloured (low albedo) surfaces of adjacent roads. The situation was similar at Pond 24, though there were two inlets close to each other which created a larger pool along the northeast section of the pond. Similar situations existed at other ponds; however they never thawed enough to provide a pool of sufficient size to attract waterfowl.

5.5 Other factors

As previously mentioned, the use of some ponds by geese cannot be explained by vegetation characteristics alone. Therefore, there may be other factors exerting influence on a goose's selection of a pond, factors that are operating outside the scale and scope of this study. In particular, the effect of the larger landscape may be exerting influence on a goose’s choice of habitat selection. Casual observations found that geese utilized agricultural fields for foraging. At ponds 15, 38 and 19, agricultural fields were only separated from the ponds by a road, resulting in easy access between foraging grounds and open water. Indeed, geese have been observed to make up to two flights per day from their refuge onto agricultural land (while such flights have been found to occur in the moments just after sunrise and just before sunset, flights are not limited to these times) (Bell and Klimastra, 1970 as reported in Mowbray, *et al.*, 2002). Therefore, the geese sighted at these particular ponds may have been temporarily pausing foraging activities and their need for open water rather than responding to the vegetation community present at the pond site.

5.6 Effect of waterfowl on the water quality of SWMPs

The results from this aspect of the study indicated that there was no relationship between the number of waterfowl sighted at a pond and the amount of *E. coli* present (Table 17). However, the sampling schedule was not intensive enough to offer defensible conclusions that waterfowl in fact do not influence levels of *E. coli*. The results did indicate that rain events increased the level of *E. coli* found in the water column (Table 16), which is consistent with other research (Nevers & Whitman, 2005; Salyers & Whitt, 2001). Such rain events may also have agitated the water column resuspension of the bacterium. Valiela, *et al.*, 2001 found that with respect to fecal coliforms as a whole, resuspension of just the top 2 cm of muddy sediments could add sufficient cells to the water column to cause adverse water quality with regard to federal limits. Intense thunderstorms would have the ability to disrupt the top layers of sediment especially in shallow ponds.

Furthermore, a study by McLellan & Salmore (2003) found that high levels of *E. coli* in Lake Michigan coincided with bird presence and stormwater effluent. Therefore, the SWMPs may already contain high levels of *E. coli* from other sources and the addition of waterfowl may not drastically increase the already elevated level of *E. coli*.

5.7 Implications and Recommendations

Based on my study, there is evidence that waterfowl responded to different vegetation management methods and strategies. Allowing vegetation to mature around a pond (eliminating mowing) can limit the number of geese that use a specific site. This has been suggested in several studies (Smith, 2004; Conover, 1985; Conover, 1989; Kania and Chasko, 1999). In addition, limiting the amount of *Poa pratensis* planted at each site may also discourage large goose numbers. However, previous research relies mostly on anecdotal claims. Alhough this research was limited to one city, similar studies can be conducted elsewhere. While exact pond replicas may not be found in other locations, the use of ponds with permanent pools should prove to be adequate in repeating this study. There is enough evidence here to suggest that the design and monitoring of SWMPs can be altered, perhaps experimentally at first, to alter waterfowl use. Specifically, the concept of SWMPs needs to be addressed in terms of whether they are used simply for stormwater flow mitigation, or whether their impact on waterfowl (and vice versa) is important. I suggest that because SWMPs will alter how waterfowl respond in an urban environment, design must consider the vegetation that is planted in and around the ponds. In practical application, this study provides information for municipalities or local groups wishing to increase wildlife in their jurisdiction. Ponds can be enhanced for mallard duck use while discouraging geese (and the negative impacts associated with geese). There are no documented cases of ducks becoming a nuisance in the same way as geese. Thus by avoiding mown lawns and allowing the vegetation to mature, nuisance geese will not be present, but there exists a reasonable probability that the pond will be used by ducks. While ponds can be used for a number of recreational purposes, there is evidence to support the use of ponds for ducks.

In municipalities where geese are a nuisance, an evaluation of the vegetation community can be undertaken. Even a visual evaluation to assess the amount of mown lawn may be sufficient. Subsequently, a vegetation plan can be implemented where naturalized vegetation is planted near the shoreline to discourage geese. In addition, the plant species list provided by the Ministry of the Environment (Appendix C) is a good starting point as it lists many species that geese do not prefer (primarily because of height) and does not recommend planting many grasses that geese find palatable. One caveat that is not mentioned is that mowing should be avoided if discouraging geese is a desired goal. Allowing the vegetation to mature in the area surrounding the pond should not negatively affect the ponds performance or hydrological function. Increasing the amount of mature vegetation may improve pond performance as vegetation could trap more sediment and pollutants, especially during storm events when overland flow increases. I emphasize that this research did not address submergent, floating, or emergent vegetation that grows within the submerged area of the pond. Changing the vegetation in this area would have the ability to change flow characteristics in the pond directly affecting the hydrological functions. A monitoring program could be implemented where a series of variables and parameters are tracked before, during, and after a change in the planting strategy is implemented. Such parameters would include pond storage, pollutant removal, and sediment detention. In addition, monitoring and maintenance may need to include an examination of levels of *E. coli* delivered to the pond via waterfowl excrement. A recent study was released that evaluated the relationship between fecal production from waterfowl and input of fecal indicator bacteria (including *E. coli*) into shallow, saline water bodies in Austria (Kirschner *et al.*, 2004). A study as intensive as Kirschner's may provide more detailed insight on how to address the issue from a Public Health perspective.

Further, monitoring of SWMPs must include variables beyond those focused on hydrology, such as population and community responses of waterfowl to SWMPs. It must be remembered that SWMPs should not be considered to be habitat substitutions for lost wetlands in urban areas. While urban ponds may achieve some of the same outcomes as a natural wetland, such as pollutant uptake and sediment impoundment, constructed wetlands can never achieve all of the positive impacts of a natural wetland (Mitsch & Gosselink, 2000). However, the reality is that waterfowl (and others) will use urban ponds if the design, and more pointedly, the maintenance encourage this use.

On a larger scale, the implications of SWMPs remain to be tested explicitly. Tests should include the effect of relative spatial location on local and long range migrations, population changes within species, and how species interact on a community or ecosystem scale. Understanding the larger scale and the matrix within which ponds are situated can assist municipal planners with situating additional SWMPs.

5.8 Summary

Overall, the three objectives of this study were addressed. It was statistically proven that waterfowl do respond to vegetation characteristics surrounding SWMPs. Specifically, Canada geese responded to the height of the vegetation surrounding SWMPs and ducks did not. Geese preferentially chose ponds with short vegetation, and where short vegetation existed in the spring before maturation. However, as the seasons progressed and vegetation matured, geese moved to those sites offering short, palatable vegetation. With respect to the third objective, no conclusive evidence was found to link waterfowl to levels of *E. coli* in SWMPs. The levels of *E.coli* did increase in relation to environmental factors such as increased rainfall, but there is no evidence linking *E. coli* levels to waterfowl.

SWMPs remain a primary component of urban/suburban stormwater management and their use can be tailored to meet a variety of objectives – beyond runoff impoundment - including recreational opportunities and wildlife habitat. This study indicated that waterfowl in particular use these facilities in great numbers, and that the composition of vegetation and the configuration of the landscape surrounding the SWMPs can be managed to either promote or discourage waterfowl presence in the area.

Appendix A- Effects of urbanization

Urbanization Effect	**Reference**
Land consumption	(Des Rosiers, 1992; Draper, 1998; Opdam & Wiens, 2002)
Change in climate- urban heat island; may cause some species to be extirpated while others thrive because of warmer urban core temperatures year-round	(Marsh, 2005, p. 320-326; Wheater, 1999, p. 4)
Air pollution	(Draper, 1998; Marsh, 2005, p.320, 326-331)
Habitat degradation and fragmentation	(Andrén, 1994; Marsh, 2005, p. 385-390; Opdam & Wiens, 2002)
Spread of invasive exotic species	(Marsh, 2005, p. 359-361; Withers *et al.*, 1998, p. 8)
Loss of terrestrial biodiversity	(Marzluff, 2001; Opdam & Wiens, 2002; Pim & Ornoy, 2005)
Loss of aquatic biodiversity	(Ministry of the Environment, 2003, p. 1-10; Morgan & Cushman, 2005)
Increased sediment loads in water courses	(Ministry of the Environment, 2003, p. 1-10)
Increased pollutant loads (incl. nutrients, bacteria, heavy metals, oil and grease, and road salt)	(Marsalek, 1991, 2003; Ministry of the Environment, 2003, pp. 1-3 - 1-9; Van Buren *et al.*, 1997)
Increased stream temperature	(Ministry of the Environment, 2003, p. 1-10; Murphy & Martin, 2001)
Altered water courses through dams, channelization, and streambank erosion; substitution of artificial water courses and storage for wetlands and creeks.	(Adams *et al.*, 1984; Leith & Whitfield, 2000; Marsh, 2005; Ministry of the Environment, 2003, pp. 1-5 - 1-7; Murphy & Martin, 2001)

Appendix B – List of plant species to plant around SWMPs

Adapted from the Ministry of the Environment, Appendix E, 2003

Planting Zones

1. Deep Water (> 0.5 m)
2. Shallow Water (< 0.5 m)
3. Shoreline Fringe (zone of frequent wetting)
4. Flood Fringe (zone of infrequent wetting)
5. Upland

1. Deep Water (advised to use submergent and floating plants)

Scientific name	**Common name**
Brasenia schreberi	Water shield
Ceratophyllum demersum	Coontail
Elodea canadensis	Common waterweed
Lemna minor	Lesser duckweed
Lemna trisulca	Star duckweed
Myriophyllum sibiricum	Northern water milfoil
Myriophyllum verticillatum	Bracted water milfoil
Nuphar variegatum	Yellow pond lily
Nymphaea odorata	White water-lily
Potamogeton gramineus	Variable-leaved pondweed
Potamogeton natans	Floating-leaved pondweed
Potamogeton pectinatus	Sago pondweed
Scirpus validus	Softstem bulrush
Spirodela polyrhiza	Great duckweed
Utricularia vulgaris	Common bladderwort
Vallisneria americana	Tape grass, Eel grass

2. Shallow Water (advised to choose robust, broad-leaved and narrow-leaved plants)

Acorus americanus	Sweet flag
Alisma plantago-aquatica	Water plantain
Calla palustris	Water arum
Carex lacustris	
Carex utriculata	
Equisetum fluviatile	Water horsetail
Glyceria borealis	Northern manna grass
Polygonum amphibium	Water smartweed
Pontederia cordata	Pickerel weed
Ranunculus reptans	Creeping buttercup
Sagittaria latifolia	Broad-leaved arrowhead

Sagittaria rigida	Stiff arrowhead
Scirpus acutus	Hardstem bulrush
Scirpus fluviatilis	River bulrush
Scirpus pungens	Common three-square
Scirpus validus	Softstem bulrush
Sparganium americanum	American bur-reed
Sparganium eurycarpum	Common bur-reed
Typha angustifolia	Narrow-leaved cattail
Typha latifolia	Broad-leaved cattail
Zizania aquatica	Wild rice

3. Shoreline Fringe

Asclepias incarnata	Swamp milkweed
Aster puniceus	Swamp aster
Bidens cernua	Nodding bur-marigold
Calamagrostis canadensis	Canada bluejoint grass
Carex bebbii	
Carex comosa	
Carex crinita	
Carex hystericina	
Carex pseudo-cyperus	
Carex stipata	
Carex stricta	
Carex vulpinoidea	
Cicuta maculata	Water hemlock
Decodon verticillatus	Swamp loosestrife
Dulichium arundinaceum	Three-way sedge
Eleocharis obtusa	Spike rush
Eleocharis smallii	Spike rush
Eupatorium maculatum	Joe pye-weed
Glyceria striata	Fowl manna grass
Iris versicolor	Wild blue flag iris
Juncus articulatus	Jointed rush
Juncus balticus	Baltic rush
Juncus canadensis	Canada rush
Juncus effusus	Soft rush
Juncus pelocarpus	Brown-fruited rush
Juncus torreyi	Torrey's rush
Leersia oryzoides	Rice cut-grass
Lobelia cardinalis	Cardinal flower
Lycopus americanus	Water horehound
Lysimachia terrestris	Swamp candles
Mimulus ringens	Monkey flower

Osmunda regalis	Royal fern
Phalaris arundinacea	Reed canary grass
Potentilla palustris	Marsh cinquefoil
Rumex orbiculatus	Great water dock
Scirpus atrovirens	Green bulrush
Scirpus cyperinus	Wool grass bulrush
Scirpus pendulus	Pendulus bulrush
Scutellaria galericulata	Marsh skullcap
Sium sauve	Water parsnip
Thelypteris palustris	Marsh fern
Triadenum fraseri	Marsh St. John's Wort

Shrubs

Alnus incana	Speckled alder
Cephanlanthus occidentalis	Buttonbush
Cornus stolonifera	Red osier dogwood
Ilex verticillata	Winterberry
Lonicera oblongifolia	Swamp fly honeysuckle
Myrica gale	Sweet gale
Nemopanthus mucronatus	Mountain holly
Rhamnus alnifolia	Alder-leaved buckthorn
Ribes triste	Swamp red currant
Rosa palustris	Swamp rose
Rubus pubescens	Dwarf raspberry
Salix bebbiana	Beaked Willow
Salix exigua	Sandbar willow
Salix lucida	Shining willow
Salix petiolaris	Slender willow
Salix pyrifolia	Balsam willow
Spirea alba	Meadowsweet

Trees

Acer saccharinum	Silver maple
Fraxinus nigra	Black ash
Quercus bicolor	Swamp white oak
Salix nigra	Black willow

Shoreline Fringe

Aster novae-angliae	New England aster
Aster umbellatus	Flat topped aster
Bidens frondosa	Common beggar-ticks
Cyperus esculentus	Yellow nutsedge
Equisetum arvense	Field horsetail

Eupatorium perfoliatum	Boneset
Impatiens capensis	Spotted touch-me-not
Impatiens pallida	Pale touch-me-not
Juncus tenuis	Path rush
Lilium michiganense	Michigan lily
Lysimachia ciliata	Fringed loosestrife
Osmunda cinnamomea	Cinnamon fern
Urtica dioica	Stinging nettle

Vines

Echinocystis lobata	Wild cucumber
Vitis riparia	Riverbank grape

Shrubs

Aronia melanocarpa	Black chokeberry
Cornus foemina	Grey dogwood
Lindera benzion	Spicebush
Physocarpus opulifolius	Ninebark
Potentilla fruticosa	Shrubby cinquefoil
Ribes americanum	Wild black currant
Rubus idaeus	Wild red raspberry
Salix amygdaloides	Peach-leaved willow
Salix discolor	Pussy willow
Salix eriocephala	Woolly headed willow
Sambucus canadensis	Elderberry
Vaccinium myrtilloides	Velvet-leaf blueberry
Viburnum cassinoides	Northern wild raisin
Viburnum trilobum	Highbush cranberry

Trees

Abies balsamea	Balsam fir
Carya laciniosa	Shellbark hickory
Fraxinus pennsylvanica	Red ash
Larix laricina	Tamarack
Picea mariana	Black spruce
Platanaus occidentalis	Sycamore
Populus balsamifera	Balsam poplar
Quercus palustris	Pin oak
Thuja occidentalis	Eastern white cedar
Ulmus americanum	American elm

Flood Fringe

Vines

Clematis virginiana	Virgin’s bower
Menispermum canadense	Canada moonseed
Parthenocissus quinquefolia	Virginia creeper
Smilax hispida	Bristly greenbrier

Shrubs

Crataegus crus-galli	Cockspur thorn
Lonicera hirsuta	Hairy honeysuckle
Prunus virginiana	Choke cherry
Viburnum lentago	Nannyberry

Trees

Acer rubrum	Red maple
Betula alleghaniensis	Yellow birch
Carya cordiformis	Bitternut hickory
Populus deltoides	Eastern cottonwood
Quercus macrocarpus	Bur oak

Upland

Trees

Acer saccharum	Sugar maple
Betula papyrifera	Paper birch
Crataegus spp.	Hawthorn
Fraxinus americana	White ash
Juniperus virginiana	Eastern red cedar
Pinus banksiana	Jack pine
Pinus strobus	Eastern white pine
Populus tremuloides	Trembling aspen
Quercus alba	White oak
Quercus rubra	Red oak
Tsuga canadensis	Eastern hemlock

Shrubs

Acer pensylvanicum	Striped maple
Amelanchier alnifolia	Service-berry
Amelanchier arborea	Juneberry
Amelanchier sanguinea	Round-leaved serviceberry
Amelanchier spicata	Shadbush serviceberry
Arctostaphylos uva-ursi	Bearberry
Ceanothus americanus	New Jersey tea
Cornus rugosa	Round-leaved dogwood
Corylus americana	American hazelnut
Corylus cornuta	Beaked hazelnut

Diervilla lonicera	Bush honeysuckle
Hamamelis virginiana	Witch hazel
Lonicera dioica	Wild honeysuckle
Prunus pensylvanica	Pin cherry
Ribes cynosbati	Prickly gooseberry
Rhus aromatica	Fragrant sumac
Rhus typhina	Staghorn sumac
Rosa blanda	Smooth wild rose
Rubus allegheniensis	Common blackberry
Salix humilis	Upland willow
Sambucus racemosa	Red-berried elder
Shepherdia canadensis	Buffalo-berry
Symphoricarpos albus	Snowberry
Viburnum acerifolium	Maple-leaved viburnum
Viburnum rafinesquianum	Downy arrow-wood
Zanthoxylum americanum	Prickly ash

Appendix C– Goose management techniques

Technique	**Application**	**Timing**	**Cost**
Discontinuance of feeding	Anywhere	anytime	low
Habitat modification			
Eliminate shorelines, islands, peninsulas	Nest	anytime	high
Place walking path near water	Anywhere	anytime	high
Place field away from water	feeding/loafing	before arrival	high-medium
Removing nesting structures	Nest	not nesting	little
Modify water levels	nest or feeding	anytime	little
Encourage early water freeze-up	feeding/loafing	fall or winter	little
String lines or grids above sites	Feeding	before arrival	medium + labour
Fence barriers	feeding/loafing	molting, before arrival	medium + labour
Vegetative barriers	nest or feeding	anytime	high
Rock barriers	nest or feeding	anytime	high
Tall tree barriers	Feeding	anytime	high
Electric fence barriers	feeding/loafing	molting, before arrival	medium + labour
Reduce or eliminate mowing	nest or feeding	spring or summer	none
Reduce fertilizer use	nest, feeding, or loafing	anytime	none
Stop watering lawn	feeding/loafing	fall or winter	none
Reduce lawn area	nest or feeding	anytime	high
Plant unpalatable grass or vegetation	nest, feeding, or loafing	anytime	high
Alternative feeding areas	Feeding	at arrival	medium
Hazing or scaring			
Sirens, air horns, or whistles	Anywhere	before arrival	medium
Blanks	Anywhere	before arrival	medium + labour
Bangers, screamers, or whistle bombs	open areas	before arrival	medium
Cracker shells	open areas	before arrival	medium

Technique	Application	Timing	Cost
Propane cannons or exploders	open areas	before arrival	medium
Other pyrotechnics	open areas, at dark	before arrival	medium
Distress calls	anywhere	before arrival	medium
Ultrasonics	anywhere	before arrival	medium
Strobe lights	anywhere	before arrival at dark	medium
Mylar tape	anywhere	before arrival	medium
Flags	anywhere	before arrival	medium
"Eye-spot" balloons or kites	anywhere	before arrival	medium + labour
Scarecrows	anywhere	before arrival	medium
Dogs	anywhere	before arrival	medium
Swans	ponds, lakes	before arrival	medium
Falcons	open areas	before arrival	medium + labour
Radio-controlled aircraft	open areas	anytime	little-high
Vehicles and boats	open areas, at dark	anytime	high
Chemical repellents	feeding	anytime	medium to high + labour
Reproductive control			
Removing nesting materials	nest	before laying	little + labour
Oil/addle/puncture eggs	nest	incubation	little + labour
Replace eggs with dummy eggs	nest	incubation	little + labour
Sterilize through surgical neutering	nest	at molting	high
Sterilize through oral contraception	nest	at molting	high
Removal			
Translocate	anywhere	anytime	high + labour
Single-sex flocks	anywhere	at molting	high + labour
Regular hunt	anywhere	anytime	none
Special-purpose kill permits	anywhere	anytime	medium + labour
Nest shooting	nest	incubation	medium + labour
Use as food bank supplement	anywhere	at molting	high + labour

Adapted from Smith, *et al*., 1999

Appendix D – Photographs of SWMPs included in study

All pictures taken on June 2nd, 2006

Pond 30 - View south from entrance to Piller's Sausage industrial complex at 443 University Avenue East.

Pond 24 - View east from Eastbridge Boulevard.

Pond 33 – View east from Eastbridge Boulevard

Pond 27 – View west from University Avenue East (across from RIM Park sports complex)

Pond 2 – View southeast from University Avenue East (RIM Park sports complex visible)

Pond 38 – View southeast from University Avenue East at Northfield Drive East

Pond 19 – View west from behind 200 Bathurst Drive

Pond 15 – View west from Westmount Road North at Benjamin Road

Pond 42 – View north from path leading from Brookmill Crescent (this pond is of the serpentine design, and remainder of pond is not visible in photo)

Pond 12 – View west from service road leading south from Laurelwood Drive

Pond 1 – View west from Ring Road across from the Environmental Studies 2 building at the University of Waterloo

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